1995–1997

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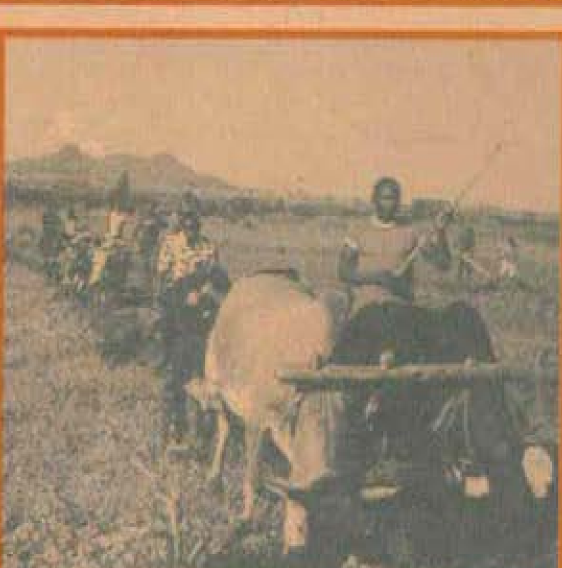
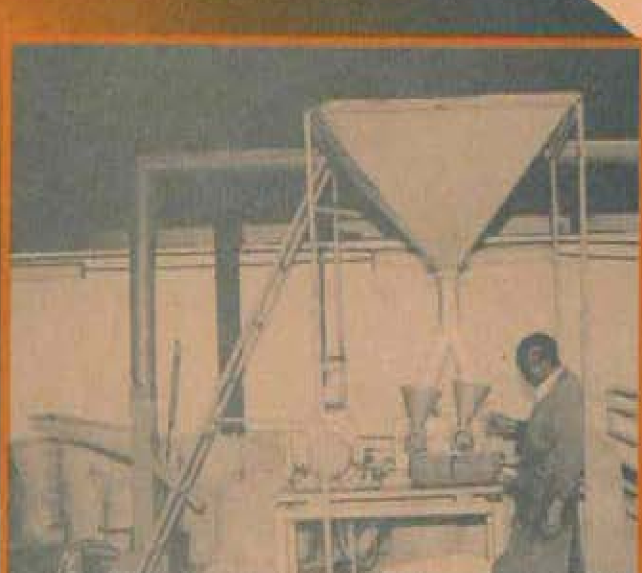
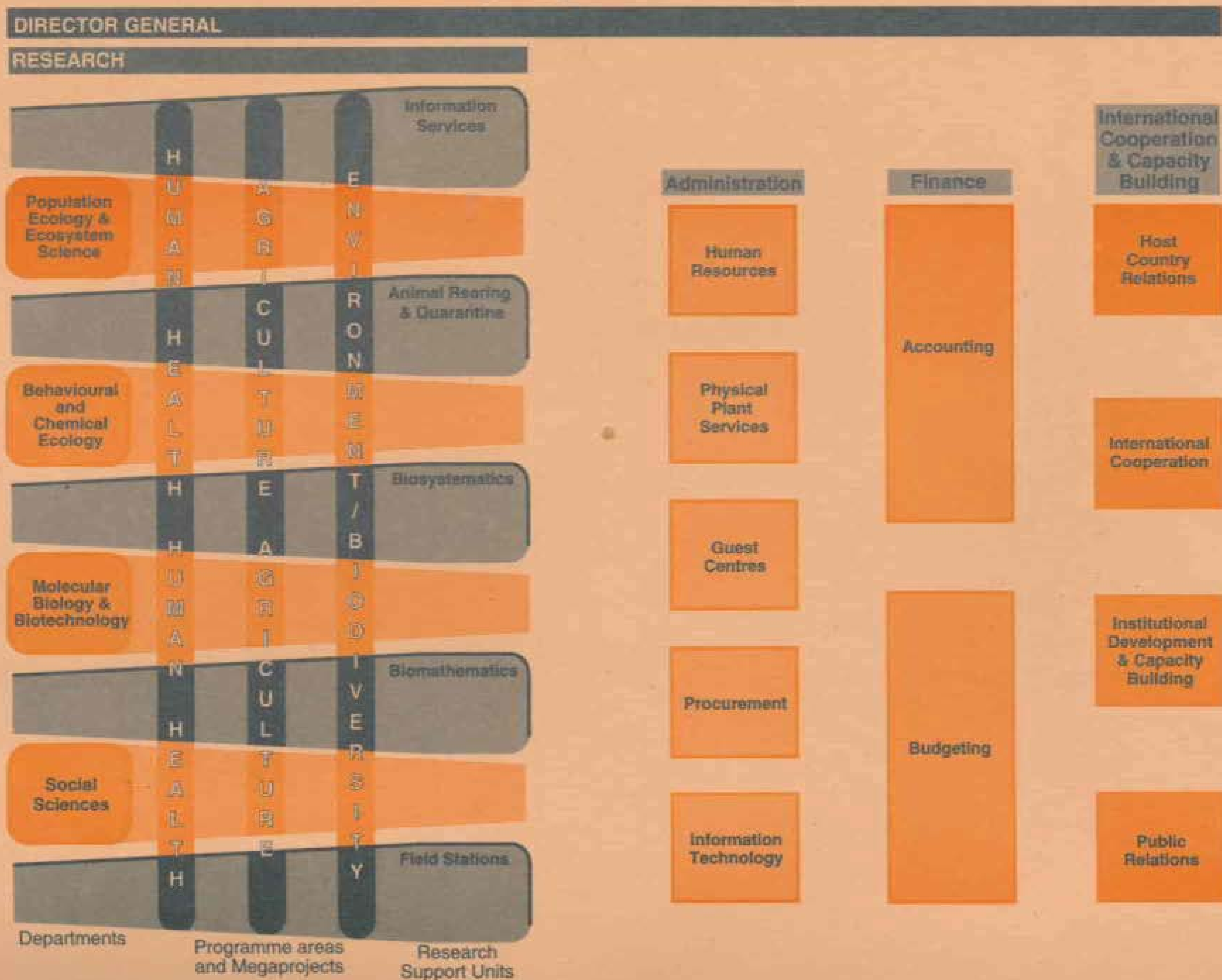
Annual Scientific Report





International Centre of Insect Physiology and Ecology

ICIPE Organogram—December 1997



Tropical Insect Science for Development

1995–1997 *icipe* Annual Scientific Report

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Neem factory at ICIPE, courtesy of N. Mwanga Komeri;
Oxen and plough in the Lake Victoria region, courtesy of Z. R. Khan;
African lunar moth, *Argema mimosae*, source of tussar silk, courtesy of S. K. Raina.

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Foreword

This scientific report covers the years 1995, 1996 and 1997. Many changes happened at ICIPE during these years, which also involved staff turnover. I want to thank the editorial staff for their work, time and energy to produce the report and all scientists contributing to it.

During the three-year period of the report, ICIPE addressed its strategy for the future. *The Vision and Strategic Framework towards 2020* documents the reorientation. ICIPE's research was organised into three programmes: Disease Vectors Management, Plant Pests Management and Arthropod Biodiversity, Conservation and Utilisation. Closely linked to R&D is the Capacity Building programme. In 1997 a further restructuring took place into eight megaprojects (sub-programmes in the *Five Year Plan 1996–2000*), each with a number of scientists and a leader coordinating research. The megaprojects are: • Horticultural Crop Pests • Food and Perennial Crop Pests • Locusts and Migrant Pests • Tsetse • Livestock Ticks • Malaria Vectors • Commercial Insects • Biodiversity and Conservation.

The megaprojects benefit from the expertise in the four research departments (see the organogram on the inside cover) and therefore are truly multidisciplinary. These departments themselves were the result of restructuring by combining a number of smaller departments. Although some work still remains to be done in terms of supervisory relationships and acting with appropriate responsibility and authority at all levels, the overall structure is functioning and showing its first benefits. Greater cohesion and efficiency in terms of strategy, proposal writing, coordination of the execution of research, and better communication with internal and external collaborators are gradually being achieved.

The megaproject structure is flexible in terms of presentation. Following recommendations of the Fourth ICIPE Periodic External Review in 1996, ICIPE is now presenting its research programme paradigm as the 4H's: Human, Plant, Animal and Environmental Health. Each of the megaprojects focuses on one of the above areas. This report is organised around these themes. Reference to project numbers in the *Five Year Plan* is cited where relevant.

The *Five-Year Plan* was based on an annual income of US$ 20 million. Major resources have been devoted to Plant Health, followed by Animal Health and then Human and Environmental Health. During the period 1993–1997 ICIPE's income rose from about US$ 6 million to $ 10 million. This level of funding is reflected in the report in the research executed. With the exception of research for the development of the tick vaccine, no second priority projects were started and some first priority projects have been delayed. Towards the end of 1997 the first thoughts about consolidation of some of the successful research projects were developed.

In April and May 1996 the Fourth ICIPE Periodic External Review was held. Many of the recommendations have been carried out, especially regarding the restructuring of R&D. The contacts with external collaborators have multiplied, both with the national research and extension systems and the international agricultural research centres (IARCS). ICIPE has formalised relationships with many institutions around the world through Memoranda of Understanding. The challenge will be to develop joint proposals and workplans for collaborative execution of research.

Many interesting results were produced during the years 1995–1997. ICIPE wants to improve the utilisation of these research results through application in practice. Towards this end, we are linking up with commercial companies for registration of products and marketing. The plans for the Technopark are in an advanced stage and will assist with the transfer of ICIPE technologies.

In the next year we will further consolidate our research efforts. We hope that this long delayed report will be useful as a source of information and for contacting our scientists for projects of joint interest.

Akke J. van der Zijpp, PhD
Deputy Director General, Research

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AGRICULTURAL RESEARCH

PLANT HEALTH MANAGEMENT

I. HORTICULTURAL CROP PESTS

Horticultural production systems play a significant role in global food security. Vegetables and fruits are a major source of vitamins and minerals. In many countries of Africa, vegetables provide balanced nutrition in an otherwise maize-based diet of the rural and urban poor. Horticultural production for local and export markets is one of the most profitable agricultural enterprises in developing countries. Out-of-season export of vegetables, tropical fruit and cut flowers to Europe has considerably increased in recent years, and substantially contributes to foreign exchange earnings of many African countries. This development has been particularly beneficial to smallholders; turning to horticultural production has enabled many to make a decent living out of minute areas of land.

This generally positive scenario for developing countries is put in jeopardy by at least two concerns. First, increased intensity both in local market production and even more so in export-oriented systems, has led to a chemical spiral with rising production costs and decreasing productivity. This is associated with a high risk to human health, especially among farm labourers, many of them women and children, and intolerable environmental pollution. Second, consumers in the importing European countries are increasingly concerned about the prevailing production methods used in the developing countries.

The research and technical support base for the African horticultural industry has been and still is a neglected area. This is despite the fact that horticultural production has enjoyed enormous growth rates in most countries of the region. Colonial administrations directed substantial resources to research on plantation crops like coffee, cotton, pyrethrum, sisal, sugarcane, tea and tobacco, including plant protection. During the post-independence era there was a shift in research priorities with emphasis on smallholder production systems, particularly towards staples, in order to attain self-sufficiency in food. This trend has not changed much, especially in the plant protection discipline, despite the recent dramatic developments in the horticultural industry, which is primarily a private sector initiative.

ICIPE's involvement in horticultural research has to be seen in this context. The initiative is new and still developing. Among the international agricultural research centres, ICIPE is one of the few that is not commodity-based. With its mandate in tropical insect science, it is ideally suited to deal with one of the most pressing technical problems in horticulture: indiscriminate use of pesticides. ICIPE's expertise in basic research, such as insect bioecology and behaviour, applied to biological control using beneficial insects and insect pathogens, as well as better crop management, can positively contribute to a sustainable and environment friendly solution to improving plant health and the pesticide problem. ICIPE also hosts a strong Social Sciences Department that can ensure research programmes are developed with active participation and in the interest of all stakeholders in the industry.

The Horticultural Crop Pests Megaproject is addressing these problems with research activities on the production for local and export markets. The area of vegetable research has been relatively successful in attracting funding. The African Fruitfly Initiative has met great interest from producers and donors alike. Activities for IPM development in cut flower production is a new area under development and requires some more investment from ICIPE before it hopefully attracts funding from the producers and eventually the donors.

II. LOCUSTS AND MIGRANT PESTS

Of some 200 species of acridids (locusts and grasshoppers in Africa, about 10–12 are of prime concern to agriculture and food security. Between them, they affect virtually the whole of the continent and have threatened the region intermittently over the past century. Damaging populations occur each year somewhere in the Sahelian, sub-Saharan or Northern Africa regions, but major and lasting outbreaks (plagues) covering vast areas are episodic.

Locusts, aggregating grasshoppers and the African armyworm have one feature in common: they are able to transform reversibly from the solitary lifestyle to dense, highly synchronous, cohesive and migratory gregarious forms. The transformation involves deep-seated physiological changes and is central to their biology and pest status. The Locusts and Migrant Pests Megaproject's prime concern is to elucidate the mechanisms of their transformation and to identify the mediating intraspecific and environmental signals. The long term goal is to identify ways of interfering with gregarisation using the insects' own communication signals, supplemented where necessary, with biocontrol agents to reduce population size and to forestall any regrouping that may take place.

The lessons learned in the Megaproject's work on the desert locust, *Schistocerca gregaria* (Forskal) is being applied to other migrant pests.

III. FOOD AND PERENNIAL CROP PESTS

The Food and Perennial Crop Pests Megaproject was established to include three related activities centered on the management of cereal crop pests. One activity is investigating novel habitat management approaches to control cereal stemborers and *Striga* in maize and sorghum. This project is developing 'push-pull' strategies to repel stemborers from the cereal crop and attract them to an intercrop or barrier of forage grasses. Other plants, such as *Desmodium* spp., have been shown to suppress the emergence of the weed *Striga hermonthica*. A second activity in the Megaproject is examining the bioecology of maize streak virus and its vectors, with emphasis on the movement of vectors between crops and native habitats.

A third activity is focused on classical biological control of the exotic stemborer, *Chilo partellus*. This project has introduced a small parasitic wasp, *Cotesia flavipes*, from Asia into Africa, where it is now established and spreading. These three interrelated activities are described in greater detail in the following sections of this Report.

Plant Health

HORTICULTURAL CROP PESTS

I. Sustainable Pest Management for Vegetable Crops

A. IPM FOR COMMON VEGETABLES

1. DEVELOPMENT OF SUSTAINABLE INSECT PEST MANAGEMENT TECHNOLOGIES FOR COMMON VEGETABLE CROPS IN THE TROPICS (HOR-1)

Background, approach, objectives

Agricultural production is fast becoming more diversified and the importance of fruit and vegetable growing is on the increase in tropical agriculture. Measures to boost and sustain vegetable production play a dual role in achieving development policy goals: they help reduce malnutrition and assist in employment and income generation opportunities. Even vegetables produced in the house-garden have the double advantage of bringing about self-reliance and access to high quality foodstuffs, and provide a periodical source of income from selling surplus produce in the market. The contribution of vegetable crops to the gross national product is substantial and tends to increase further in many countries.

Production techniques in the tropics are rudimentary and many important production aids (fertilisers, irrigation equipment) are lacking, consequently the level of production is low. Very few cultivars that are adapted to the climatic conditions of the wet tropics are available. Commercial seeds of European-type vegetables grown for marketing are mostly imported.

Insect pests are important constraints to vegetable production in the region and it is important to seek sustainable options to contain damage and yield losses to the crops. The goal of ICIPE's new initiative in horticultural pest management is to improve food security, nutrition and human welfare through the development and implementation of sustainable pest management technologies on the economically important common, export and indigenous leafy vegetable crops in the tropics, especially in Africa. During 1995, research activities on vegetable crops were initiated for the first time at ICIPE under core funding.

Participating scientists: *K. Ampong-Nyarko*, K. V. Seshu Reddy, S. Sithanantham, J. Baumgärtner, N. K. Maniania* (* Project Leader)

Assistants: *W. Ogutu, D.O. Nyagol, J. A. Orwa, G. Jira*

Donor: *ICIPE Core Funds*

Collaborators: *• GTZ-IPM Horticulture Project • Asian Vegetable Research and Development Centre (AVRDC) • Kenya Agricultural Research Institute (KARI)*

1.1 IDENTIFY PEST STATUS OF SELECTED INSECTS AND FARMER CONSTRAINTS

Work in progress

1.1.1 *A survey of insect pest problems of common vegetables in central highlands and coastal lowlands of Kenya*

A field survey was undertaken in Thika, Kiambu, Nakuru, Kilifi and Kwale Districts of Kenya in June/July of 1996. The objectives of the survey were to identify main insect pest problems, indigenous pest control practices and farming practices in vegetable production. The methodology adopted, combined field observations by the survey team and interviews of farmers, where they were available in their farms. In the field, observations were recorded on the crop mixtures; presence or absence of major insect pests and scores of damage caused (1–5 scale).

MAJOR INSECT PESTS

Farmers in different areas were found to specialise in the crops they grow. For example around Kiambu, kales and cabbages (*Brassica*) were predominant and onions and carrots were popular in Nakuru District. Tomatoes, capsicum and French beans were important in Thika. The most common insect pests on the brassica crops were the diamondback moth, *Plutella xylostella* L. and the cabbage aphid, *Brevicoryne brassicae*. In Longonot area, up to 100% damage was observed in cabbage by diamondback moth even in fields that have been sprayed weekly. This was an indirect indication of existence of local populations having become resistant to the commonly used insecticides. Cutworms (*Agrotis* sp.) were also important in almost all the vegetable crops and appeared to be most serious in onions. Some farmers reported that the cutworm problem was worse in fields where manure has been applied. Onion thrips, *Thrips tabaci* occurred in the three districts. *Helicoverpa armigera* appeared to be the major insect pest on tomato. Farmers also mentioned early and late blight as some of the production constraints in tomatoes.

Farming practices

Vegetables were normally grown as monocrops, but intercropping of French beans with maize was a common practice in all the districts. Relay cropping of onion and beans was also observed. A few farms were observed to have complex crop mixtures such as kales, cabbage, snowpea, onion or potato, beans, collards and cabbage. Crop rotation is a common practice in all the districts.

Farmers' indigenous pest control methods

About 95% of the farmers were found to resort to insecticides for controlling insect pests. All the farmers interviewed were unaware of the availability of pest tolerant crop varieties or the use of biological control agents. However, some farmers recognised the natural predatory activities of spiders in their fields. The beneficial effects of some cultural practices such as crop rotation for reducing the pest severity was known to about half of those interviewed.

Production constraints

Farmers' perceived vegetable production constraints included insect pests, plant diseases, lack of market, damage by wild animals, poor soil fertility, low rainfall, seed variety, frost and lack of credit. Insect problems were the only constraint mentioned by all the farmers. The survey confirmed the importance of the target insects focused by this research project.

1.1.2 *Evaluation of the extent of yield losses caused by common insect pests in tomato*

An experiment to establish the insect pest problems and yield losses due to insects in tomato, *Lycopersicum esculentum* (cv Money Maker), was conducted in the first and second cropping seasons of 1995 at the Mbita Point Field Station. Treatments consisted of protected (grown under mosquito net of fine mesh) and unprotected, each replicated four times. The design was randomised complete block with plot size of 10 x 9 m. The plants were transplanted at a spacing of 100 cm between rows and 50 cm within rows. Pruning and staking were carried out during plant growth. Sampling was done at weekly intervals. At each sampling, entomological observations were made on arthropod complex throughout growing period, damage caused and yield components at harvest.

The insect pests observed at the seedling stage, after transplanting were grasshoppers, causing severe damage to early transplanted crop. The main fruit pest was the fruit borer, *Helicoverpa armigera*. The larvae attacked flowers and fruit, resulting in fruit rot. Yield loss due to *H. armigera* was 15% in the first cropping season. There was generally lower infestation in the second cropping season than the first. Within the season, fruits formed earlier in the season were most damaged, compared to the late developed ones. Tomato fruit yield was 44.3 t/ha. Another tomato crop (cv Money Maker) was planted at MPFS in the long rains of 1996 for assessment of yield loss caused by insects. *Helicoverpa armigera* and *Agrotis* sp. were the main insect pests recorded. The mean fruit damage reached 24%. Crop yields were low, about 14.2 t of healthy fruits per ha.

1.1.3 *Evaluation of the extent of yield losses caused by common insect pests in onion*

An experiment to establish the insect pest problems and yield losses in onion (cv Red Creole C-5) was planted in the long rains on 8 April 1995 and harvested on 29 August 1995 at the Mbita Point Field Station. Treatments consisted of protected (by covering plots with mosquito net of fine mesh) and unprotected under natural infestation. The design was randomised complete block with four replications with plot size of 6 x 5 m. Onion was directly planted from seed at a spacing of 30 x 8 cm. Sampling was done at weekly intervals. At each sampling, entomological observations were made on arthropod complex throughout growing period, damage caused and their effects on yield components at harvest.

Onion thrips, *Thrips tabaci* Lind. (Thysanoptera: Thripidae), was the most damaging insect pest during growth, where incidence was 22.4% in protected plots and 29% in unprotected plots, 14 weeks after emergence. At harvest, however, infestation due to thrips had risen to 100% in all treatments. Cutworm, *Agrotis* sp. caused less than 5% damage. Covering plots with mosquito netting did not provide adequate protection to prevent yield losses. Dry onion yield was 10.6 t/ha. In further field studies in 1996 *Thrips tabaci* was once again the main insect pest in onion. Yields of up to 19.3 t/ha were recorded in protected plots (Table 1.1). The yield loss due to *Thrips tabaci* damage was estimated at 54% in replicated on-station trial at MPFS during the first cropping season.

1.1.4 *Evaluation of the extent of yield losses caused by* Plutella xylostella *in cole crops*

Yield losses in both collards and cabbage due to diamondback moth (DBM), *Plutella xylostella* were determined in 1997. Yield loss in cabbage due to *P.*

Table 1.1. Effect of time of protection from onion thrips on onion bulb yield (t/ha) for three crops grown at MPFS

Protection regime (MAT)	First crop	Second crop (t/ha)	Third crop
Full season control	19.29 a	6.87 ab	24.5 a
Unprotected control	8.84 c	3.32 c	31.3 a
Protection during 1st	13.83 abc	4.83 bc	26.3 a
Protection during 2nd	18.66 ab	4.04 bc	25.4 a
Protection during 3rd	11.9 bc	4.54 bc	30.0 a
Protection during 4th	9.52 c	3.71 c	25.9 a
Protection during 1st and 2nd	18.28 ab	8.07 a	33.9 a
Protection during 2nd and 3rd	21.45 a	4.57 bc	27.2 a
Protection during 3rd and 4th	11.52 bc	3.72 c	31.0 a
Protection during 1st, 2nd & 3rd	19.74 a	7.01 ab	31 .0 a
F value	8.39**	3.23*	1.85 NS

Means followed by the same letters are not significantly different at $P < 0.05$ by Tukey's studentised range test
MAT=Month after transplanting.
*Significant at 5% level.
**Significant at 1% level.
NS: Not significant.

xylostella was 39%. The yield of collards over 160 days was 40.2 t/ha for the protected crop and 18.6 t/ha for the unprotected crop, giving a yield loss of 54% in the first cropping season of 1997.

1.2 ASSESSMENT OF MULTI-STRESS FACTORS ON YIELD FORMATION OF VEGETABLE CROPS

Background, approach and objectives

The analysis of growth and development of vegetable crops provides the basis for assessing the effects of multi-stress factors and for decision-making in crop pest management. To meet these objectives we rely on a three stage procedure: (1) statistical analysis of controlled field experiments, (2) the on-going development and use of explanatory growth models, and (3) the planned coupling of simulation models with geographical information technologies. Among the stress factors, there are phytophagous arthropod populations such as onion thrips, *Thrips tabaci* Lindeman, negatively affecting yield formation of onion. Field experiments have shown that onions are most susceptible during the medium phase of crop development. Thrips effects were expressed with a multivariate regression model that provides the basis for calculating an operational threshold.

The development and use of simulation models provides a more general framework than regression models for assessing the effects of arthropod populations and for separating them from other yield limiting factors, such as drought and temperature stresses. Moreover, these models can be combined with geographical information systems, to assess the land-use potential for growing vegetables.

The objectives of this activity were,

(i) to determine critical periods of pest occurrences and crop sensitivity, to quantify their effects on crop yield, and to establish an operational economic threshold;
(ii) to develop mechanistic crop growth models for studying the interactions between phytophagous arthropods and crop growth;
(iii) to assess the land use potential for growing vegetables in East Africa; and
(iv) model development: the development and use of models for representing growth and development of vegetables; emphasis on the temporal dimension. Plant mapping and dry matter measurements as a basis for model parameterisation. Model use for separating the effects of yield limiting factors.

Work in progress

1.2.1 *The effect of onion thrips* T. tabaci *on* Allium cepa *L: Emphasis on statistical relationships*

CRITICAL GROWTH STAGES TO *THRIPS TABACI* ATTACK AND ECONOMIC THRESHOLDS

Bulb onion, *Allium cepa* L., is a major vegetable crop in Africa with an annual production of 2,252,000 t from about 176,000 ha. Insecticides are used almost routinely in many African countries to control onion thrips despite the fact that no sound economic threshold is available. Three field experiments were conducted during 1996–1997 at ICIPE's Mbita Point Field Station, to establish the effect of onion thrips, *T. tabaci*, on red onion yields and to determine their economic threshold.

Since thrips can attack the crop at any time during crop growth, it is important to determine the time onion crop is most susceptible to thrips attack. An experiment was established in the second cropping season at MPFS using the cultivar 'Red Creole'. Treatments consisted of protecting the onion crop with thiodan at the following crop growth stages: 9–13, 13–17, 17–21, 21–25, 9–17, 13–21, 17–25 and 9–21 weeks after emergence. In addition, there were plots that were unprotected and those that were completely protected as controls. The crop was harvested at 21 weeks after emergence. In 1996 short rains and long rains of 1997, an onion crop was exposed to thrips for various periods of development. A randomised complete block design with three replications and 10 treatments, i.e. infestation periods, was used. Dry weights of leaves and bulbs were taken at weekly intervals. In all studies, the thrips occurred after the seventh week after emergence (Figure1.1). The difference between the infested treatment and the control was divided by the number of thrips-days to assess the critical period. The most sensitive period of growth to thrips attack was between 80 and 108 days after emergence. The proportional final yield was expressed as a product of bulb dry matter survival

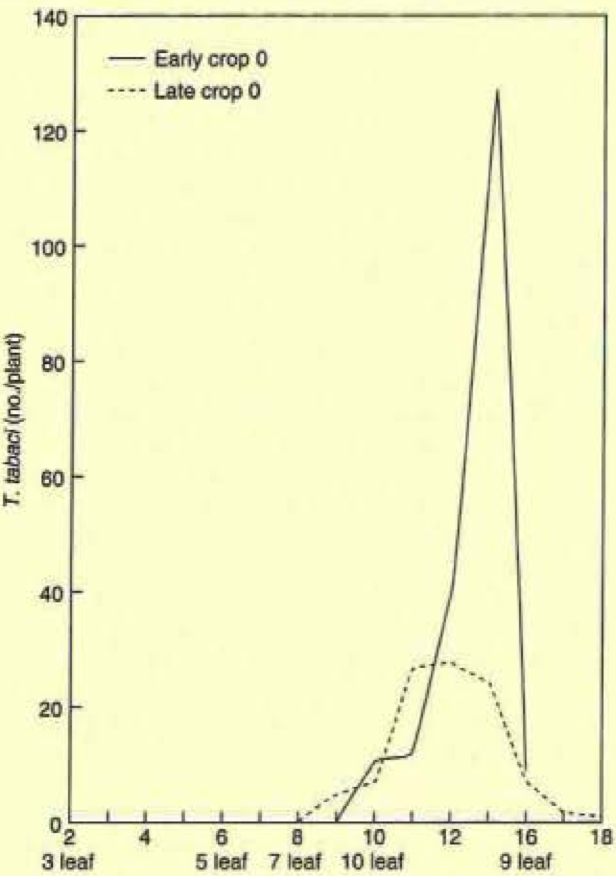


Figure 1.1. Crop growth and development and thrips occurrence in two growing periods

probabilities lx which depend on thrips-day's. The occurrence of thrips and the phase-specific sensitivity of the crop is used to narrow the window of crop development in which thrips densities should be monitored and a decision based on threshold is an efficient control strategy. The sensitivity index derived from yield loss data in relationship to thrips-days is illustrated in Figure 1.2. The three year data on effect of different protection regimes is furnished in Table 1.1.

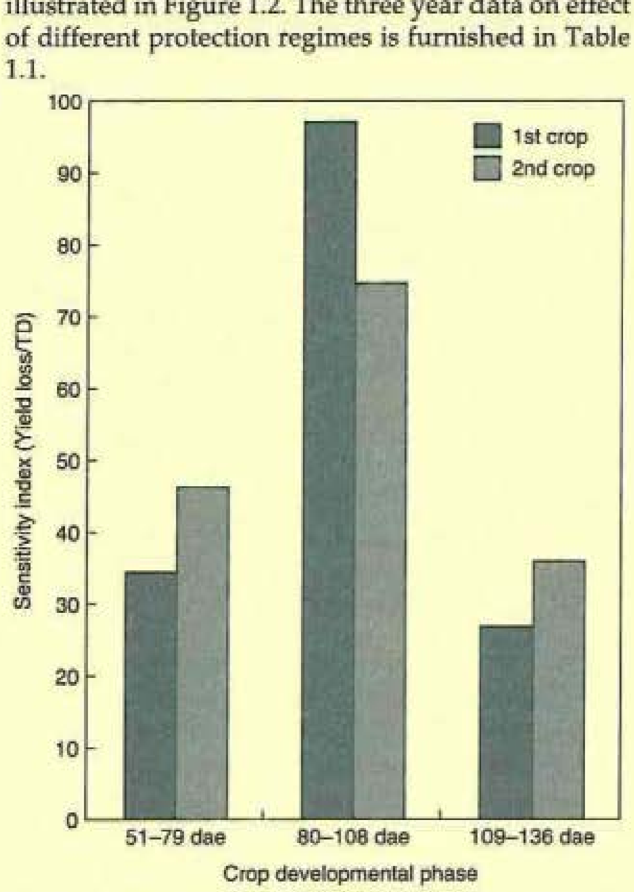


Figure 1.2. The sensitivity of onion crop developmental phases

1.3. ASSESSMENT OF THE SCOPE FOR UTILISING HOST PLANT RESISTANCE

Work in progress

1.3.1 *Evaluation of local and exotic tomato germplasm for insect pest resistance/ tolerance*

In 1995 sixty tomato genotypes/lines were evaluated in field trials at the Mbita Point Field Station in both the first and second cropping seasons. These lines were received from AVRDC, India, Kenya, Spain, Malawi, South Africa and Zambia among others. A randomised complete block design was used with four replications, with a row of 5 m long as a plot. The lines were rated for damage to *Helicoverpa armigera* and their adaptability.

The genotypes differed in their reaction to the main pest, *Helicoverpa armigera*, ranging from highly susceptible to moderately resistant. Malawi Local 1, Malawi Local 2, EC-7288, NTDR-1, Malawi 4, were moderately resistant and had fruit damage of less than 10% (Table 1.2). Varieties Roma and Heinz Florida 93 KT 85, were susceptible and had 30–45% fruit damage. The fruit damage in locally recommended Money Maker was 15.9%. The fruit size of the Malawi

Table 1.2. Yield potential and susceptibility of promising tomato genotypes/cultivars to diseases and fruit borer at MPFS

Genotype/ Line	Days to 50% flowering	Reaction to late blight[1]	Screenhouse resistance to *H. armigera*[2]	Field resistance to *H. armigera*[2]	Yield (t/ha)
Heinz	50	3.7	35.1	4.1	63.3
Marglobe	51	3.3	59.7	5.8	62.9
Elin F1	50	3.0	40.0	3.0	57.8
93 KT 82	54	3.0	40.0	4.5	57.5
93 KT 9-1	50	3.7	19.2	2.3	52.1
94 RT 301	52	2.3	58.2	5.2	51.6
CAL J	51	4.0	42.8	8.6	50.8
Money Maker	50	3.0	55.6	2.4	50.5
Roma	53	2.7	50.5	3.8	50.5
ARP 365-3	53	3.3	64.5	3.8	50.0
93 KT10	48	1.7	26.3	1.2	48.9
ARP D2	52	3.7	47.9	4.2	48.5
ARP D1	51	4.0	52.0	10.6	48.5
ARP 365-2	54	2.3	82.8	2.9	48.1
ARP 367-2	51	2.3	51.9	2.5	47.5
Sixpak	52	3.0	60.1	5.2	47.1
ARP 366-4	54	2.3	70.2	1.7	47.0
Heinz 1370	50	4.3	70.0	3.2	46.9
Alok	50	3.3	41.6	5.6	46.8
ARP 366-3	50	2.3	45.0	2.9	46.7
ARP 366-1	52	2.3	61.6	4.4	46.3
ARP 366-2	52	2.3	72.1	2.5	45.7
Nyar Uganda	51	3.7	58.9	8.4	44.9
Floradade	53	3.7	46.4	5.1	43.6
Beauty	53	3.3	58.5	7.6	42.6
Early Pearson	51	3.3	82.5	9.4	40.9
ARP 365-1	52	2.3	49.4	4.5	39.1
ARP367-1	52	2.0	53.0	2.4	36.7

[1] Rating : 1= Least/ No damage; 5= Very severe disease.
[2] Based on percent fruit damaged during the cropping season.

Local was commercially unacceptable, 3.6 g compared to 60.4 g of Money Maker. There appears to be positive correlation between fruit size and *Helicoverpa* damage.

More germplasm was assembled from diverse sources for further identification of usable resistance in 1996. The lines of tomato for resistance evaluation increased to 120. Under natural infestation, the lines differed in their reaction to *H. armigera* from highly susceptible to moderately resistant. Based on growth habit, fruit quality (size, resistance to cracking), besides susceptibility to blight disease, 17 lines were advanced for further evaluation.

To confirm the field resistance observed, in the second cropping season of 1997, screening of 30 promising lines / varieties were undertaken using pre-mated *H. armigera* adult moths reared on natural diet in the screen house. Under artificial infestation, percent fruit damage ranged between 19 to 83% and under natural infestations in the field, the range was between 1.8–10.6%. The most tolerant genotypes from the artificial screening were 93 KT9-1 (19%), 93kT10 (26%), Heinz (35%). The varieties Heinz, Elin F1, 93KT 82, 93KT 9-1 were less susceptible to *H. armigera* and higher yielding than Money Maker.

1.4 ASSESSMENT OF THE POTENTIAL FOR IMPROVED PEST HABITAT MANAGEMENT COMPONENTS FOR COMMON VEGETABLE CROPS

Background

Insecticide use has risen over 10-fold over the last 40 years and yet losses due to insects have nearly doubled over the same period. These increased losses occur because of numerous changes that have taken place in agricultural practices. This strengthens the need for ecological analyses of agroecosystems, to determine what factors in each cropping system contribute to pest outbreaks.

Work in progress

1.4.1 *Evaluating of the role of intercropping and crop combinations as means of reducing pest damage*

Four vegetable crops, tomato, cabbage, onion, and okra were planted as monocultures and in all possible mixtures in the first and second cropping seasons of 1995 at the Mbita Point Field Station. There were 15 treatments consisting tomato + cabbage, tomato + onion, tomato + okra, cabbage + onion, cabbage + okra, onion + okra, tomato + cabbage + onion, tomato + cabbage + okra, tomato + okra + onion, okra + onion + cabbage, tomato + cabbage + onion + okra, tomato monocrop, cabbage monocrop, onion monocrop and, okra monocrop. The plot size was 10 x 10 m with three applications. The crops were planted at a constant inter row spacing of 60 cm and in two row strips. Pest's dynamics and their related natural enemies were studied in all the crops and their combination.

The results indicate that intercropping could reduce *Plutella xylostella* damage in cabbage. At harvest, cabbage monocrop had 10 larvae/pupae per 10 plants compared to 1 larvae/pupae in cabbage + tomato, cabbage+ onion strips cropping. The tri-crop mixtures were significantly different from the di-crop mixtures. Cabbage + onion gave the best crop vigour. No effect of crop diversity was observed in the case of onion thrips. At harvest, there was 100% infestation in all treatments. Because of low infestation, no treatment differences were observed in the case of *H. armigera* in tomato.

As a follow up of the 1995 trials that indicated that intercropping could reduce *P. xylostella* damage in cabbage, four vegetable crops, tomato, cabbage, onion and okra, were planted as monocultures and in all possible mixtures in the long rains of 1996. There were no significant differences in the incidence levels of thrips between intercropping treatments. The onion–cabbage mixture offered the least intercrop competition and gave greater onion bulb yields (11.5 t/ha), which was higher than the monocrop of 7.3 t/ha. The least compatible combination seemed to be the onion–okra mixture. Incidence levels of flea beetles in okra seemed to be greater in the presence of onion in the mixture. The cabbage plant population in the study was too variable in the growth to allow satisfactory analysis of effect of the mixtures on the diamondback moth incidence.

1.4.2 *Mulching studies*

In the second cropping season of 1996 the effect of two different mulches (*Melinis minutiflora, Cynodon dactylon*), were compared with onion–cabbage intercropping together with thiodan-treated and untreated controls. At 39 days after transplanting, (DAT), the number of *P. xylostella* was significantly lower in all treated plots compared with the untreated control. However, at harvest the number of diamondback moth (DBM) in insecticide treated plots had increased from 0.2 per plant at 39 DAT to 15 per plant compared to 1 per plant and 3.5 per plant, respectively, in the untreated control.

The possibility of using cultural practices including mulching with molasses grass, *Melinis minutiflora*, and intercropping with onions, in the management of *P. xylostella* was examined further during 1997. Mulching with molasses grass gave the best suppression of DBM at harvest. The cabbage yield was depressed by the mulch. The onion–cabbage intercropping gave a high intercropping advantage with land equivalent ratio of over 1.7 and seems to be a good cropping system alternative with several advantages (Table 1.3).

1.4.3 *Cabbage*–Gynandropsis *intercropping*

It is anticipated that it may be difficult to have these crops cultivated as sole crops. To promote the use of these vegetables, their possible use in pest control as an intercrop with European type vegetables was investigated in the second cropping season of 1997. Cabbage was intercropped with *Gynandropsis gynandra* in different row-ratios for the control of *P. xylostella* (Table 1.4). The best pest suppression of *P. xylostella* was obtained with single alternate row arrangement. The possibility, therefore, exists for the promotion of indigenous leafy vegetables through intercropping.

Table 1.3. Effect of intercropping and mulching on *Plutella xylostella* incidence at harvest and yield of cabbage

		Yield (kg/ha)		
		Cabbage		Onion
Crop combination	Larval/pupal density	Heads (no./ha)	Weight (kg/ha)	Weight (kg/ha)
Cabbage protected with insecticides	65.8	14917 a	8732 a	
Cabbage monocrop no protection	55.5	10373 ab	5297 ab	
Cabbage + *Melinis* grass mulch	28.5	7373 b	3617 b	
Cabbage + onion intercrop	55.0	9945 ab	5362 ab	16333
Cabbage + mixed grass mulch	58.0	9769 ab	4573 ab	

Means followed by the same letters are not significantly different at $P< 0.05$ by Tukey's studentised range test.

Table 1.4. Effect of intercropping the indigenous leafy vegetable *Gynandropsis gynandra* on *Plutella xylostella* incidence in cabbage 60 days after transplanting

Crop combination	Row ratio	Larval/pupal density/10 plants
Cabbage + *Gynandropsis*	(1:1)	42.0 b
Cabbage + *Gynandropsis*	(2:1)	50.7 ab
Cabbage + *Gynandropsis*	(4:1)	64.3 ab
Cabbage + *Gynandropsis*	(6:1)	102.7 ab
Cabbage monocrop		79.0 ab
Cabbage protected with *Gynandropsis* extract		99.0 ab
Cabbage protected with lambdacyhalothrin		133.7 a

1.5 ASSESSMENT OF THE SCOPE AND COMPONENTS FOR BIOLOGICAL CONTROL

Work in progress

1.5.1 *Identification of the key natural enemies of* P. xylostella

An experiment was conducted to establish insect pest problems and yield losses in cabbage (cv Copenhagen Market) at the Mbita Point Field Station. Treatments consisted of protected, by covering plots with fine mosquito mesh and unprotected, replicated four times. The design was randomised complete block and plot size was 10 x 10 m. Cabbage spacing was at 60 cm between rows and 60 cm within rows. Sampling was done at weekly intervals. At each sampling, entomological observations were made on arthropod complex damage caused and yield components at harvest. In the second cropping season there were three treatments, comprising non-protected control and protected with neem and insecticide.

In the first cropping season, the diamondback moth, *Plutella xylostella*, was the most abundant species followed by cabbage aphid, *Brevicoryne brassicae*. In the unprotected crops, *P. xylostella* infestation started in late June and reached a mean density of 8 (larvae/ adults/pupae) per plant, at 11 weeks after emergence. At harvest, 47% of *P. xylostella* larvae and pupae were found parasitised. *Oomyzus sokolowskii* and *Tetrastichus* sp. nr. *atriclavus* were recorded as parasitoids of diamondback moth (DBM).

1.5.2 *Induction of resistance in* P. xylostella

Bacillus thuringiensis and neem gave an acceptable control of the diamondback moth and yields similar to lambdacyhalothrin control in collards. In the second cropping season, the yield was 29 t/ha in protected and 19.9 t/ha in the unprotected plots. *Plutella xylostella* appeared to have two distinct peaks in the long rains with the second peak reaching 28 larvae/pupae per plant. A field experiment was conducted in 1997. The additional observation was that at harvest the number of DBM in insecticide-treated plots had increased from 0.2 per plant at 39 DAT to 15 per plant, compared to 1 per plant and 3.5 per plant, respectively, in the untreated control. The treatment consisted of neem (as Neemroc EC 0.3% azadirachtin), *Bacillus thuringiensis*, lambdacyhalothrin, (Karate) and unprotected control. A similar result was obtained for the second peak of *P. xylostella* where the insecticide attained a peak of 10 larvae/pupae per plant compared to less than 3 per plant in the neem and *Bt*-treated plots. In the 1997 long rains the level of parasitism of *P. xylostella* in insecticide-treated plots of collards was 1.8% compared to 7.4% in the untreated control. The total number of predators caught in pitfall traps were 88 for lambdacyhalothrin, 110 for *Bt*, 124 for neem, and 152 for the untreated control. This is an interesting phenomenon that will be investigated further.

1.5.3 *Control of onion thrips with* Metarhizium anisopliae

Collaborative studies have been initiated on the usefulness of the fungus, *Metarhizium anisopliae* in controlling thrips on onions. Explanatory data are promising and follow-up research is in progress.

(See following sections.)

Output

Publications

Annan I. B., Ampong-Nyarko K. , Tingey W.M. and Schaefers G. A. (1997) Interactions of fertilizer, cultivar selection and infestation by cowpea aphid (Aphididae) on growth and yield of cowpeas. *International Journal of Pest Management* 43(4), 307–312.

Githiri S.M. , Ampong-Nyarko K. , Osir E.O. and Kimani P.M (1996) Antixenosis component of resistance to aphids in the cowpea. *East African Agriculture and Forestry Journal* 61(3), 249–253.

Conferences attended

K. Ampong-Nyarko, Z. R. Khan and K.V. Seshu Reddy 1997. Habitat management strategies for the control of cereal stemborers in the tropics. Joint Congress of the Entomological Society of Southern Africa and the African Association of Insect Scientists, Stellenbosch, 3 June–4 July 1997.

Research proposals written

One written and submitted to BMZ in 1997, but was not successful:

Strategic Planning of Vegetable Production in East Africa: A Synoptic Analysis for Assessing Land Use Potential.

Capacity building

Lectures to GTZ-Tanzania National extension staff.

1.6 MICROBIAL CONTROL OF THRIPS

Background, approach and objectives

Thrips are economically-important insect pests on vegetable and flower crops worldwide. Their infection can cause total crop failure, and some transmit plant diseases. The most predominant species include flower thrips (*Megalurothrips sjostedti* Trybom) on cowpeas and beans (causing 20–100% yield loss) (and western flower thrips (*Frankliniella occidentalis* Pergande) on a variety of crops (causing 10–80% yield loss) and onion thrips (*Thrips tabaci*) on onions and cucumbers (causing 30–80% yield loss).

Metathripol is the name of a biological insecticide being developed from the entomopathogenic fungus *Metarhizium anisopliae* at the International Centre of Insect Physiology and Ecology (ICIPE), Kenya, as an environment-friendly alternative to chemical insecticides for control of thrips. This particular strain of *M. anisopliae* was selected among other fungal strains, because of its broad temperature range of pathogenic activity (15–30° C) against *M. sjostedti*.

Participating scientists: *N. K. Maniania, K. Ampong-Nyarko, S. Ekesi, S. Sithanantham*

Assistants: *J.A.Oluoch, D.Nyagol, E.Wesonga*

Donor: *ICIPE Core Funds*

Collaborator: *Yoder Kenya Limited (chrysanthemum experiments)*

Work in progress

Metathripol is being produced on semi-solid medium, and used as dry conidia suspended in water. Research is still in progress to work out proper formulation.

The efficacy of Metathripol has been tested in the field against *M.sjostedti*, on cowpea, the onion thrips, *T.tabaci* on onion (Figure 1.3), and the western flower thrips, *F. occidentalis*, on French bean (Figure 1.4). The product was applied as aqueous suspension at concentration of 1.0×10^{13} conidia/ha, using the normal knapsack sprayer. Results indicate that Metathripol is as effective as chemical insecticides generally used

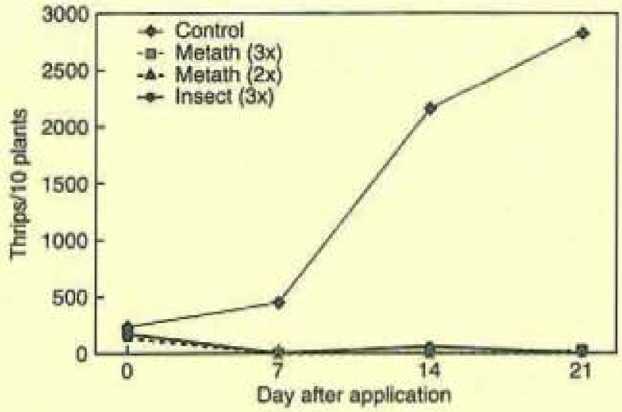


Figure 1.3. Effect of weekly and bi-weekly application of Metathripol and insecticide on onion thrips populations of *Thrips tabaci*, MPFS, 1997

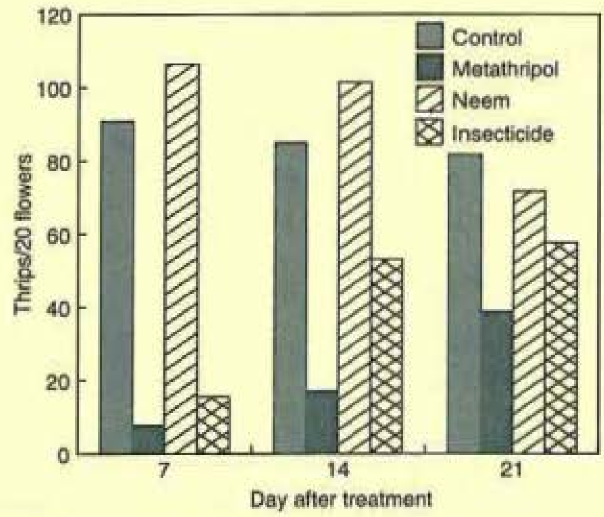


Figure 1.4. Number of *Frankliniella occidentalis* on French bean following three applications of Metathripol, neem oil and insecticide MPFS, 1997

for the control of thrips (Table 1.5). Contrary to chemical pesticides, Metathripol does not have toxic effect on auxillary fauna (Table 1.6).

Future activities will involve evaluation of Metathripol on western flower thrips, *F.occidentalis* on French beans, snowpeas and flower cuttings on a large scale.

Output

Publications

Ekesi S., Maniania N.K. and Onu I. Antibiosis and antixenosis of two cowpea varieties to legume flower thrips. *African Crop Science Journal* 6, 49–59.

Ekesi S., Maniania N. K., Onu I., and Lohr B. Pathogenicity of entomopathogenic fungi (Hyphomycetes) to the legume flower thrips, *Megalurothrips sjostedti* (Trybom) (Thysanoptera: Thripidae). *Journal of Applied Entomology*. (In press).

Table 1.5. Effect of three field applications of Metathripol and chemical insecticides on thrips and grain yield (kg/ha)

	Target crop				
	Cowpea		Onion		Chrysanthemum
Treatment	*M.sjostedti*[1]	Yield	*T.tabaci*[2]	Yield	*F.occidentalis*[3]
Control	472	384	2808.0	22326	33.4
Metathripol	76	1730	13.8	26498	11.3
Chemical	6	1826	20.5	25748	11.6

[1]Mean of insects/20 flowers; [2]Mean of insects/10 plants; [3]Mean of insects/20 cuttings.

Table 1.6. Impact assessment of Metathripol and chemical insecticide on few non target organisms in cowpea agroecosystem, following treatment against legume thrips, *M.sjostedti*

	Organisms+			
Treatment	Coccinellid beetles	Earwigs	Ants	Spiders
Control	2.2	2.8	10.3	6.4
Metathripol	2.6	3.1	9.4	6.5
Chemical	0	0	1.3	1.2

+Data collected following three applications of Metathripol and chemical insecticide.

Conferences attended

S. Ekesi, N. K. Maniania, K. Ampong-Nyarko and I.Onu. Joint Congress of the Entomological Society of Southern Africa and the African Association of Insect Scientists, Stellenbosch, 30 June–4 July 1997, South Africa.Theme: Insects in African Economy and Environment. Presentation title: "Field evaluation of the entomopathogenic fungus, *Metarhizium anisopliae* (Metsch) Sorok. for the control of legume flower thrips, *Megalurothrips sjostedti* (Trybom) on cowpea.

Capacity building

Sunday Ekesi, ARPPIS, Research topic: Variability of pathogenic activity of entomopathogenic fungi towards the legume flower thrips, *Megalurothrips sjostedti*, and their potential for biological control.

Impact

A strain of *M. anisopliae* with appropriate pathogenicity properties for the management of thrips under field conditions has been found. Fresh produce growers find Metathripol acceptable for large-scale field trials.

B. IPM FOR EXPORT VEGETABLES

2. REGIONAL INITIATIVE FOR IMPROVED PEST MANAGEMENT IN EXPORT VEGETABLES IN AFRICA

Background, approach and objectives

Export vegetable cultivation is emerging as an important income source for smallholder farmers in Africa and elsewhere in the tropics. However, the premium price offered for blemish-free produce often induces farmers to resort to 'excessive' use of crop protection chemicals, especially synthetic pesticides. To enable them to shift away from this single dependence on the use of environmentally undesirable pesticides, there is an urgent need to identify, validate and verify alternative options, compatible with the sustainability of the agroecosystems. This initiative to contribute to smallholder agriculture was launched at ICIPE in 1996.

Participating scientists: *S. Sithanantham*, K. Ampong Nyarko, K. V. Seshu Reddy, A. M. Varela, N. K. Maniania, G. T. Lako, J. Baumgärtner (*Project Leader)*

Assistants: *L. Chongoti, W. O. Ogutu, M. A. Mbeke, G. Jira, D. Nyagol, B. Muia, R. Odhiambo, J.Ondijo*

Donors: *USAID/ ICIPE Core Funds*

Collaborators: *• Asian Vegetable Research and Development Centre (AVRDC) • GTZ/IPM Horticulture Project • Kenya Agricultural Research Institute (KARI) • Ministry of Agriculture (MOA) • Horticultural Crops Development Authority (HCDA) • Fresh Produce Exporters Association of Kenya (FPEAK)*

Work in progress

2.1 USAID/ICIPE EXPORT VEGETABLE IPM INITIATIVE

This USAID/ICIPE initiative has been launched for a two-year exploratory phase from October 1996, mainly for improved and sustainable pest management on export vegetable crops in eastern and southern Africa. The first year (October 1996–September 1997) was focused on understanding the situation and developing collaborative linkages among the stakeholders, namely farmers, exporters, extensionists and researchers in Kenya. It is estimated that over 200,000 farm families derive substantial income from cultivation and marketing of export vegetables in Kenya and the average value of the produce exported annually during 1994–1996 was over US $25 million.

2.1.1 *Understanding the pest problems and priority needs of farmers*

Stakeholders meeting

A national level stakeholders meeting on pest management in export vegetables was convened in February 1997 at ICIPE Headquarters in Kenya. The objectives of the meeting were as follows:

(i) to assess the existing knowledge on pests and their control options, and to identify the research gaps;
(ii) to comprehend the ongoing pest management related activities of different institutions/ projects; and
(iii) to identify the priority areas of concern in pest management.

In addition, the meeting was to also document the potential interest of researchers, extensionists, and the farming community to collaborate in the project to be developed. Accordingly, the consultation meeting was convened by ICIPE in Nairobi during February 1997, with representation from a broad range of institutions/stakeholders in Kenya.

The outcome included ranking of pest problems on six major vegetable crops: French bean, snowpea, okra, capsicum, eggplant and bittergourd (Karela). The status of the different control options for demonstration/adoption was also clarified (Table 2.1), besides identifying 'hot spots' in the country for individual pest problems (Table 2.2). The on-going research/activities of different institutions and projects on related areas was also documented, to ensure complementation and avoid duplication of efforts.

2.1.2 *On-farm surveys for pest damage*

Pest problems and their severity on peas—pilot survey of 20 farms

A field survey was carried out on 20 farms in Molo, Nakuru District, Kenya to assess the pest problems on peas (Table 2.3). Most of the farmers grew four cultivars: Kagoci, Kikuyu, Grano and Kigondoro. Among the crop production constraints, pest problems were perceived as the major biotic factor and soil, credit, seed supply and infrastructure/policy constraints were mentioned. None of the farmers have used insecticides, but the majority (65%) have

Table 2.1. Ranking of insect pests in Kenya and status of readiness of control options for adoption as perceived at stakeholders meeting (February 1997)

		Status of control options					
Crop	Insect pest and importance	Chemical control (pesticides)	Biological control	Use of botanicals	Use of cultural practices	Use of tolerant cultivars	Other methods
French beans	Bean flies (1)	B	B	B	B	B	-
	Bean flower thrips (1)	A	C	C	-	-	-
	Spider mites (2)	A	B	-	-	-	-
	Aphids (2)	A	-	C	B	-	-
	Helicoverpa sp. *Maruca* sp. (2)	A	C	C	-	-	-
	Cutworms (2)	A	C	-	B	-	-
Snowpea	Pod borers *Helicoverpa* sp. *Maruca* sp. (1)	A	C	C	-	C	-
	Aphids (2)	A	-	-	B	-	-
	Flower thrips 2)	C	C	C	-	-	-
	Cutworms (2)	A	C	-	B	-	-
Okra	Leaf miners (1)	A	B	B	B	-	-
Okra,eggplant, capsicum	Aphids and whiteflies (1)	A	B	B	B	-	B
	Spider mites (2)	A	B	-	B	B	B
	Thrips (3)	A	B	-	-	B	-
Karela	Fruit fly (Melon fly) (1)	A	-	-	B	-	B

A= Research completed, ready for demonstration.
B= Research promising, needs verification before demonstration.
C= Research inadequate, needs intensification of research and further verification.

Table 2.2. List of hot spots identified for specific pest problems on export vegetables in Kenya

Crop	Pest/ diseases	Districts (sites)
French bean	Thrips	Mwea/ Naivasha
	Whiteflies	Baricho
	Red spider mite	Mwea/ Yatta/ Mbooni
	Root rot	Vihiga/Meru/ Makueni/ Machakos
	Bean rust	Naivasha/ Thika
Snowpea	*Ascochyta* disease	Molo/ Timboroa/Limuru/ Kinangop
	Powdery mildew	Yatta/ Thika/ Embu
Okra	Aphids	Nguruman/Loitokitok
	Powdery mildew	Nguruman
	Nematodes	Nguruman
	Leaf miners	Kibwezi
Eggplant	Red spider mite	Nguruman
	Nematodes	Yatta/ Nairobi
Capsicum	Red spider mite	Nguruman
	Viral diseases	Coast
Bittergourd	Nematodes	Kibwezi/ Mtito Andei
	Viral diseases	Kibwezi
	Bacterial wilt	Coast/Nguruman/Kibwezi/Mtito Andei
	Nematodes	Yatta/ Nairobi

Table 2.3. Pest problems and their severity on peas in 20 farms in Molo, Nakuru District, Kenya September 1996

Pest observed	% Farms in which found
Aphids	70
Caterpillars	35
Cutworms	25
Pod borer (*Etiella*)	10

used fertiliser (diammonium phosphate) as input. All farmers expressed interest and need for technical guidance on pest control.

On-farm pest damage surveys

Two pilot on-farm surveys, one in Molo Division, Nakuru District (highlands) and another in Kwale and Kilifi Districts (coastal lowlands) were undertaken and the range of pests attacking the crops and their severity were recorded. In Molo Division, pea crops were found to be commonly attacked moderately to severely by aphids, pod borers, thrips and leaf miners. In Kwale-Kilifi, moderate to severe damage was observed by aphids, leafhoppers, leaf beetles, leaf miners and fruit borers on eggplant and capsicum (Table 2.4).

Understanding farmers' perceptions and constraints

Besides information assembled during on-farm surveys, community/group discussions were also held (Nguruman, Thika) to understand the export vegetable farmers' perceptions and constraints in pest management. Most farmers regarded pests as a major constraint to the production of these crops and expressed interest to shift away from unilateral dependence on chemical pesticides. Among their main constraints for improved pest control was lack of knowledge on pest ecology and identification, and pesticide residues (and waiting periods), besides lack of access to information on improved and environment-friendly options like biological control and botanicals.

Table 2.4. Pests and their severity in farmers' export vegetable crops, coastal Kenya, July-October 1996

Crop	Number of fields surveyed	Target pest	Pest severity rating+
Eggplant	11	Aphids	2
		Beetles	4
		Caterpillars	4
		Leafhoppers	3
		Bugs	4
		Grasshoppers	4
		Leaf miners	3
		Fruit borers	3
Capsicum	3	Leaf miners	3
		Bugs	4
		Grasshoppers	4
		Caterpillars	4

+Visual scores on 1–5 scale:
1= Little/ No damage 2= Light damage
3= Moderate damage 4= Severe damage
5= Very severe damage.

2.1.3 *Initiatives to stimulate community involvement and group action*

COMMUNITY INITIATIVES IN NGURUMAN

A meeting of over 200 export vegetable farmers in the Nguruman location (Kajiado District, Kenya) and representatives from research, extension and export sectors was held on 24 May 1997. Highlights of the Nguruman community consultation meeting for ICIPE assistance in improved pest management for sustainable export vegetable production were as follows:

(a) Participants: Representatives of export vegetables farmers groups, community elders, ministry of agriculture officers, HCDA, exporters, ICIPE scientists.

(b) Requests to ICIPE:
   (i) to assist in reducing the cost of pest control in export vegetables;
   (ii) to help in methods which can reduce the bad effects of pesticides;
   (iii) to guide in testing/using neem and any other good methods for pest control.

(c) Response from ICIPE:
ICIPE is willing to assist in determining the important pests known on each crop, the season they are more severe, the losses they cause, and will help in testing of the control methods which may be of use, as well as training in identifying the beneficial and harmful insects in the crop/field as follows:
   (i) attempt to understand the locally occurring pests and their seasonality,
   (ii) prioritise 2–3 pests of each crop (okra, eggplant, capsicum, karela),
   (iii) clarify the economic loss due to each of the major pests,
   (iv) locally test the new methods, like use of neem and other locally available materials,
   (v) test/demonstrate the usefulness of biological control agents,
   (vi) train local farmers and extensionists in all the improved pest control methods, and
   (vii) try to develop training materials to help further local training activities.

(d) Partnership for action:
   (i) ICIPE to assist as a partner in developing a suitable project proposal and in exploring for funding support with the community, Ministry of Agriculture, HCDA and any other stakeholders.
   (ii) ICIPE to assist the extensionists in conducting a systematic awareness building training on pest ecology for frontline staff and farmers' leaders, through a modified farmers' field school model, as soon as possible.

GROUP LEARNING

Based on the meeting held in May 1997, a series of discussions with leaders of the farmers' groups (belonging to five different export company outgrowers), group-learning and technology testing initiatives were proposed. As a start-up, fortnightly group meetings and field visits, followed by lectures on special topics were arranged for trainers (leaders of groups) during August–November 1997.

Fortnightly group learning activities at Nguruman, covered the following topics, conducted by specialists invited from different institutions/projects in Kenya.

(i) Diseases of vegetables (GTZ-IPM Project)
(ii) Nematode problems (Israel-Nairobi University Project)
(iii) Safe use of pesticides (Safe Use Project-GIFAP)
(iv) Residues of pesticides (KARI - NARL)
(v) Waiting periods and other healthy practices (FPEAK)
(vi) Organic farming methods (KIOF)
(vii) Weed control (KARI-NARL)
(viii) Cultural practices (ICIPE)
(ix) Use of neem (ICIPE)
(x) Use of insect pathogens (ICIPE)
(xi) Beneficial/useful insects (KARI-NARL)

Impact of the training on farmers' knowledge was also found to be positive (Table 2.5).

Table 2.5. Impact assessment of training on farmers knowledge awareness

Aspect	Percentage of the participants with knowledge: Before training	After training
Knowledge on pest damage (symptoms)	77.8	88.9
Knowledge on beneficial insects	33.3	88.9
Waiting period before harvesting	55.6	88.9
Knowledge on alternative control methods	33.3	66.7

UNDERSTANDING FARMERS' PERCEPTIONS AND CONSTRAINTS: THIKA FARMERS' GROUP CONSULTATIONS

A rapid rural appraisal was undertaken on 6 August 1997 on vegetable farmers' group at Ngoliba sublocation, Gatuanyaga Location, Thika District, to assess their problems, priorities and needs for pest control on export vegetables. The survey was conducted jointly by ICIPE and Ministry of Agriculture (Thika) officials, on a group consisting of 20 farmers. They are smallholder farmers growing export vegetables as outgrowers for different exporters operating in the area.

Some important points relating to pest management based on rapid rural appraisal are summarised below:

(a) Major crops grown: capsicum, eggplant, bittergourd, French bean
(b) Major pest problems: aphids, thrips, whiteflies, mites and caterpillars
(c) Major methods adopted for pest control: applying insecticides e.g. Dimethoate, Karate
(d) Perceived problems in pest control:
    (i) Pest control becomes less effective when pesticides are repeatedly used;
    (ii) Lack of knowledge on how to select pesticides;
    (iii) Lack of knowledge on improved methods for pest control;
(e) Request for information / assistance for improved pest control:
    (i) Identification of pests by damage in life stages
    (ii) Identification of the beneficial insects and how to conserve them
    (iii) Choice and safe use of chemical pesticides without negative effects on crop produce
    (iv) Alternatives to chemical pesticides and how to test/use them.

The survey revealed the farmers' lack of knowledge on alternatives to pesticides and their eagerness to be involved in learning about the use of rational pesticide and alternatives to pesticides on their crops.

Improved understanding of the diversity of pests and their natural enemies

Periodical inspection of crops (both on-station and on-farm) provided information on the diversity of pests on the major export vegetable crops. In particular, our gap in the knowledge of pests infesting peas was substantially filled (Table 2.6). Some natural enemies have also been observed and their firm identification is being pursued.

Table 2.6. List of phytophagous insects associated with export vegetable crops in Kenya, 1996–1997+

Crop	Order	Family	Scientific name	Collected/reared +
French bean	Coleoptera	Curculionidae	*Sphrigodes subdemudatus* Hust.	Collected
French bean	Coleoptera	Chrysomelidae	*Luperodes quaterwus* Frm.	Collected
Snowpea	Coleoptera	Tenebrionidae	*Gonocephalum simplex* F.	Collected
Snowpea	Lepidoptera	Noctuidae	*Plusia circumflexa* L.	Reared
Snowpea	Lepidoptera	Noctuidae	*Diacrisia investigatorum* Karsch	Reared
Snowpea	Coleoptera	Chrysomelidae	*Epilachna hirta* Thunbg	Collected
Snowpea	Coleoptera	Cantharidae	*Silidius* sp.	Collected
Snowpea	Heteroptera	Cicadidae	*Platypleura divisa* Germ	Collected
Snowpea	Heteroptera	Coreidae	*Plectocnemia bicolor* Hag	Collected
Snowpea	Heteroptera	Pyrrhocoridae	*Dysdercus cardinalis* Gerst	Collected
Snowpea	Lepidoptera	Pieridae	*Pontia helice* L.	Reared
Snowpea	Lepidoptera	Lycaenidae	*Lampides boeticus* L.	Reared
Snowpea	Lepidoptera	Noctuidae	*Helicoverpa armigera* (Hubn)	Reared
Snowpea	Orthoptera	Acrididae	*Phymateus viridipes* Stal.	Collected
Snowpea	Coleoptera	Chrysomelidae	*Monolepta leuca* Olivier	Collected
Brinjal	Coleoptera	Coccinellidae	*Epilachna hirta* Thunbg	Collected
Brinjal	Coleoptera	Coccinellidae	*Epilachna fulvosignata* Sic.	Collected
Brinjal	Coleoptera	Curculionidae	*Nematocera* sp.	Collected
Brinjal	Coleoptera	Meloidae	*Epicuata albovittata* Gerst.	Collected
Brinjal	Coleoptera	Meloidae	*Coryna apicicornis* (Guer)	Collected
Capsicum	Coleoptera	Curculionidae	*Systates sauberichi* Fst.	Collected
Capsicum	Heteroptera	Lygaeidae	*Lygaeus festivus* Thumb.	Collected
Okra	Coleoptera	Anthicidae	*Motoxus jeanneli* Pic.	Collected
Okra	Heteroptera	Pyrrocoridae	*Dysdercus cardinalis* Gerst.	Collected
Okra	Heteroptera	Pyrrocoridae	*Dysdercus nigrofasciatus* Stal.	Collected
Okra	Heteroptera	Lygaeidae	*Oxycarenus hyalinipennis* Costa	Collected
Okra	Lepidoptera	Pyralidae	*Acylolomia* sp.	Reared
Okra	Lepidoptera	Noctuidae	*Earias biplaga* Wlk.	Reared
Okra	Lepidoptera	Noctuidae	*Earias insulana* Boisd.	Reared
Okra	Lepidoptera	Papilionidae	*Papilio demodocus* Esper.	Collected
Bittergourd	Coleoptera	Chrysomelidae	*Copa delata* Er.	Collected
Bittergourd	Hemiptera	Coreidae	*Leptoglossus membranaceus* F.	Collected
Bittergourd	Hemiptera	Coreidae	*Anoplocnemis curvipes* F.	Collected

+Collected: Found feeding on the plant.
Reared: Completed its development by feeding on the plant parts.

2.1.4 *Estimation of yield losses due to pests*

Empirical estimation of avoidable yield loss due to pests was made in the on-station trials. Percent yield loss in okra, capsicum and eggplant was estimated at 40, 15, and 32% respectively, across sites and/or seasons. Assessment of yield loss through on-station trials by comparing yields, in protected and unprotected plots, was one of the criteria being developed for prioritising the pest problems across crops. The yield loss due to pests during 1996 short rains season at Muhaka in coastal Kenya was around 14% in capsicum, 24% in okra and 32% in eggplant (Table 2.7).

Further studies are being undertaken to improve the criteria of yield loss assessment in these crops, besides estimates across sites and seasons.

Table 2.7. Extent of avoidable yield loss in three Asian vegetables at Muhaka, coastal Kenya, 1996 short rains

	Yield (kg/plot)		
Crop	Protected plot	Non-protected plot	Yield loss (%)
Capsicum	1.14	0.98	14.0
Okra	1.66	1.26	24.1
Eggplant	14.73	10.07	31.6

2.1.5 *Supportive research on improved pest control options*

TESTING OF NEEM FORMULATIONS

(See also the main reports on neem under project V)

ICIPE has been building awareness on the potential of neem, *Azadirachta indica* A. Juss. (Family Meliaceae), as a source of natural pesticides. Neem can be used in a variety of applications. However, its efficacy against many pests in East Africa has remained largely untested. The objective of this activity was to test various formulations and doses of neem against the common pests of French bean.

Foliar sprays: On-station trials were initiated on the efficacy of standardised neem formulations (powder, oil) on some of the target crop pests. Initial results appear promising for neem sprays in the control of flower thrips on French beans. To explore the scope for systemic protection through seed treatment, a range of doses were tested to identify the safe dose limit that would not affect seed germination in French bean and okra. Farmer-participatory testing of neem on bittergourd has also been initiated at Nguruman.

In a trial conducted at Matuga (KARI-Station), Kwale District in 1997 long rainy season, comparing two formulations of neem (powder and oil) at two doses each as foliar sprays in two application regimes (weekly, fortnightly), indicated some improvement in yield over unprotected plots due to weekly application of neem powder (150 g/l) or fortnightly application of neem oil (15 ml/litre).

***Neem sprays in French bean* (Phaseolus vulgaris):** In a trial conducted at Machakos during the long rains of 1997, comparing neem formulations with a synthetic chemical (Karate), under two spray regimes, against thrips and aphids, up to 6 weeks after planting, the incidence of pests was low. It was observed that thrips control by neem appears to be satisfactory (significantly less insects than in unsprayed plots). However, aphid infestation did not appear to be satisfactorily controlled by neem sprays.

Further studies are being designed to include the promising formulations in comparison with chemical pesticides, to develop sustainable options.

Neem seed treatment: In an effort to study seedling vigour and seed germination so that safe doses for seed treatment with neem could be identified, net house trials were undertaken on three crops: French beans, snowpea and okra. The safe limit was established for the two neem formulations—oil and powder. This study has helped identify the maximum doses that do not affect seed viability.

Table 2.8. Effect of neem oil and *Metarhizium* as sprays on thrips incidence (per 20 flowers) and yields in French beans, Mbita 1997 SR

	After spray 1	After second spray		After third spray		
Treatment	No. of adult thrips	No. of adult thrips	No. of thrips larvae	No. of adult thrips	No. of thrips larvae	Yield (kg) 10.5 per m²
Neem oil (15 ml/l)	79.5	68.0	25.0	82.8	36.0	3.32
Neem oil (30 ml/l)	107.0	102.5	49.3	72.3	26.8	3.46
Metarhizium (Low dose)	14.5	33.3	11.0	48.0	16.0	4.71
Metarhizium (high dose)	7.0	18.0	5.8	39.5	11.8	4.89
Karate dose	16.0	53.8	12.8	58.8	15.8	4.49
Untreated control	91.8	85.3	65.3	82.8	32.8	3.32
Mean	52.6	60.1	28.2	64.0	23.2	4.03
CV%	45.5	32.2	78.0	32.6	60.2	27.5
LSD(0.05)	35.04	28.35	32.13	32.13	30.55	20.41

INSECT PATHOGENS FOR BIOLOGICAL CONTROL OF PESTS

Preliminary evaluation of* Metarhizium anisopliae *for thrips control: Preliminary trial comparing a selected strain of the fungus *Metarhizium anisopliae* with synthetic insecticides, showed that the thrips incidence was significantly reduced, resulting in significantly higher yields than the unsprayed plots. Another trial comparing *Metarhizium* with neem oil and chemical pesticide, showed that *Metarhizium* resulted in significant reduction of thrips numbers, resulting in higher yields per plot comparable to those obtained in chemical sprayed plots (Table 2.8). It is proposed to further study this aspect and also examine for any complementation between neem and *Metarhizium* application.

TESTING OF POTENTIAL CROP CULTIVARS / GENOTYPES FOR PEST TOLERANCE

Testing of crop cultivars: The potential for minimising the losses due to pests by selecting tolerant cultivars was examined, in view of meeting exporters'/ consumers' preferences. The popular cultivar planted extensively in Kenya (Pusa Sawani) was compared with seven other cultivars. During the short rainy season of 1996, all the cultivars showed much less yield potential than Pusa Sawani and two of them (Parbhani and Abhay) tended to indicate least difference between 'protected' and 'unprotected' plot yields, suggesting some tolerance. During the 1997 long rains, Parbhani and Dwarf Green showed less fruit damage by fruit borers, *H. armigera / Earias* spp. compared to Pusa Sawani. However, Spineless Clemson showed marginal yield advantage over Pusa Sawani. While pursuing this aspect, efforts are also being made to include additional improved genotypes from the Asian Vegetable Research and Development Centre (AVRDC) and Indian Vegetable Research Project (IVRP) in particular.

Snowpea varietal trial: Five varieties were evaluated at MPFS for adaptability and pest resistance. The varieties tested were Cascadia, Green Feast, Sugar Snap, Oregon II and Prussian Blue. Except for Cascadia, the varieties appeared to be unadapted to the lake basin environment and failed to produce any yields. They were also affected by powdery mildew, *Helicoverpa armigera* and aphids, but there were no varietal differences observed.

2.1.6 *Other potential pest control options*

FRENCH BEAN FERTILISER / TILLAGE STUDIES

A study to verify the effects of common cultural practices on the infestation of stem maggots in French beans was conducted in the second cropping season of 1996 at the Mbita Point Field Station. The experiment was conducted in a four-replicate trial in a randomised complete block design. The treatments were 3x2x2 factorial (3 levels of nitrogen 0, 45, 90 kg/ ha; 2 levels of phosphorous 0 and 45 kg /ha; and two types of land cultivation: planting on flat and ridges). Plot size was 4 x 5 m. The spacing was 65 cm in the inter-row and 15 cm within the row. The study was repeated in the first cropping season of 1997 at the Mbita Point Field Station. The experiment was sown in a four-replicate trial, in a randomised complete block design. The treatments were 4x2 factorial (4 levels/sources of nitrogen and phosphorous, farmyard manure at 20.8 tons/ha, 46 kg P with 18 kg N/ha, 0, 45, 90 kg/ha; 92 kg P with 36 N kg/ha and two types of land cultivation: planting on flat and ridges). Plot size was 6 x 4 m. The spacing was 30 cm in the inter-row and 15 cm within the row.

There were no significant differences between treatments on the infestation by bean fly maggots. The number of stem maggots per plant was on average about 20% less in the crops planted on the flat than those on the ridges. There were no significant differences in yield between treatments; however, the highest yield was obtained with 45 kg phosphorous plus 45 kg nitrogen per ha treatment. In the second study, due to low incidence of bean fly, there were no significant differences between treatments and the number of bean fly maggots. The number of stem maggots on damaged plants, was about 6% higher in the crops planted on the ridges than those on flat ground. There was no significant difference in yield between treatments; the ridging treatment gave 11% higher yield than planting on the flat.

Output

Publications

The following communications were prepared for the project goals and activities:

(1) Scientific articles - 2
(2) Lecture outlines - 2
(3) TV coverage - 1
(4) Radio coverage - 1

Conferences organised

Organised and convened a Stakeholders Consultation Meeting for improved pest management for export vegetables in Kenya, 26–27 February 1997.

Conferences attended

The project staff participated in the following seminars/workshops:

- Workshop on Export Horticulture—Protrade/ HCDA (14–15 April 1997) at KARI headquarters
- National Workshop on Horticultural Research and Development of Agriculture and Technology, January 30–31, 1997, Panafric Hotel

- Horticultural Export Seminar, FPEAK Kenyatta Conference Centre, 13–15 March 1997.

Research proposals

Submitted a proposal for farmer participatory development of sustainable pest management options by smallholder income generating/ export vegetable farmers in sub-Saharan Africa —Accepted by IFAD, Project for funding from 1998.

Submitted a proposal for funding on farmer-participatory development of sustainable pest management options for smallholder subsistence and export vegetables farmers in semi-arid irrigation zone (Nguruman) of Kajiado District, Kenya to the European Commission—Community Development Trust Fund—Proposal under review.

Capacity building

Human resource capacity building for national research extension institutions

REFRESHER TRAINING FOR NATIONAL HORTICULTURAL DEVELOPMENT AUTHORITY TECHNICAL OFFICERS

Technical field officers of the Horticultural Crops Development Authority (HCDA) of Kenya had a one-day refresher training workshop on improved crop protection, to update their technical skills. There were 35 participants including those from other projects and farmers' organisations. A total of 12 resource persons from ICIPE and other organisations provided the scientific back-up. The participants adjudged the course contents and structuring as good to very good: Course contents included symptomatology of diseases and insect pests of tropical vegetables, potential for biological control, biocontrol using bacterial pathogens, use of botanicals, pesticide residues and pre-harvest interval, safe use of pesticides and resistance management, cultural practices in vegetable farming and weed control in vegetable crops.

SCIENTIFIC UNDERPINNING FOR AFRICAN REGIONAL VEGETABLE PRODUCTION TRAINING COURSE

The project Coordinator, Dr S. Sithanantham, undertook an invited lecture-cum-discussion session on IPM in export vegetables for a group of about 24 middle level professionals drawn from 8 countries in the region as part of a regional training course for vegetable production practitioners in Eastern and Southern Africa jointly organised by the Israel Government and University of Nairobi during July/ August, 1997.

MSC / MPHIL RESEARCH TRAINING

One MPhil student of Moi University (Kenya) working on 'Non-target effects of neem in export vegetables' commenced in June 1997 to complete by April 1998. The student is being supervised formally by the project coordinator Dr S. Sithanantham and UNEP/ FINNIDA/ICIPE Project scientist, Dr R. C. Saxena.

By special arrangement with the Kenyatta University (Kenya), four MSc students were identified for undertaking research on the following aspects relating to export vegetable IPM:

(1) Bioecology of pests and yield losses on okra and capsicum
(2) Bioecology of pests and yield loss on cucurbits vegetables (including bittergourd).
(3) Evaluation of neem on pests and beneficial insects on French beans
(4) Potential for use of insect pathogens in control of caterpillar pests on vegetables.

These students will commence the research from mid-1998.

Networking with regional/national initiatives on themes

Most of the partner institutions in Kenya concerned with export vegetable production/protection were linked up with the project in different activities. Some of these are as below in addition to the collaborators mentioned earlier:

- Kenya Institute of Organic Farming (KIOF)
- Pesticide Safe Use Project (GIFAP)
- GTZ - IPM Horticulture Project (GTZ-IPMH)
- Kenya Small Scale Farmers' Association (KESSFA)
- Association for Better Land Husbandry (ABLH).
- Invitations for partnership input were also received by ICIPE from the Department of Agriculture, Zanzibar (Tanzania) and the Investment for Development of Export Agriculture (IDEA) project from Uganda.

C. IPM FOR AFRICAN INDIGENOUS VEGETABLES

3. DEVELOPMENT OF SUSTAINABLE INSECT PEST MANAGEMENT TECHNOLOGIES FOR AFRICAN INDIGENOUS VEGETABLE CROPS (HOR-2)

Background, approach and objectives

There is a diversity of indigenous wild and cultivated plants that are used as leafy vegetables in the tropics. About 1000 different plant species from 125 different families have been reported in the tropics. These leafy vegetables are of major importance, especially in the tropical lowlands. Several limitations have contributed to the decline of interest in indigenous vegetables. Seeds or planting material of good cultivars are seldom available and knowledge of nutritional value among the public is lacking. Indigenous leafy vegetables are of immense nutritional importance in Africa and elsewhere in the tropics. Leaves, roots, shoots and tubers of a wide variety of vegetables have for generations been an important element in daily diet. Sustainable cultivation of these vegetables depends upon their ability to withstand stress, especially the damage caused by pests and diseases. However, there is very little information available on the insect pest spectrum of these crops and their importance in crop yield formation.

The range of insect pests infesting the common African indigenous vegetables, namely *Cleome gynandra, Solanum nigrum, Amaranthus* spp., *Crotolaria* spp. and *Corchorus* spp. and the extent of yield loss due to pests, besides exploratory observations on the potential for host plant tolerance to pests among the local landraces, constituted the focus of the first phase of study.

Participating scientists: *S. Sithanantham*, K.V. Seshu Reddy, K.A. Nyarko (*Project Leader)*

Assistants: *W. Ogutu, G. Jira, D. Nyagol, J. Orwa*

Donor: *ICIPE Core Funds*

Collaborators: *• Genebank of Kenya • University of Nairobi, Dr Florence Olubayo and Prof. J.A. Chweya*

Work in progress

3.1 ASSESSMENT OF THE PEST SPECTRUM

The pest spectrum was monitored by growing the crops in large plots without pesticidal protection and inspecting them at periodic intervals in on-station plantings. Supplementary information was also collected during on-farm visits.

The range of insect pests infesting some of the common indigenous vegetables grown in Kenya are listed in Table 3.1. In *Gynandropsis*, stemborers (both caterpillars and weevil grubs) were identified as important. In *Amaranthus*, caterpillar pests (mainly pyralids), weevils and bugs were found to occur and in *Corchorus*, both beetles and caterpillar pests were observed.

Collaborative studies with University of Nairobi showed that other insects also occur on these crops. In addition, the insect pests observed in *Crotolaria* included leafminers, whiteflies, leaf beetles, true bugs and caterpillars. This study has brought to light several insect associations in these crops, which are new records (Table 3.2).

A comprehensive listing of the range of pests with illustrations is worth producing for the benefit of extension practitioners and farmers.

3.2 ASSESSMENT OF YIELD LOSS DUE TO PESTS

On-station assessment of avoidable yield loss due to pests was made by comparing the yields between plots protected from pests (through regimes of selected contact/systemic insecticides) and those in which

Table 3.1. List of insect pests recorded on indigenous vegetables in Kenya, 1996–1997

Crop/Site	Order	Family	Scientific name
Cleome gynandra			
Mbita	Lepidoptera	Pyralidae	*Lygropia quaternalis* Zell
Mbita	Heteroptera	Reduviidae	*Rhinocoris* sp.
Mbita	Coleoptera	Cetoniidae	*Diprognatha silacae* Macl
Mbita	Coleoptera	Curculionidae	*Lixus germaini* Hust
Amaranthus sp.			
Mbita	Lepidoptera	Erastiinae	*Amyna octo* Guen
Mbita	Lepidoptera	Pyralidae	*Hymenia fascialis* Cram
Mbita	Lepidoptera	Pyralidae	*Hymenia perspectalis* Hb
Mbita	Heteroptera	Coreidae	*Cletus fuscescens* Wlk
Mbita	Heteroptera	Coreidae	*Cletus* sp.
Mbita	Heteroptera	Pentatomidae	*Agonoscelis pubescens* Thnb
Muhaka	Coleoptera	Curculionidae	*Alcidodes* sp.
Kwale	Coleoptera	Curculionidae	*Baris* sp.
Shimba Hills	Coleoptera	Curculionidae	*Lixus* sp.
Kilifi	Coleoptera	Curculionidae	*Systates sauberichi* Fst
Corchorus spp.			
Mbita	Lepidoptera	Nymphalidae	*Acraea* sp.
Mbita	Coleoptera	Lagriidae	*Lagria villosa* F

Table 3.2. Pests of indigenous vegetables observed at Kabete Campus, University of Nairobi and Mbita Point Field Station, ICIPE

Insect pest	*Amaranthus* Kabete	*Amaranthus* Mbita	*Gynandropsis* Kabete	*Crotolaria* Kabete	*Corchorus* Kabete
Liriomyza spp. (leafminer)	+		-	+	-
Monolepta leuce (leaf beetles)	+	+	-	+	+
Empoasca spp. (cotton jassids)	+		-	+	+
Lygus spp. (hemipteran bugs)	+	+	+	+	+
Deraecoris spp. (hemipteran bugs)	+		+	-	-
Phyllotreta spp. (flea beetle)	+		+	+	+
Systates pollinosus (systates weevils)	-		+	+	+
Lampides boeticus (blue butterfly)	+		-	+	-
Helicoverpa armigera (African bollworm)	+		+	-	+
Agrotis spp. (cutworms)	+		-	-	-
Dysdercus spp. (cotton stainers)	+		-	-	-
Cletus spp. (coreid bugs)	+		-	-	-
Athalia spp. (saw flies)	+		+	-	-
Nezara viridula (stink bugs)	+		+	-	-

+ = Observed in the crop causing damage.
- = Not observed on the crop.

pests were allowed to attack the crop naturally (Table 3.3). Losses ranging from 11 to 21% were observed in *Amaranthus*, 10 to 36% in *Cleome* and 19 to 23% in *Crotolaria*. In *Corchorus*, the loss estimate was 22%, while in *S. nigrum* the loss was recorded around 36%.

While this information was limited to one site (Mbita), the intention is to collect information from additional sites and seasons to provide a general assessment of the pests of importance in these crops. Comparison of yields is also a component of the assessment.

The situation in 'protected' plots and 'unprotected' conditions in one season at Mbita is illustrated in (Figure 3.1). Interestingly, in *Crotolaria* and *Cleome* the difference in yield loss between 'protected' and 'unprotected' is greater compared to *Amaranthus* and *Corchorus* indicating that the yield loss in the former group is greater than the latter if crops are unprotected.

3.3 ASSESSMENT OF HOST PLANT TOLERANCE TO PESTS

In collaboration with the Genebank of Kenya, studies have been initiated to assess the natural biodiversity in landraces of these crops for tolerance to pests.

In *Cleome*, a comparison of six landrace accessions showed that the stemborer damage in terms of percent stem length bored, as well as in terms of number of stemborers infesting each plant, was found to vary substantially among the accessions (Figure 3.2).

These preliminary indications on the potential for host plant tolerance as means of reducing the yield losses, will be pursued further with other pests on this crop as well as other crops.

Table 3.3. Summary of observed yield loss due to pests on indigenous vegetables at Mbita, Kenya, 1996–1997

Crop	Year	Yield per plot (kg) Protected	Yield per plot (kg) Unprotected	Yield loss (%)
Amaranthus	1996(LR)	25.3	20.0	20.9
	1997(LR)	15.6	11.3	27.6
Cleome	1996(LR)	16.9	10.8	35.9
	1997(LR)	21.2	20.1	5.2
Corchorus	1997(LR)	13.9	13.2	5.0
Crotolaria	1996(LR)	26.7	20.7	22.5
	1997(LR)	29.4	22.3	24.1

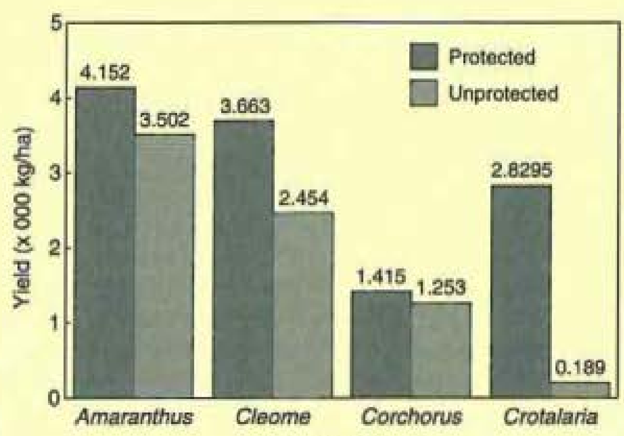


Figure 3.1. Effect of insects on yield of selected indigenous leafy vegetables

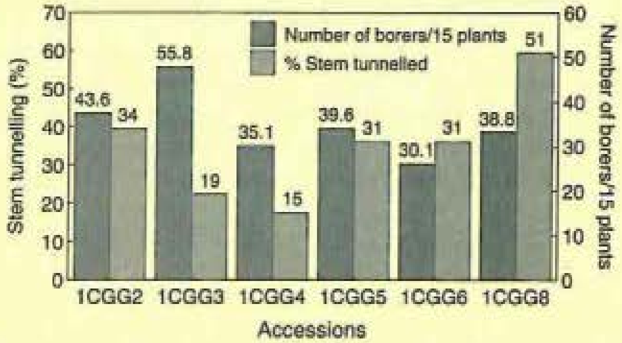


Figure 3.2. Extent of tunnelling and infestation by stemborers of *Cleome (Gynandropsis) gynandra* landraces

3.4 SAMPLING STRATEGIES FOR PEST DAMAGE

In *Cleome*, we compared the extent of stem tunnelling and the infestation at two growth stages. It was evident that the length tunnelled rather than the percent tunnelling, correlated with the number of borers per plant at the two growth stages.

Stemborer infestation comparison was also made between main stem and primary branch in *Cleome*. It was found stemborer damage was similar in the two plant parts.

Output

Publications

Sithanantham S., Olubayo F. M. , Seshu Reddy K.V. and Nyarko K.A. (1997) Collaborative research for understanding and managing the insect pest problems among indigenous (leafy) vegetable crops in Kenya, pp. 74–77. In *Proceedings of the National Horticultural Research and Development Seminar*. 30–31 January 1997, Nairobi, Kenya; JKUAT and JICA, Nairobi.

Conferences attended

Presented the summary of research on pests of indigenous vegetables in Inter-Centre Systemwide Workshop on Agrobiodiversity in October 1996 at ICIPE Headquarters, Nairobi.

Research proposals

Concept note development in consultation with University of Nairobi and IPGRI being pursued.

Impact

Stimulated interest for ICIPE collaboration with Kenyan institutions and IPGRI.

D. SYSTEMWIDE WHITEFLY IPM INITIATIVE

4. STUDIES ON WHITEFLIES AS PESTS AND VECTORS OF PLANT VIRUSES IN VEGETABLE-BASED CROPPING SYSTEMS IN EASTERN AND SOUTHERN AFRICA

Background, approach and objectives

Whiteflies (Homoptera: Aleyrodidae) have emerged as a global pest problem affecting tropical agriculture across the continents. As part of the Inter-CGIAR Centres Initiative for Ecoregional Collaboration for Integrated Pest Management (IPM), a Systemwide Programme on IPM of whiteflies has been launched under the leadership of CIAT, Cali, Colombia. Four subprojects have been developed, of which the one on whitefly problems in vegetable-based cropping systems in eastern and southern Africa is being led by ICIPE. The first phase of this ecoregional project on whitefly IPM is for two years (1997–98) and focused on improved understanding of the distribution and importance of whiteflies, the viruses they vector and the natural enemies of whiteflies occurring in vegetable-based cropping systems in eastern and southern Africa.

Participating scientists: *S. Sithanantham*, M. Ali Bob* *(*Project Leader)*

Donor: *Danish International Development Agency (DANIDA)*

Collaborators: *• Asian Vegetable Research and Development Centre (AVRDC), African Regional Programme, Arusha, Tanzania • John Innes Centre (JIC), Norwich, UK • Kenya Agricultural Research Institute (KARI), Kenya • Bvumbwe Agricultural Research Station (BARS), Malawi • University of Gezira (UOG) and the Agricultural Research Corporation (ARC), Sudan • Horticultural Research and Training Institute (HORTI), Tanzania*

Work in progress

4.1 START UP

The start up efforts included establishing basic facilities and suitable human support resources at ICIPE. For each partner country, a two-member team (entomologist and virologist) was identified. A planning and methodology workshop was held at ICIPE in April 1997, to form the basis for the diagnostic activities of the first phase. This helped the national teams to also update with current literature and to adopt standardised methodologies. ICIPE scientists also visited the teams at least once later, and participated in initial surveys, so as to harmonise the survey methodologies.

Table 4.1. Whitefly species encountered in vegetable-based systems

Whitefly species	Comments
Bemisia tabaci (Gennadius)	Most common species
Bemisia afer (Priesner & Hosney)	Common species on cassava in Malawi and Tanzania
Aleyrodes proletella Linnaeus	Collected from velvet beans in Malawi
Trialeurodes vaporariorum (Westwood)	Common on beans and some other weeds
Trialeurodes ricini (Misra)	Common species

4.2 UNDERSTANDING THE OCCURRENCE OF WHITEFLY SPECIES AND REPRODUCTIVE HOST PLANTS

4.2.1 *Whitefly species identification*

Joint ICIPE–national team surveys in Kenya, Malawi, Sudan and Tanzania, have shown that the adults of whitefly, *Bemisia tabaci* are commonly found in most tomato fields and the other life stages, nymphs and pupae were seldom found on this crop, except in Sudan. This observation indicates that in some of these countries, there are populations of *B. tabaci* which reproduce on other host plants, while the adults visit tomatoes mainly for feeding. This is a significant and new finding which is useful in developing suitable strategy for monitoring the whitefly population. Identification of the whitefly samples collected from vegetable crops and weeds indicated the occurrence of five whitefly species listed in Table 4.1.

Other whitefly species from non-target crops were also collected and identified. These include: *Aleurothrixus floccosus* (Maskell) on citrus, *Siphoninus phyllyreae* (Haliday) on a tree plant.

4.2.2 *Whitefly reproductive hosts*

Among the range of host plants on which *Bemisia tabaci* reproduces were several crops and weeds, including *Euphorbia heterophylla* which is a common weed around tomato fields and is a known reservoir for TYLCV in the region (Table 4.2). Most of these alternative hosts are weeds and some are apparently new records for the different whitefly species identified. Their role in the off-season survival of the whiteflies needs to be investigated.

4.2.3 *Whitefly biotype identification*

Studies on the regional distribution of the 'B' biotype of *B. tabaci* have indicated (based on 'silver leaf' symptoms on squash) that this biotype occurs in Gezira in central Sudan, while earlier knowledge of their occurrence in Africa is mainly from Egypt and South Africa. Molecular characterisation of the whitefly collections from the countries is being pursued with John Innes Centre, UK.

4.2.4 *Study of relative suitability of four host plants to* Bemisia tabaci *infestation under choice situation*

Studies under net-house conditions were undertaken at ICIPE, Nairobi, Kenya during 1997, using potgrown plants of four hosts, French bean (*Phaseolus vulgaris*), *Dolichos lablab*, cowpea (*Vigna unguiculata*) and okra (*Abelmoschus esculentus*) under field cages. Observations showed that adult numbers per plant were significantly greater on French bean, followed by *Dolichos*, which supported more adults than the other two hosts. The overall ranking for number of eggs laid per plant was bean>*Dolichos*>cowpea>okra. However, the pupa:egg ratio (indirect index of survival) was greatest on cowpea, followed by bean, *Dolichos* and okra.

4.3 NATURAL ENEMIES

Besides confirming the local occurrence of several known natural enemies of whiteflies, additional genera/species of predators/parasitoids have also been identified. The common natural enemies of whiteflies intercepted include the parasitoids *Encarsia formosa*, *Encarsia transvena* (the most common species), *Eretmocerus mundus*, *Eretmocerus* spp. and several Eulophid parasitoids. Predators (mainly coccinellid beetles and predatory bugs) were common in vegetable-based cropping systems. Collections from IITA (Sub-project 4 on cassava and sweet potato) showed predominance of phytoseiids and ladybird beetles. Several other insect species suspected to be predators, including phytoseiid mites have been collected and their identification/association awaits to be confirmed by specialists. The work on identifying pathogens could not be undertaken for want of mechanisms for inter-country shipment of diseased whitefly specimens at present. There is also need to assign additional resources to ensure specialists' support.

4.4 UNDERSTANDING THE OCCURRENCE OF TOMATO YELLOW LEAF CURL VIRUS

4.4.1 *Survey in Kenya*

Dr G. A. Dafalla of University of Gezira, Sudan together with ICIPE project scientists undertook a pilot survey of virus diseases on tomatoes in Kenya in June, 1997. The major findings are as follows: Out of 14 fields/plots of tomato surveyed, the incidence of plants with distinct symptoms of whitefly transmitted viruses (WTVs) ranged from 0–100%, with about half the number of fields showing 15–50% incidence. The

Table 4.2. List of whitefly reproductive host plants identified from surveys in Kenya, Malawi and Tanzania

Plant host	Crop/weed	Whitefly species	Country
Achyranthes asprea	Weed	*Trialeurodes ricini* (Misra)	Tanzania
		Trialeurodes vaporariorum (W)	Kenya
Ageratum conyzoides	Weed	*Bemisia tabaci* (Genn.)	Tanzania
Aspilia sp.	Weed	*B. tabaci* (Genn.)	Kenya
Asystasia schimperi	Weed	*B. tabaci* (Genn.)	Kenya
Beans	Crop	*B. afer* (Priesner & Hosney)	Kenya
		B. tabaci (Genn.)	Kenya, Malawi, Tanzania
		T. ricini (Misra)	Malawi
		T. vaporariorum (W)	Kenya, Malawi, Tanzania
Bidens pilosa	Weed	*B. tabaci* (Genn.)	Kenya
Cassava	Crop	*B. afer* (Priesner & Hosney)	Kenya, Malawi, Tanzania
		B. tabaci (Genn.)	Kenya, Malawi, Tanzania
Commelina benghalensis	Weed	*B. tabaci* (Genn.)	Kenya
Cotton	Crop	*B. afer* (Priesner & Hosney)	Kenya
		B. tabaci (Genn.)	Kenya
Crotolaria sp.	Weed	*B. tabaci* (Genn.)	Kenya
Datura stramonium	Weed	*B. tabaci* (Genn.)	Kenya
Desmodium sp.	Weed	*B. tabaci* (Genn.)	Tanzania
Emilia descifolia	Weed	*B. tabaci* (Genn.)	Kenya
Euphorbia heterophylla	Weed	*Bemisia?*	Kenya
		Bemisia hirta?	Tanzania
		B. tabaci (Genn.)	Kenya, Malawi, Tanzania
		T. ricini (Misra)	Kenya
		T. vaporariorum (W)	Tanzania
Galinsoga parviflora	Weed	*B. tabaci* (Genn.)	Kenya, Tanzania
		T. ricini (Misra)	Tanzania
Lantana camara	Weed	*B. tabaci* (Genn.)	Tanzania
Lionotis molissima	Weed	*B. tabaci* (Genn.)	Kenya
		T. ricini (Misra)	Kenya
Mito (Local name)	Weed	*B. tabaci* (Genn.)	Kenya
Morning glory	Weed	*B. tabaci* (Genn.)	Kenya
Nicandra physaloides	Weed	*B. tabaci* (Genn.)	Kenya
Sweet potato	Crop	*B. tabaci* (Genn.)	Kenya
Tithonia diversifolia	Weed	*B. tabaci* (Genn.)	Kenya
		T. ricini (Misra)	Kenya
		T. vaporariorum (W)	Kenya
Tomato	Crop	*B. tabaci* (Genn.)	Kenya
		T. ricini (Misra)	Kenya
		T. vaporariorum (W)	Kenya
Unidentified	Weed	*B. tabaci* (Genn.)	Kenya
		T. vaporariorum (W)	Kenya
Velvet beans	Weed	*Aleyrodes proletella* Linnaeus	Malawi
		B. tabaci (Genn.)	Malawi
Wild cassava (?)	Weed	*B. tabaci* (Genn.)	Tanzania

whitefly adults were found to occur on the tomato crop in most fields observed, and were generally highly abundant (Table 4.3).

On-farm surveys on tomatoes showed that the percent fields with tomato yellow leaf curl virus (TYLCV) in the four countries—Kenya, Malawi, Sudan and Tanzania was 38, 57, 97 and 97% respectively, and the average disease incidence levels per farm was 3, 7, 15 and 67% in that order (Table 4.4). On beans, there was abundant whitefly population, but no disease problem was seen.

Indications obtained from test of 28 samples by JIC, UK for presence of TYLCV (Israeli strain) are furnished in Table 4.5.

As indicated by JIC, when there is a weak hybridisation signal or a strong signal, it might be due to a difference in the percentage nucleic acid homology, suggesting different strains of geminivirus. However, it is impossible at this stage to tell whether or not the difference in signal strength is to do with a sampling problem, because of virus titre in the particular bits of tissue sampled or low virus titre due to an early stage of infection.

4.5 UNDERSTANDING THE ECONOMIC IMPORTANCE

4.5.1 *Farmers' perceptions*

Almost all farmers interviewed in Kenya and Tanzania and the majority of farmers in Malawi and Sudan were able to recognise whiteflies. In Kenya farmers

Table 4.3. Incidence of whitefly transmitted viruses and whiteflies in tomatoes and other crops in some regions of Kenya, June 1997

Region	Site/crop	Whitefly abundance[1]	% Infestation with whitefly-transmitted viruses[2]
Thika	Site 1 (Tomato)	+ + +	0
	Site 2 (Tomato)	0	0
Machakos	1 - Tomato—Money Maker: Field 1	+ +	15%
	2 - Tomato—Money Maker: Field 2	+ + +	30%
	3 - Tomato—Cal-j : Field 1	+ + +	>10%
Lake Naivasha	1st Site (tomato)	+ +	5%
	2nd Site (tomato)	+ ++	30%
	3rd Site (tomato)	+ +	40%
	4th Site (tomato)	+ ++	40%
Kibwezi	Plot 1 (tomato)	+ +	50%
	Plot 2 (tomato)	+ +	10%
	Plot 3 (tomato)	+	50%
	Plot 4 (tomato)	+	0
	Plot 5 (tomato)	+ ++	100%
Kibwezi	Sweet pepper 1	+ +	0
	Sweet pepper 2	+ ++	90% (?)
	Watermelon	+ ++	5% (?)
	Okra	+ +	

[1]Insect populations: + = Low; + + = High; + + + = Very high.
[2]Percentages of plants showing symptoms over total plant population.

Table 4.4. Field incidence of tomato yellow leaf curl virus (TYLCV) in partner countries

% Plants with TYLCV	Tanzania (29)+	Malawi (7)	Kenya (16)	Sudan (34)
None	1	3	10	1
0.1–25	23	3	4	10
26–50	0	1	1	3
51–75	3	0	0	3
76–99	2	0	1	0
100	0	0	0	17
Average %	15	7	3	67
% Fields with TYLCV	97	57	38	97

+Number of fields surveyed.

Table 4.5. Results of preliminary testing for occurrence of tomato yellow leaf curl virus (Israeli strain) on tomatoes in target countries

Country	Province/ Division/ Region	Samples tested	Samples positive to Israeli strain of TYLC	Remarks on signals
Kenya	Central	2	2	Strong
	Eastern	3	3	Weak
	Nyanza	3	0	-
	Western	3	0	-
Malawi	Blantyre	1	0	-
	Ntcheu	4	2	Very weak
	Bvumbwe	2	0	-
Tanzania	Arusha	9	6	Strong/Weak
	Kilimanjaro	1	1	Strong

call whiteflies "mbuu", "rwagi", "ebichuni", "okogatua", "kudni", "oulolo" and "gathuri". In Malawi they are known as "msambe". In Sudan farmers call whiteflies "dubbana", "dubbana beida", "zubaba", "zubaba beida" and "asala" and in Tanzania they are called: "wadudu", "wadudu weupe", "kipepeo", "sughru", "tukorokotwa", "sunhuu", "inzi weupe" and "mbuu". The TYLC problem was known as 'leaf curl' in these countries besides other names; in Sudan farmers know TYLC as "karmata", "karmasha" and "kurmut" and Tanzania "rasta", "masai", "dume", "ukoma", "bondia" and "ngumi". Most or all the farmers interviewed in the four countries recognised that whiteflies were the cause of TYLC in their crops (Figure 4.1).

The TYLCV transmitted by *B. tabaci* was found to be commonly occurring in all the target countries. Producer estimates of on-farm losses due to TYLCV in tomato were up to 40% in Malawi, 50% in Kenya, 75% in Tanzania and 100% in Sudan. Several farmers abandoned their tomato crops due to severe TYLC incidence in 1994/95 in Tanzania, 1997 in Malawi and Kenya and 1996/97 in Sudan. The occurrence of two other whitefly-transmitted viruses—okra leaf curl virus (OLCV) and water melon chlorotic stunt virus (WMCSV)— was important in Sudan. Yield loss due to WMCSV on Galia melons in Sudan was estimated at 25% in fruit size, 50% in fruits harvested per plant and 48% in ratio of marketable fruits. The loss in revenue to melon farmers was about 64%, and monetary loss per hectare US$ 3252.

The majority of farmers seem to believe that they have whitefly/virus problem every year (Figure 4.2). Interestingly, all farmers in Malawi mentioned that in 1997 the whitefly/disease problems were especially severe. The majority of farmers in Kenya said that the problem was more severe in 1996/97 season. In the Sudan, the problem was severe in 1997 while in Tanzania the problem was worse in 1996 and 1997.

The majority of farmers interviewed also seem to believe that there is direct relationship between the climate and the whitefly/disease incidence. Farmers believe that there is more whitefly/TYLC incidence in hot and dry seasons. In Malawi, the majority of farmers around Lilongwe believed that they have more whitefly/disease problem when the weather is hot and the rains are more.

4.6 ESTIMATION OF ECONOMIC IMPORTANCE/YIELD LOSS

In Malawi, the main pests and diseases recorded on tomatoes according to importance were—late blight, red spider mites, wilt, cutworms, tomato yellow leaf

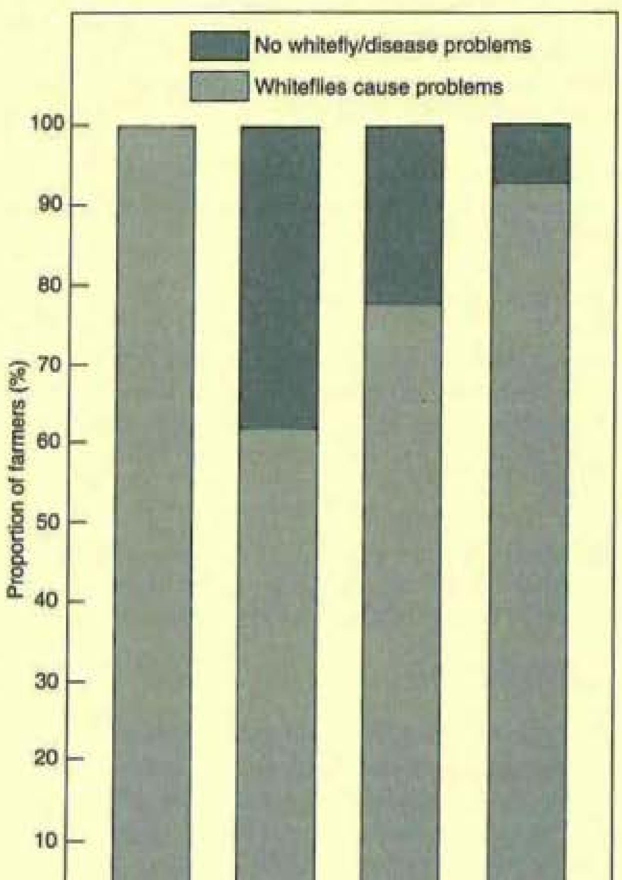


Figure 4.1. Proportion of farmers perceiving that whiteflies cause problems in their crops

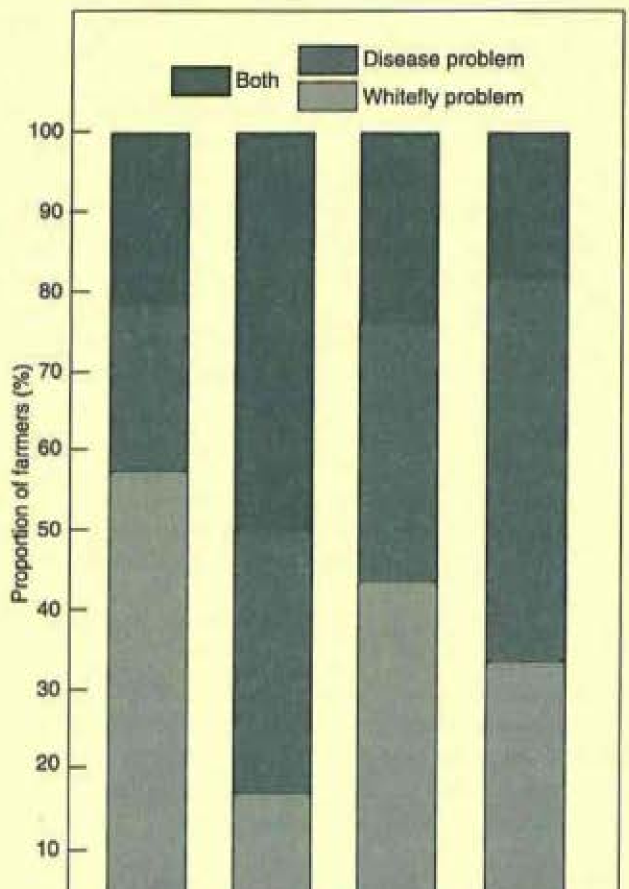


Figure 4.2. Farmers perceptions of whitefly/disease problems on tomato

curl and whiteflies. In Kenya the main pests and diseases appear to be—late blight, whiteflies, bollworms, wilt, TYLC and red spider mites. In Malawi the important pests and diseases were—blight, mites, wilt, cutworms, TYLC and whiteflies. In Sudan, the main pests and diseases were whiteflies, TYLC and fruitworms. In Tanzania the main pest and disease constraints appear to be: late blight, TYLC, whiteflies and red spider mites. Whiteflies ranked 2, 6, 1 and 3 among biotic constraints in Kenya, Malawi, Sudan and Tanzania, respectively. The respective ranking for TYLC was 5, 5, 2 and 2.

In Sudan the loss in yield and production of melons due to whitefly transmitted virus, WMCSV was found to be high (Table 4.6).

Table 4.6. Incidence of water melon chlorotic stunt virus on Galia melons and effect of disease severity on some yield/quality parameters, Gezira, Sudan

WMCSV Incidence category	% Plants with symptoms	% Loss due to infection over healthy		
		Fruit yield (g/plant)	Mean fruit weight (g)	Marketable fruits (%)
Very severe	16	38.1	73.9	89.6
Severe	21	23.8	70.6	58.4
Moderate	18	23.8	42.8	28.6
Mild	27	14.3	16.4	15.6
Healthy	18	2.1	68.2	77.0

4.7 LINKAGES WITH WHITEFLY RESEARCHERS IN AFRICA

4.7.1 *Symposium on whitefly research in Africa*

ICIPE organised a symposium on whitefly research in Africa in conjunction with the African Association of Insect Scientists (AAIS) and the Entomological Society of Southern Africa (ESSA) Conference at Stellenbosch, South Africa. A total of 32 researchers from 12 countries in Africa participated and expressed interest in participation in a regional information exchange network led by ICIPE.

4.7.2 *Workshops*

ICIPE organised a planning workshop on 21–23 April 1997 ICIPE for the whitefly IPM project partners.

4.7.3 *Identification assistance provided by ICIPE*

Assistance has been extended by the ICIPE team in identification of specimens of whitefly species and natural enemy collections from surveys across 5 countries in Africa for the IITA-led subproject on whiteflies on cassava and sweet potato.

4.7.4 *Assembling and sharing information*

Assembling local whitefly-related information including grey literature has also been initiated. A vigorous initiative by the Sudanese team resulted in assembling substantial grey literature from local stations/project reports in the Sudan. Copies of these are being deposited with the documentation centres at ICIPE and CIAT.

Output

Publication/presentations on whitefly research

Bob M.A., Sithanantham S. and Nono-Womdim R. (1997) Whitefly problems in Africa: Known importance and research needs, pp. 859–866. In *Proceedings of ANPP-Fourth International Conference on Pests in Agriculture*, 7–9 Jan. 1997, Montpellier, France Vol 3. ANPP, Paris.

Conferences attended

Sithanantham S. and Bob M.A. Joint Congress of the Entomological Society of Southern Africa and the African Association of Insect Scientists, Stellenbosch, 30 June–4 July 1997. Paper presented: Known importance, host range and natural enemies of whiteflies in Africa and research towards their sustainable management'.

Bob M.A. and Sithanantham S. (1997). Joint Congress of the Entomological Society of Southern Africa and the African Association of Insect Scientists, Stellenbosch, 30 June–4 July, 1997. Paper presented: Distribution and determination of species and biotypes among whiteflies in Africa'.

The project scientists convened and participated in a symposium on whiteflies in July 1997 at Stellenbosch, South Africa.

Research proposals

Natural enemy-based management of whiteflies in vegetable-based cropping systems in Kenya: A joint proposal between ICIPE and Tel Aviv University, Israel. Concept note accepted and full proposal invited.

Characterisation of whitefly populations of eastern and southern Africa. Concept note submitted to the hold back facility of DFID in June, 1997: declined.

Capacity building

PhD Project in progress: Evaluation of distribution of whitefly species (and biotypes) and their natural enemies in vegetable-based cropping systems in Sudan (Mr Ahmed Gaffar, University of Gezira, Wad-Medani, Sudan.

MSc project being initiated: Assessment of resistance to insecticide in some whitefly populations from Kenya (Mr Thomas Njuguna, Kenyatta University, Nairobi).

Short term attachment completed: Effect of host plants on the oviposition and survival of the sweetpotato whitefly, *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) under choice situation (Ms Rebecca Raini, University of Nairobi).

Short training: Dr M. Ali Bob participated in a short training course on identification of whiteflies and their natural enemies at the International Institute of Entomology (IIE, London). Dr M. Ali Bob and Mr Ignas Swai of HORTI-Tanzania attended a practical workshop on DNA Techniques held at ICIPE, Nairobi in November, 1997.

Impact

- Improved understanding of the whitefly problem in the partner countries.
- Improved understanding of the whitefly species, natural enemies and whitefly reproductive hosts in partner countries.

II. Sustainable Pest Management for Fruit Crops

A. FRUIT FLY RESEARCH

1. SUSTAINABLE PEST MANAGEMENT FOR FRUIT FLIES

Background, approach and objectives

A number of major trends in international trade has created the need for this initiative. These trends include greater freedom in movement of goods and services due to the more open and liberalised global trade regime and progressing urbanisation. These have created on the one hand greater risk of translocation of fruit pests, and on the other hand, demand for production systems for raw, perishable horticultural products of high quality to meet both expanding domestic urban markets and export. Stringent quarantine and quality regulations on export markets and increasing quality expectations in domestic markets, makes it necessary to avail the latest fruit protection technologies to enable local fruit growers to meet these standards.

There is tremendous potential for East Africa to be a major fruit producing and exporting region. Among key indicators of this potential are a favourable climate for fruit growing, the existence of strong formal co-operative links between East African countries, emerging indigenous entrepreneurship, and a rapidly growing domestic fruit market driven by changes in dietary priorities and preferences among the African urban communities. The importance of horticulture is recognised by the local authorities.

Following requests from fruit growers from East Africa and, in response to the growing international demand, ICIPE initiated research on the biology of the African fruit flies of economic importance. In its research, ICIPE collaborates with 14 institutes from the USA, Latin America, Europe, Middle East and Africa.

Participating scientists: *S. A. Lux*, W. Overholt, S. Kimani, N. Maniania, S. Miller, E. Osir* (* Project Leader)

Collaborators: *• Univ. Exp. Station, Kauai, Hawaii, USA • USDA • Texas A&M Univ. Texas, USA • Natural History Museum (NHM), UK • Treveuren Museum, Belgium • A. Malacrida, Pavia Univ., Italy • CIRAD-FLHOR, Reunion • ARC-South Africa • NARS (KARI-Kenya, ARI-Tanzania, ARI-Uganda) • Regional organisations (ASARECA, SACCAR, CORAF, OAU)*

Donor: *IFAD.*

1.1 LAUNCHING THE AFRICAN FRUIT FLY INITIATIVE

Background

The major problem impeding quality fruit production in East Africa is severe fruit infestation by fruit flies and lack of expertise to manage it. Therefore, fruit production remains an unexploited opportunity.

In response to the requests from the fruit growers from East Africa and based on IFAD funded pre-project assessments, ICIPE initiated research on African fruit flies of economic importance and proposed an integrated programme for applied research, technology adaptation, transfer and training, named the African Fruit Fly Initiative. This programme will be discussed during a meeting to be organised jointly by ICIPE, IFAD and FAO in February, 1998, to be attended by representatives of farmers, local authorities, regional organisations, collaborators and donors.

Highlights of the results obtained to-date are given.

Work in progress

1.1.1 *Economic role and distribution of fruit flies*

Participating scientists: *S. A. Lux, W. Overholt, S. Kimani*

Assistants: *T. Chole, P. Nderitu, F. Nyamu, H. Mburu*

Donor: *IFAD*

Exploratory surveys were initiated in several regions in Kenya (Nairobi, Thika, Embu, Koru, Nguruman, South and North Coast), as well as on Pemba and Zanzibar in Tanzania. It appears that the mango fruit fly, *Ceratitis cosyra*, is the major mango pest in most mango growing areas, while other fruit flies, such as the Natal fruit fly, *C. rosa* and mediterranean fruit fly, *C. capitata*, seem to be of secondary importance. The latter do, however, play an important role in the case of other fruits.

Our preliminary data indicate that, out of about 90,000 tonnes of mangoes produced in Kenya, about 20–40% are infested with fruit flies at the time of ripening and in some areas, like Nguruman, the infestation level occasionally reaches 80%. Fruit losses in the orchards of professional producers are at the level of 10–25%, while smallholders, who produce most of the fruit, lose 30–80% of mango due to infestation by fruit flies. A similar situation prevails in the other countries in the region. The widespread fruit fly problem and lack of expertise to manage it are major obstacles in the development of quality fruit production in the region.

In general, distribution and composition of the fruit fly complex in East Africa appears to be rather far from being uniform and continuous (*C. capitata* and *C. rosa* in Thika; *C. cosyra* and *C. rosa* in Embu and North Coast in Kenya and on Pemba and Zanzibar in Tanzania; *C. capitata* and *C. anonae* in Nyanza; only *C. cosyra* in Nguruman). The results from one area cannot be, therefore, easily extrapolated to other areas and more detailed description of fruit fly distribution in the region is necessary.

1.1.2 *Exploration for and research on natural enemies of medfly*

Participating scientists: *W. Overholt, S. Kimani, S. A. Lux*

Assistants: *T. Chole, P. Nderitu, F. Nyamu, H. Mburu*

Collaborators: *• Univ. Exp. Station, Kauai, Hawaii, USA • USDA • Texas A&M Univ. Texas, USA*

Donor: *USDA*

With limited funding provided by the USDA through the universities of Hawaii, Florida and Texas A&M, ICIPE has begun surveys of fruit flies and their natural enemies in four locations in Kenya. To-date, nearly 10,000 field-collected fruit fly puparia have been sent to quarantine in Hawaii. From these puparia, several parasitoid species in at least four genera (*Fopius, Diachasmimorpha, Psyttalia* and *Tetrastichus*) have been reared. One species, *Psytallia humilis*, has been successfully cultured and sent to Guatemala for evaluation in laboratory and field trials.

1.1.3 *Assessment of the effect of experimental conditions on calling and mating periodicity in the wild medfly*

Participating scientist: *S. A. Lux*

Assistants: *F. Munyiri, T. Chole, F. Nyamu*

Donors: *FAO/IAEA*

The reported research was based on the insect material emerging from coffee berries collected in Ruiru near Nairobi. Three species of fruit flies were identified: *C. capitata* (45–72%), *C. rosa* (25–55%) and *C. coffeae* (0–4%). Several species of parasitoids emerging from fruit fly pupae were collected and identified. The rate of parasitisation varied greatly over the season within the range 0–30% and culminated in December 1995.

In order to estimate proper parameters for recording of medfly courtship behaviour, both calling and mating periodicity were recorded in the laboratory and field cage conditions. In the laboratory, all parameters: temperature (25 °C±1), relative humidity (55–60%) and artificial illumination with a fixed photoperiod (12:12), were strictly controlled. Two levels of light intensity were used. In all experiments, only insects emerging from the field-collected larvae were used.

Calling

In the laboratory, the maximum calling was recorded between 1000–1200 hrs, with nearly no callings after 1400 hrs, regardless of the lighting conditions. However, the light intensity clearly affected the calling propensity, which decreased nearly threefold at the low light level. In the field cage, the maximum calling was noticed later between 1000–1400 hrs, with only occasional calling after 1500 hrs. Majority of the calling (about 80%) took place on the leaves of a small coffee tree placed inside the cage. The calling intensity in the field was only marginally higher as compared to the high light level in the lab. Both in the lab and in the field conditions, no calling was observed within the first week after emergence, the maximum was noticed between 10–18 days, and the calling activity remained at a high level to the end of the first month after emergence.

Mating

In general, mating behaviour was correlated with calling behaviour, both in daily rhythm and age-related periodicity. Likewise, no cases of mating were noticed within the first week after emergence and, in the laboratory conditions, daily maximum mating activity was noticed about two hours earlier than in the field.

Only after proper establishment of the optimum conditions (ambient laboratory conditions, insect age, time of the day), recordings of the courtship behaviour were initiated.

1.1.4 *Comparison of courtship behaviour of medfly strains from various geographical regions*

Participating scientist: *S. A. Lux*

Assistants: *F. Munyiri, T. Chole*

Collaborators: *• USDA-APHIS-PPQ, Methods Station, Guatemala • Joint FAO/IAEA Laboratories, Austria • Univ. of Crete, Greece • The Hebrew Univ., Israel • Univ. of Costa Rica • ECOSUR, Chiapas, Mexico • Univ. Buenos Aires, Argentina • CIRAD-FLHOR, Reunion*

Donors: *FAO/IAEA*

Since 1995, jointly with FAO/IAEA and 12 other institutes, ICIPE is involved in research on courtship behaviour of medfly strains from various parts of the world: from Greece, Madeira, Israel, Hawaii, Mexico, Guatemala, Argentina, Kenya and Indian Ocean Islands. The main objective is to test the hypothesis on the existence of geographical strains of medfly which differ in their courtship behaviour and are incompatible behaviourally to build confidence on the use of the genetically modified strains of medfly developed for the sterile insect technique (SIT).

So far, no major qualitative differences in the courtship sequence were found, which indicate possible lack of mating incompatibility among medfly strains worldwide. However, quantitative differences among the strains were found and their implications on male mating competitiveness remain to be evaluated.

1.1.5 *Effect of sterilisation procedure (irradiation) on medfly male courtship success and its possible implications for SIT were quantified (two strains were tested from Seibersdorf, Austria and Mendoza, Argentina)*

Participating scientist: *S. A. Lux*

Assistant: *F. Munyiri*

Collaborators: *• Joint FAO/IAEA Laboratories, Austria • Univ. Buenos Aires, Argentina • ECOSUR, Chiapas, Mexico*

Donors: *FAO/IAEA*

Measurable negative effects of irradiation on male mating performance, resulting in its reduction by 20–30%, were detected in both strains tested. Further evaluation of their practical implications for SIT operations is in progress, in collaboration with Dr Pablo Liedo from MOSCAMED, Mexico.

Research was based on the mass-reared males obtained from Seibersdorf colony (GS-44). The males were reared and irradiated following the usual procedures. Each male (7 days old) was released into an observation chamber and a female (of the same age) was released 5 min after he started calling or after 30 min, whichever happened earlier. Their behaviour was recorded for 90 min after release of the male. The data collected were qualitatively analysed using the QuanEtho program.

The analysis revealed substantial differences between the irradiated males vs non-irradiated. The irradiated males:

(1) were less vigorous, more passive,
(2) incidence of calling activity just before meeting with a female was much lower,
(3) when approached by female or chased during the courtship, were inclined to fight rather than retreat,
(4) started wing vibration much later (if at all), when a female approached them very close,
(5) when sometimes approached by the female, just started buzzing and skipping the vibration altogether,
(6) during buzzing, were pushing females more frequently and the females responded to their buzzing more aggressively (frequently chasing them)
(7) during buzzing, gave up easily when female showed disinterest,
(8) were getting positive feedback from the courted female more seldom and less intense,
(9) seemed to be less motivated and less attractive (less calling, later approached by females),
(10) took more time to get engaged in mating ,
(11) during meeting with a female, were more passive,
(12) when close to the female, suddenly switched either to aggressive or sexual behaviour.

Interestingly, however, many of those males that switched to sexual behaviour were immediately accepted by females. Many of them (nearly 50%) mated just after the first attempt compared to less than 10% of non-irradiated males. The final mating success of the irradiated males was only negligibly lower as compared to the non-irradiated males.

However, the majority of those males who were immediately accepted by females did not call; they met with females just by chance, and frequently their courtship was shorter or incomplete (they skipped vibration or even buzzing). Therefore, in field conditions, it seems unlikely for them to appear or establish in lek arenas, participate in calling and attract females. Hence, females would be unlikely to find those males and prompt them to mate. In consequence, in the field conditions and in a properly designed field-cage test, the overall performance of the irradiated males may be reduced by 20–40% as compared to non-irradiated males.

In conclusion, our research reveals that the irradiation process does measurably alter male mating behaviour. However, practical implications of the irradiation on male mating performance in the field conditions and on the overall efficiency of SIT remain to be evaluated.

1.2 EXPLORING THE PRACTICAL IMPLICATIONS OF DIVERSITY OF THE FRUIT FLIES COMPLEX IN AFRICA (AGEC-3)

1.2.1 *Pilot studies on species diversity, distribution and host range of fruit flies and their natural enemies in Kenya*

Background, approach and objectives

Tephritid flies are known to cause immense devastation to fruit crops worldwide, resulting in economic losses estimated at hundreds of millions of dollars. In some regions of the world, the value of the annual fruit production is over US $ 680 million, and potential losses if fruit flies are not controlled are believed to exceed US $ 80 million. Some of these fruit flies have become pests in regions far from their native range. *Ceratitis capitata*, the mediterranean fruit fly, a native of East Africa, has invaded most of the warmer parts of the world. Since horticulture has become one of the most important income-generating activities of East African farmers, studying the distribution of the medfly in its region of origin and diversity of other tephritid fruit flies is very important.

These pests are of economic importance in the Afrotropical Region and especially in East Africa; there is need to understand the biology and ecology of these insects in order to develop management strategies for the major tephritid pests in the region. There have been virtually no ecological studies on the Tephritidae in tropical Africa. These studies have been hindered in the Afrotropical region by lack of accurate biosystematic knowledge of the group by regional researchers; many of the species and their host plants still remain unidentified. In addition, the taxonomy of their natural enemies also requires research before they can be developed as potential biological control agents. Pilot surveys were therefore initiated to map out the distribution of the tephritids, their host crops and natural enemies in Kenya.

Participating scientist: *J. B. Okeyo-Owuor*

Assistant: *P. Ollimo*

Donor: *Norwegian Government*

Collaborators: *• National Museums of Kenya (NMK) • Kenya Agricultural Research Institute (KARI) • Coffee Research Institute*

Work in progress

Several regions of Kenya with diverse ecological zones were selected for the study between March and October 1995. These were the Kenya coast (Kwale and Kilifi), western Kenya (Migori and Homa Bay), central Kenya (Thika and Nairobi) and the Rift Valley (Kajiado-Nguruman). To investigate the occurrence, diversity and natural enemies of fruit flies, fruit-associated tephritids were collected from infested fruit. Fruit samples were collected from cultivated plants and horticultural crops, namely mangoes, oranges and watermelon from farmers' plots in the different locations listed above. In the case of mangoes and oranges, both dropped and intact fruits were sampled. Sampling from watermelons was done on fruits which showed clear signs of fruit fly damage, while sampling from coffee plantations was done on nearly ripe coffee berries. Wild fruits were also sampled: guava (*Psidium guajava*) from western Kenya, sodom apples (*Solanum incanum*) from Nguruman and 14 wild fruit species from coastal forests. Apart from guava, all the wild fruit plants were preserved using the routine pressing technique for later identification at the Kenya National Herbarium. Collected fruits were transferred singly into labelled transparent plastic jars with sterilised sand placed at the bottom to act as pupation medium. Pupating fruit flies were sieved out of the sand and from these, emerging fruit fly adults or their parasitoids were collected and preserved for identification.

The most widespread species was *Cetatitis capitata* (Wiedemann) (infesting mangoes from Kwale and coffee from Thika); *C. rosa* Karsch (infesting guavas, oranges and mangoes from Homa Bay, Kwale and Nguruman, respectively). Other species were *C. anonae* (infesting guava from Homa Bay) and *Bacterocera curcubitae* (infesting watermelon from Mtwapa). Apart from guava, there were no fruit flies found attacking wild fruits. The natural enemies found parasitising *C. rosa* (collected from guava) from Homa Bay was the parasite *Fopius silvestrii* (Wharton). *C eratitis capitata* (collected from coffee) from Central Province and *C. rosa* (collected from mango) from Nguruman were hosts to the parasite *Psyttalia* spp. These parasitoids can be targeted as potential biocontrol agents in areas where the fruit fly has become an exotic pest.

Output

Publications

Lux S. A. and Gaggl K. (1995) Ethological analysis of medfly courtship: Potential for quality control, pp. 425–432. In *Fruit Fly Pests: A World Assessment of Their Biology and Management* (Edited by B. A. McPheron and G. J. Steck). St Lucia Press, Delray Beach, Florida.

Conferences, workshops and invited lectures

Lux S.A. and Munyiri F. N. (1996) Assessment of the effect of experimental conditions on calling and mating periodicity in the wild medfly, p. 32. Working material.

Second FAO/IAEA Research Coordination meeting on "Medfly Mating Behaviour Studies under Field Cage Conditions" 19–23 February 1996, Tapachula, Chiapas, Mexico. IAEA, Vienna, Austria.

Lux S.A., Munyiri F. N. and Gaggl K. (1996) Courtship behaviour of irradiated *vs.* non-irradiated males: Ethological comparisons, pp. 33–34. Working material. Second FAO/IAEA Research Coordination meeting on "Medfly Mating Behaviour Studies under Field Cage Conditions, 19–23 February 1996. Tapachula, Chiapas, Mexico. IAEA, Vienna, Austria,

Lux S. A., Vilardi J. and Munyiri F. (1997) Comparison between two Argentinean strains of medfly: The mass reared in Mendoza and wild ones from Patagonia, p. 24. Working material. Third FAO/IAEA Research Co-ordination meeting on "Medfly Mating Behaviour Studies under Field Cage Conditions", September 1997, Tel Aviv, Israel. IAEA, Vienna, Austria.

Lux S. A., Vilardi J. and Munyiri F. (1997) Courtship behaviour of irradiated *vs.* non-irradiated males—Ethological comparisons, p. 25. Working material. Third FAO/IAEA Research Coordination meeting on "Medfly Mating Behaviour Studies under Field Cage Conditions", September 1997 Tel Aviv, Israel. IAEA, Vienna, Austria.

Lux S. A. and Gaggl K. (1995) Medfly male dilemma: "Sexual aggressiveness" or "good manners"—Implications for mating success and effectiveness of sterile insect technique. XXIV International Ethological Conference, Honolulu, Hawaii USA, 10–17 August 1995.

Lux S. A. (1995) Prospects for application of pheromones for monitoring stemborer populations. Regional course on classical biological control of gramineous stemborers in Africa, ICIPE, 15–28 October, Nairobi, Kenya.

Lux S. A., Gaggl K. and Munyiri F. N. (1996) Quantifying courtship behaviour in Mediterranean fruit flies. Pacific Entomology Conference, 12–13 February 1996, Honolulu, Hawaii, USA.

Lux S. A. (1996) The potential use of pheromones for monitoring *Chilo partellus* and *Busseola fusca* in east and southern Africa. International Workshop on the Management of Tropical Gramineous Stemborers, 14–16 May, 1996, ICIPE, Nairobi, Kenya.

Lux S. A. (1996) Role of pheromones in IPM. National Group Training Course on Integrated Management of Crop Pests, Tanzania, 13 October –26 November, 1996.

Capacity building

A PhD student from Sudan has joined ICIPE's ARPPIS programme to study biology of parasitoids of African fruit flies. Four students from JKUAT were accepted for attachment and training on survey techniques and biology of fruit flies.

B. IMPROVED PEST MANAGEMENT FOR BANANA

2. DEVELOPMENT, VALIDATION AND TRANSFER OF INTEGRATED TECHNOLOGIES FOR THE MANAGEMENT OF BANANA WEEVILS IN EAST AFRICA (FOP 4)

Background approach and objectives

Banana and plantain are among the world's major food crops and rank fourth after rice, wheat and maize in terms of gross production value. In Eastern Africa where 22% of the world's total production is found, it is a major source of dietary carbohydrate and income for millions of households.

The banana weevil is a major constraint to banana production, reducing yields substantially. This project, which is in two parts, attempts to address this constraint. Part A builds on the achievements of the BMZ-funded project (1989–1994) implemented by ICIPE, and tests, validates and disseminates already developed technologies. Part B explores an alternative weevil management option, the 'trap-treat-release' approach, again building on ICIPE's work on reproductive biology and chemical communication systems of the banana weevil. The project aims to increase banana production in East Africa through development of technologies that reduce damage by banana weevils.

2.1 TRANSFER OF BANANA WEEVIL IPM TECHNOLOGIES TO NARES

Participating scientists: *K. V. Seshu Reddy*, J. W. Ssennyonga, L. Ngode (*Project leader)*

Assistants: *P.O. Ochanjo, M. W. Ochieng*

Donor: *BMZ*

Collaborators: *• Federal Biological Research Centre for Agriculture and Forestry (FBRCAF), Darmstadt, Germany • University of Bonn, Germany • Eastern and Southern Africa Centre for the Improvement of Cassava, Banana and Plantain (ESARC), IITA, Uganda • Kenya Agricultural Research Institute (KARI) • Ministry of Agriculture, Livestock Development and Marketing, (MOALDM) Kenya*

Work in progress

2.1.1 *Banana germplasm transfer to NARES*

The banana germplasm collected from 1989 to 1992 and maintained at the ICIPE for research and development purposes consisting of 177 diverse cultivars (57 sweet/dessert types, 67 cooking types, 36 for beer, 9 for roasting (plantains), and 8 tissue culture material), was transferred to Kenya Agricultural Research Institute (KARI) and planted at the Regional Research Station Kisii, Kenya.

In Tanzania, the germplasm maintained at the Agricultural Research Institute, Maruku was handed over to the Tanzanian government as part of technology transfer. More than 80 of these diversified cultivars had been studied and evaluated for their resistance/ tolerance to the banana weevil borer.

2.1.2 *Multiplication of clean planting material*

The use of clean planting material at plantation establishment time was identified as an important first step towards banana IPM. In order to address this important issue among the smallscale farmers, the production of clean banana planting materials using the split corm technique on popular and tolerant cultivars was initiated. The corm splits are easy to clean due to their small size and are maintained in a nursery where they are protected from weevil infestation. The corm splits are ready for planting in only 3–4 months. The method provides a cheap alternative for obtaining clean planting material from otherwise infested plantations.

Two experimental nursery sites have been set up in Kisii District at Bobaracho Primary School and Ondawa site in Rachuonyo district during the year 1997. The varieties that have been entered are Nakyetengu AAA-EA, Ngombe AAA-EA, Bogoya AAA, Kampala AAA and Chundobuleku AAA-EA. So far a total of 7700 clean planting materials have been produced from cormsplits. The cost effectiveness of producing clean planting material for and by the smallscale farmers has therefore been demonstrated. In addition, 2684 clean planting material from conventional suckers have been supplied to 85 individual farmers and 21 farmer group outlets. The planting material supplied to farmers goes with IPM information. In 1996, 4493 clean banana planting material was supplied to 103 farmers.

2.2 VALIDATION EXPERIMENTS ON BANANA IPM

Multilocational IPM validation and demonstrative experiments have been set up at four different localities to finetune IPM options for their efficacy and suitability to the end users. The components include the role of planting material and cleaning techniques, continuous weevil trapping using pseudostem traps, incorporation of leguminous intercrops, deep planting, field sanitation and assessment of associated crop losses.

2.2.1 *The importance of paring and hot water treatment for clean planting material*

The importance of paring and hot water treatment for clean planting material and resulting crop performance have been undertaken. The following treatments were studied

(i) Infested unpared suckers from weevil infested field
(ii) Clean suckers from clean field
(iii) Infested suckers, pared and hot water treated
(iv) Infested suckers, pared, hot water treated and protected with furadan.

The experimental plots measured 9 x 9 m and enclosed 16 banana mats and was replicated three times in a RCBD. Banana cultivar Nakyetengu AAA-EA suckers were planted in each treatment in 60 x 60-cm-deep holes. Diammonium phosphate fertiliser was applied to each hole at 200 g. Furadan @ 60 g/mat protection was repeated every 6 months. Data was generated on crop performance and damage index. Results showed that reduced damage percent coefficient infestation (PCI) to the banana crop and increased bunch weights were obtained from the pared and hot water treated infested material as opposed to the planting of untreated suckers (Tables 2.1 and 2.2). By the third harvest, the damage in the infested suckers had reached 66% compared to 17.6% in the pared and hot water treatment and 12.6% under insecticide protection. Likewise, in terms of crop yield, the unpared infested sucker yielded only 6.8 kg/bunch significantly different from 13.3 kg/bunch in the pared and hot water treated infested material and insecticide protection yield of 14.5 kg/bunch. Thus, the yield loss suffered was over 50% through planting infested planting material within three crop cycles.

2.2.2 *The effect of trapping, plant density and groundnut intercropping on banana weevil*

The effect of banana weevil trapping, plant density and groundnut intercropping on banana weevil populations was studied in eight treatment combinations (Table 2.3). Results showed that continuous weevil trapping by use of split pseudostem traps could keep their populations low, especially at low densities by systematic trapping and hence reducing their damage to the banana crop. This results in prolonging the productive life of the banana plant, hence the plantation. Thus the cultivar Nakyetengu AAA-EA a susceptible cultivar to the weevil used in the experiment had been protected from premature

Table 2.1. The effect of clean planting material on percent coefficient of infestation (PCI)

Treatment	Plant crop	First ratoon	Second ratoon
Infested suckers	24.7 ± 1.5 a	34.5 ± 1.7 a	66.0 ±2.3 a
Healthy suckers	4.8 ± 0.6 bc	15.3 ± 0.5 b	16.3 ± 1.3 b
Infested, pared, hot water treated	5.9 ± 0.5 b	17.1 ± 1.5 b	17.6 ± 3.7 b
Infested, pared, hot water treated and furadan	2.1 ± 0.4 c	8.8 ± 1.5 c	12.6 ± 0.7 b

Means in a column followed by the same letter are not significantly different from each other as determined by REGWQ multiple range test at $P = 0.05$.

Table 2.2. The effect of cleaning planting material on crop yield (kg/plant)

Treatment	Plant crop	First ratoon	Second ratoon
Infested suckers	8.7 ± 0.4 a	7.6 ± 1.1 a	6.8 ± 1.0 a
Healthy suckers	11.0 ± 1.5 a	12.4 ± 1.0 b	15.3 ± 1.0 b
Infested, pared, hot water treated	10.3 ± 0.7 b	11.9 ± 0.8 b	13.3 ± 0.7 b
Infested, pared, hot water treated and furadan	12.3 ± 1.0 a	14.4 ± 0.5 b	14.5 ± 0.5 b

Means in a column followed by the same letter are not significantly different from each other as determined by REGWQ multiple range test at $P = 0.05$.

Table 2.3. Effect of spacing, trapping and groundnut intercropping on banana weevil populations

Treatment	Period 1	Period 2	Period 3	Period 4
3 x 3 m G'nut No trap	39.3 ± 14.4 ab	46.0 ± 13.1 a	60.0 ± 7.5 a	88.7 ± 13.1 a
3 x 3 m G'nut Trap	18.7 ± 0.9 b	29.3 ± 5.1 a	54.3 ± 13.3 a	47.6 ± 18.5 a
3 x 3 m Mono No trap	78.0 ± 19.1 a	62.0 ± 14.4 a	75.0 ± 16.0 a	102.7 ± 7.5 a
3 x 3 m Mono Trap	17.0 ± 7.5 b	25.0 ± 4.5 a	38.3 ± 9.5 a	66.0 ± 3.5 a
5 x 5 m G'nut No trap	50.0 ± 16.7 ab	29.3 ± 13.8 a	76.7 ± 23.3 a	85.3 ± 23.5 a
5 x 5 m G'nut Trap	19.3 ± 5.6 b	21.7 ± 3.8 a	26.6 ± 8.1 a	50.7 ± 10.7 a
5 x 5 m Mono No trap	34.6 ± 2.6 ab	50.7 ± 17.9 a	77.3 ± 5.8 a	82.7 ± 8.6 a
5 x 5 m Mono Trap	24.3 ± 13.9 b	23.7 ± 7.1 a	42.0 ± 7.0 a	66.3 ± 10.5 a

Means in a column followed by the same letters are not significantly different as determined by Tukey's studentised range test (HSD) at $P = 0.05$.
G'nut = Groundnut.

damage by trapping. The groundnut intercrop did not affect the colonisation by the weevil, but affected its distribution in the early stages.

(For the use of neem in controlling banana pests, see Report IX)

2.3 SOCIOECONOMIC ASPECTS

Building upon the information generated from the diagnostic studies and theories of adoption, socioeconomic research focused on the factors influencing the adoption of banana IPM technologies. Already over 150 farmers have been given over 8000 clean planting material. This population formed the nucleus of the sample of farmers who have participated in the adoption studies.

The first step was to develop a model for guiding the integration of socioeconomic and biological components as well as research itself. The second step was to carry out baseline diagnostics in select farming communities in western Kenya. Information was compiled to facilitate the tailoring of banana weevil IPM technologies to the objectives, needs, resources and constraints of banana growers in Eastern Africa. Investigations focused on seven key parameters:

2.3.1 *Banana producers' goals and objectives*

Research aimed to unravel producers' overall goals (subsistence, commercial, etc.) and objectives (food, cash income, beer brewing, etc.) for growing bananas. Food security and cash income generation together account, in equal measures for 50% of farmers' objectives, but overall, bananas are produced to meet subsistence needs.

2.3.2 *Importance of bananas*

The theoretical importance of bananas is portrayed in terms of its contribution to diet for people and livestock, cash income, postharvest products and environmental conservation. All these advantages were cited by farmers.

2.3.3 *Characteristics of banana producers*

Adoption of technology is greatly influenced by several personal characteristics including sex, education and producer units.

2.3.4 *Major constraints*

Farmers' ranking of constraints to banana production revealed a large number (14) of bottlenecks, but the two single most important ones are disease and labour. Insect pests were rated very low due to poor understanding of weevils and nematodes, but pests and diseases as a syndrome have the highest share, 34% of weighted scores.

2.3.5 *Study of banana management*

This focused on selection of planting material, spacing, intercropping, weed control, inputs, residue management and adoption of new technologies.

2.3.6 *Resources for banana production*

Resources identified include land, labour, money and inputs (including extension services) in that order. Banana production was rated less resource-intensive than other crops.

2.3.7 *Postharvest and marketing*

The components addressed included: (i) volume of banana produced, consumed and sold; cash earned, pricing, transport, middlemen and constraints, (ii) use of other by-products such as fibre and dry leaves.

Output

Conferences attended

The following six scientific papers were presented during the International Conference on Banana and Plantain for Africa in Kampala, Uganda from 14–18 October 1996:

Seshu Reddy K.V. Relative susceptibility and resistance of some banana cultivars to the weevil, *Cosmopolites sordidus* (Germar).

Ngode L., Seshu Reddy K.V. and Ampong-Nyarko K. Effect of spacing, trapping and intercropping banana (*Musa* spp.) with groundnut (*Arachis hypogaea* L.) on banana weevil, *Cosmopolites sordidus* (Germar).

Musabyimana T., Seshu Reddy K.V., Ngode L. and Prasad J.S. Evaluation of banana cultivars for resistance/tolerance to the banana weevil, *Cosmopolites sordidus* and nematode complex in western Kenya.

Prasad J. S., Seshu Reddy K. V., Ngode L. and Sikora R. A. Development of the banana root lesion nematode, *Pratylenchus goodeyi* Sher and Allen and the banana weevil, *Cosmopolites sordidus* (Germar) in susceptible and tolerant banana cultivars.

Satyanarayan Prasad J., Seshu Reddy K. V., Ngode L. and Sikora R. A. Studies on the longevity of *Pratylenchus goodeyi* in banana-based cropping systems.

Ssennyonga J. W., Seshu Reddy K. V. and Gold C. S. A conceptual model for managing banana pest control strategies and assessing their impact.

Communication, dissemination of information

- The banana IPM developed at the ICIPE was highlighted to the member countries of BARNESA (Banana research network for Eastern and Southern Africa) at the BARNESA steering committee meeting held in Kampala, Uganda, October 1997. The BARNESA outlet is important in reaching other countries in the region for banana IPM information exchange.
- The IPM was exhibited during the World Food Day provincial celebrations for Nyanza, Kenya in October 1997. The importance of banana crop was stressed. The Nyanza Provincial Agricultural Board consisting of 60 members visited the project and then resolved that each homestead should plant banana using IPM techniques in the province.
- The on-going multilocational validation experiments are important demonstration points, where farmers assemble to learn banana IPM.

Capacity building

Training in banana IPM

- A national training workshop on banana IPM was organised in Kenya in 1997. The course was attended by the provincial and district horticultural crops officers drawn from 19 banana growing districts and 5 provinces in Kenya.
- Group training courses on banana IPM were given to the Ministry of Agriculture, Livestock Development and Marketing personnel from three districts, namely Gucha, Trans Mara and Rachuonyo. Each session was attended by 25 participants.
- Mobile training courses on banana IPM for farmers were initiated due to the demand for banana IPM by farmers. In these training courses, a mobile unit consisting of ICIPE banana project team, together with the Ministry of Agriculture personnel, conduct practical training courses to a targeted group of farmers in a particular locality. A total of six training sessions were

conducted in the localities of Ungoye, Magunga, Kuja river, Kabondo, Kendu and Sikiri. The attendance ranged from 75 to 100 participants in each session.

- 20 Uganda nationals were trained on banana IPM in October 1996.
- 20 senior officials from Tanzania working in different sectors concerned with agriculture were trained on banana IPM in November 1996.

3. EVALUATION OF TREAT-TRAP-RELEASE (TTR) APPROACH IN CONTROL OF BANANA WEEVIL, *COSMOPOLITES SORDIDUS*

Background, approach and objectives

Earlier research on banana weevil has shown a remarkably long life span of individuals and low reproductive rate of the weevil in the field, their aggregative life style and high sensitivity to the host plant-produced attractants. The weevils are virtually monophagous and appear to have few natural enemies. Due to the very secluded life style of the weevils, it is difficult to reach this pest with any control agent.

Our concept for possible control of the banana weevil is based on an assumption that it should be possible to attract the weevils to an artificial device for a time sufficient to infect the attracted weevils with a contagious pathogen. These then serve as a vehicle to transfer the pathogens to and spread it within natural shelters, where the weevils aggregate and hide.

Participating scientists: *S. A. Lux, W. Lwande, N. Maniania*

Assistants: *A. Mbiru, E. Nyandat, P. Agola, L. Moreka*

Collaborator: *IAEA (Uganda)*

Donor: *BMZ*

3.1 STUDY ON BEHAVIOURAL AND ECOLOGICAL FEATURES OF THE WEEVIL, RELEVANT TO THE TTR CONCEPT

A systematic study on weevil behaviour was initiated in three parallel set-ups of different scale: (1) small-scale laboratory arena (60 x 60 cm); (2) experimental field arena (3 x 3 m) with released weevils; and (3) a banana planted field with established natural weevil population. In the laboratory conditions, behaviour of weevils was continuously recorded on S-VHS recorder and in the experimental field arena and banana plot, behaviour of weevils was observed directly during night time.

Preliminary results indicate that the weevils have

(i) a highly secluded life style
(ii) strictly nocturnal rhythm of their activity,
(iii) strong dependence of their migration and explorative activities on moisture (rains); and
(iv) relatively low attractiveness to the traps baited with fresh pseudostem tissue, when challenged with competition from banana plants and plant material usually left on banana plot.

To localise natural shelters preferred by weevils and assess their absolute number on a plot, methodical dissection of plants and plant material present normally on banana plantation was carried out. The plantations chosen for the dissections were located at Ungoye and Embu and were naturally and heavily infested by established populations of banana weevils.

Majority of weevils were found on decayed material (wet-rotten). Dissections were carried out during rainy weather and all materials present on the plot were wet, but few weevils were found on fresh banana tissue or tissues which have undergone dry-decaying process. The results confirmed our anticipation about relatively low absolute numbers of adult weevils present on naturally and heavily infested banana plots (about 30 weevils/mature banana mat, or 33,000 weevils/hectare).

3.2 ASSESSMENT OF THE MIGRATION AND REINVASION CAPABILITIES OF THE WEEVILS

A large plot of carefully cleaned (weevil-free) banana plants was planted about 50 metres apart from a large, naturally infested banana plot with established weevil population. To trace insect movements between the infested plot and the newly established clean banana mats, an array of unbaited pit-fall traps was set up in the area. In addition, split pseudostem traps were set up within the infested plot and newly planted plants.

Remarkably, within the first 6 months after the initiation of the experiment, no weevils were found to infest the newly established banana mats. This appears to confirm the very low migration and reinvasion potential of the banana weevil, which may justify a farm-based rather than area-wide approach in pest management.

To identify an optimal natural source of attractants, fresh and decomposed banana tissues were tested. A pit-fall trap technique was used for all the tests and the traps were arranged, following the same 4 x 4 latin square design. All the tests were conducted concurrently in three set-ups of different scale, the same as those used for the behavioural study.

The results indicated a higher attractiveness of decomposed (wet-rotten) banana tissue as compared to the fresh one. Banana tissue decomposed under conditions of limited access of air (oxygen) and seems to be more attractive than the one decomposed under 'open air'. In the field test, the efficiency of traps baited with extracts made from 12.5 g of banana tissue was found comparable to a traditional split-pseudostem trap. The results seem to confirm the fundamental assumption of the Project, that it is possible to construct a trap based on pre-processed natural banana tissue and its crude extracts, which would be superior to the traditional split-pseudostem trap, and competitive to the natural sources of attraction present in the banana field.

3.3 CONSTRUCTION OF AN ARTIFICIAL DEVICE BAITED WITH CRUDE OR REFINED EXTRACTS OF HOST PLANT BASED ATTRACTANTS

Profiles of volatiles (GC) from: (1) fresh banana tissue, (2) decayed at unlimited access of air, and (3) decayed at limited access of air, were compared.

The analysis revealed a remarkable increase in the complexity of the volatile profile following the decaying process, especially, when the process was conducted at the limited access of air.

To identify an optimal method of extraction of the host-plant based attractants, a steam distillation of the decayed banana tissue and its sequential solvent extraction, were conducted. Hexane, chloroform and methanol were used for the sequential extraction. All extracts were bioassayed at a standard range of four concentrations, graded by one order of magnitude.

Steam distillation gave less attractive material, than the products of solvent extraction. The best results were achieved with hexane extracts, followed by chloroform. The fraction extracted by methanol was not attractive.

In an attempt to reconstitute the full complex of components of the attractant, bioassays of combined hexane and chloroform extracts were conducted. Indeed, a 1:1 blend of the two active extracts, proved superior to any of the individual ones. Addition of the methanol extract, however, did not increase the attractiveness of the blend.

4. STUDIES OF GENETIC BIODIVERSITY IN THE BANANA WEEVIL, *COSMOPOLITES SORDIDUS*, IN BANANA GROWING REGIONS OF THE WORLD

Background, objectives and approach

The banana weevil evolved in Asia and is now widely distributed in all the major banana growing regions of the world. Due to restricted mobility and monophagy, it is expected that discrete populations confined to banana plantations will develop. Local selection and a build-up of genetically distinct biotypes may occur in these isolated populations. The importance of studying intra-specific diversity of arthropods goes beyond the realm of basic genetics. In the case of banana weevil, insight into the existence of biotypes has several levels of application. The first is the extrapolation of research results and an understanding of inconsistencies found between similar studies. For example, how relevant is a study conducted in Latin America or West Africa to the East African context? Are there differences in weevil biology between lowland and mid-elevation banana systems? Are weevils found attacking dessert bananas similar to those found attacking highland cultivars? Awareness of how much variability exists among local populations within and between geographical regions can help both in the interpretation of studies on weevil biology and also contribute to a better understanding of population dynamics, habitat characteristics, dispersal patterns and resource utilisation. Second, the existence of biotypes may suggest the need for multi-location testing with respect to resistant germplasm, to different fungal strains. Differences in pest behaviour may influence efficacy of biological control agents.

The objective was to analyse genetic variability in different banana weevil populations and to evaluate the implications of these differences for management and quarantine strategies.

Scientist: *E. O. Osir*

Assistant: *V. O. Oduol*

Donors: *The Rockefeller Foundation, ICIPE Core Funds*

Collaborators: *• IITA (Uganda) • State University of New York (SUNY, Buffalo) • National agricultural research and extension services (NARES) • International agricultural research centres (IARCs) worldwide*

Work in progress

Intact adult weevils were collected from Australia, Florida, France and Kenya, then preserved and shipped to ICIPE in 70% ethanol. DNA from the head and appendages of 50 weevils from each of the collections was used for RAPD-PCR analysis. Total DNA was extracted by cetyl trimethyl ammonium bromide (CTAB) method. Random amplified polymorphic DNA-polymerase chain reaction (RAPD-PCR) amplifications were performed in 25 μl volumes containing, 1X PCR buffer, 2mM MgCl 2, 0.2 mM dNTP mix and two units of Taq polymerase. A drop of mineral oil was added to the samples and amplified in a model PTC-100 PCR machine. The amplification conditions were 94 °C (1 min), 36° C (1 min) and 72 °C (2 min). Amplification was continued for 40 cycles with a final extension (72 °C; 10 min). The PCR products were resolved in 1.2% agarose gels, stained with ethidium bromide and visualised under UV light.

Forty primers (Operon 10-mer Kits A and O) were screened. Five of these primers (OPO 14, 18, 19, 20 and OPA 17) produced discrete band patterns suitable for subsequent analysis of the diversity in weevil populations. These primers produced 28 polymorphic

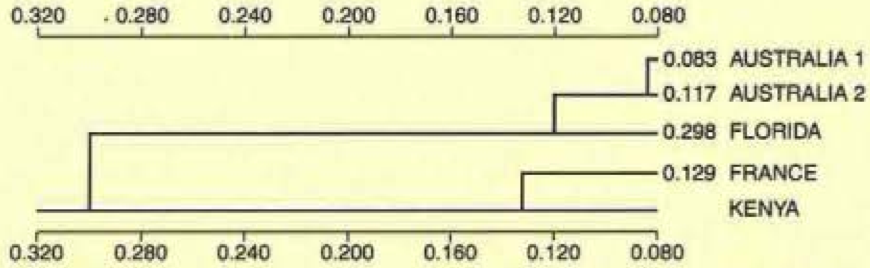


Figure 2.1. UPGMA dendrogram representing genetic relationship in *C. sordidus*

bands. From these, genetic distance matrix was developed and used to construct UPGMA cluster. Two well separated clusters (Australia / Florida (USA) and France / Kenya were observed (Figure 2.1). The two banana weevil populations collected from Australia were closely related genetically.

Future effort will be towards analysis of weevil populations from other parts of the world. Analysis of the spreading patterns of the weevils from their ancestral home in Asia will be of interest. In addition, DNA mini- or micro-satellite markers will be developed for a more detailed analysis of weevil populations.

Capacity building

One ARPPIS PhD student (V.O. Oduol) is working on the project.

Impact

The achievements of the banana project were highlighted in April 1996 by a Swiss TV team on a documentary portraying the ICIPE Director General's work.

Plant Health

LOCUSTS AND MIGRANT PESTS

III. Development of Semiochemical-Based Management Strategies for the Desert Locust, *Schistocerca gregaria* (Forskal) (Loc-1)

Donors: SAREC, IFAD, AFESD through IFAD

Background, approach and objectives

Gregarisation — the ability of the insect to transform reversibly between two extreme phases, solitaria and gregaria—is central to the biology and pest status of the desert locust and other locust and aggregating grasshopper species. Work on the desert locust started in 1990 with the objective of characterising the pheromones mediating the cohesive behaviour, maturation synchrony and communal oviposition in gregarious-phase insects. In addition, studies were initiated on environmental signals associated with the onset of maturation of solitarious individuals, the chemical communication system in this phase of the insect, their food preferences, and habitat features associated with gregarisation.

The goal has been twofold: to explore the use of the insect's own communicational signals to manipulate the process of gregarisation for control; and to develop a quantitative understanding of locust outbreaks associated with gregarisation in order to assemble the components of a preventive intervention strategy.

Funding for the first phase of the project ended in 1995. However, the project was kept ticking during 1996 and 1997, partly from savings and core-funds. During the period 1995–1997 the following activities envisaged in the *5-Year Plan* were undertaken:

- Studies on food preferences of solitarious locusts, their growth and oviposition behaviour and preferences (activities 1.3 and 6.3).
- Characterisation of additional oviposition pheromone components of gregarious phase desert locust (activity 6.1).
- Sexual maturation of solitaria and their mating communication (activity 7.1 and 7.2).
- Documentation of the effects of the adult pheromone on hopper bands in the field (activity 4.2).

1. AGGREGATION/GREGARISATION

*Participating scientists: B. Torto, P.G.N. Njagi, A. Hassanali** (*Project Leader)

Assistant: H.C. Amiani

Work in progress

Previously, we reported several electrophysiologically-active linear aliphatic compounds from the volatiles of fifth-instar nymphs of the gregarious desert locust. In olfactometric bioassays, the pheromone system of second to fifth-instar nymphs has now been identified as a blend of C_6, C_8, C_9 and C_{10} aldehydes and their corresponding carboxylic acids emitted by the insects themselves and phenols (guaiacol and phenol), derived from their faeces. The same blend is responsible for retarding sexual maturation in young adults. Details of these studies have been published in two articles: *Journal of Chemical Ecology*, 22, 2273–2281 (1996) and *Journal of Chemical Ecology*, 23, 5, 1373–1388 (1997).

Detailed studies have been carried out on the pheromone system of first instar nymphs which respond strongly in a dose-dependent fashion to their own volatiles and to those of the sand (includes eggpod remnants) from which they hatch. Analysis by GC-EAD showed that the emissions of the two volatile sources were similar in composition, but varied quantitatively with nymphal and eggpod batch and in antennal recordings. Electrophysiologically-active compounds identified so far are being investigated in bioassays.

In another study, intra- and inter-specific aggregation responses of fifth-instar nymphs and mature adults of the migratory locusts and counterparts of the desert locust were compared in olfactometric assays. Strong inter-aggregation responses were observed in nymphal stages. In adults, these were weaker. GC-EAD and GC-MS studies showed a number of common components in nymphal stages (acids and phenols) and account for mixed hopper bands often found in the fields.

2. OVIPOSITION PHEROMONE SYSTEM ASSOCIATED WITH THE GREGARIOUS PHASE

Participating scientists: *B. Torto, P.G.N. Njagi, A. Hassanali*

Assistants: *H.C. Amiani, P.M. Njiru*

Work in progress

Previously, two pheromone components, acetophenone and veratrole, from the eggpod froth were shown to induce egg-laying by gravid females (*ICIPE Annual Report, 1994*). In detailed laboratory observations, females were found to select their egg-laying sites based on additional signals associated with previously laid eggs, in sand which did not contain froth. Analysis of the volatiles of sand in which females previously oviposited showed the presence of three electrophysiologically-active compounds, which were identified by GC-MS as (*Z*)-6-octen-2-one, (*E,E*)-3,5-octadien-2-one and (*E,Z*)-3,5-octadien-2-one (Figure 2.1). The relative amounts of these compounds in the sand increased with consecutive oviposition as female preference for oviposition into the sand increased (Figure 2.2). Interestingly, the three components were also present in the eggs. Froth volatiles only contained trace amounts of the compounds. Synthesis of the three ketones is in progress for their evaluation in bioassays.

In another study, a novel volatile collection system (Figure 2.3) was designed to collect volatiles directly from ovipositing females with the objective of investigating whether additional more volatile compounds than those previously identified may be involved in oviposition aggregation of the desert locust. GC-EAD and GC-MS analyses identified

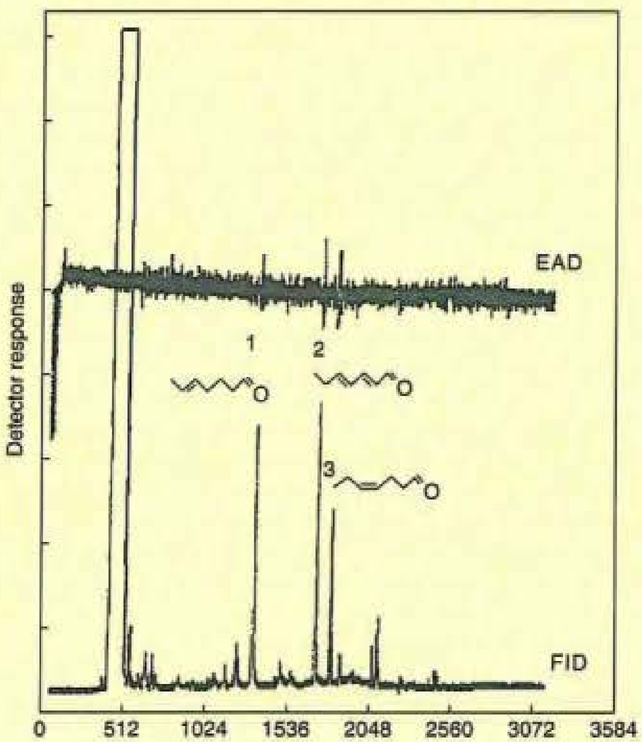


Figure 2.1. Representative reconstructed computer GC-EAD recordings of female *S. gregaria* antennae, responding to compounds 1, (*Z*)-6-octen-2-one, 2, (*E,E*)-3-5-octadien-2-one, 3, (*E,Z*)-3,5-octadien-2-one in the crude volatile extract of sand contaminated by ovipositing gregarious females

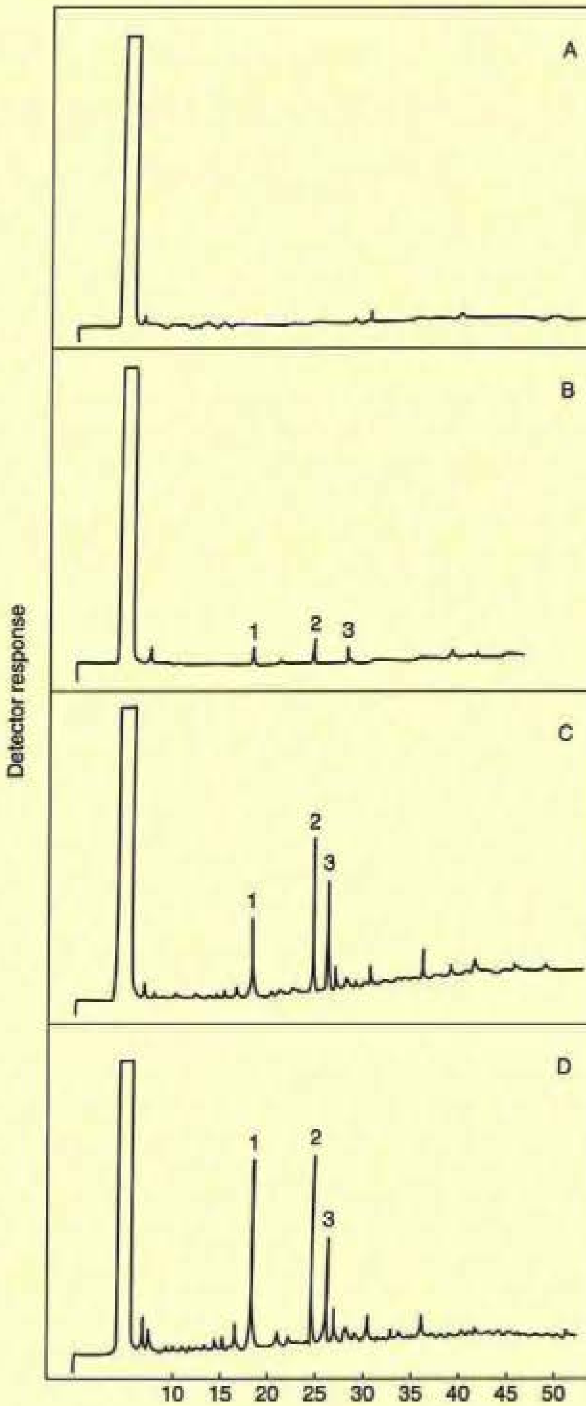


Figure 2.2. Gas chromatograms of volatiles collected from (a) non-contaminated sand or air-dried contaminated sand (contaminated with 7 eggpods), and (b–d), moistened contaminated sand in which females had laid (b) 7 eggpods, (c) 21 eggpods and (d) 35 eggpods. Labelled peaks are: 1, (*Z*)-6-octadien-2-one; 2, (*E,E*)-3,5-octadien-2-one and 3, (*E,Z*)-3, 5-octadien-2-one

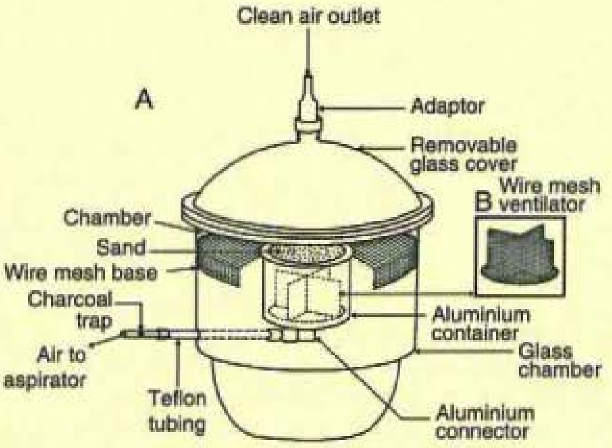


Figure 2.3. Diagram of the desiccator system used for trapping volatiles from female locusts (A) with the cross folded wire mesh, (B) for ventilation of the sand in the aluminium container

nonanal as a candidate pheromone component. In laboratory assays, nonanal was found to induce significant oviposition responses from gravid females, but not their cohesive behaviour. Video camera recordings of the behaviour of gravid females showed that 80% of them made an initial choice to oviposit in nonanal-treated sand, as compared to untreated sand. Similarly, about 65% of the time spent on probing the substrate prior to oviposition was on the treated sand.

Thus, a hierarchy of pheromone signals appears to mediate oviposition in gregarious desert locust: a volatile recruitment signal associated with ovipositing females, froth-associated signals and compounds secreted into the soil during oviposition. The relative importance of these in the oviposition process now remains to be elucidated.

3. SEMIOCHEMICAL SIGNALS ASSOCIATED WITH OVIPOSITION IN SOLITARIA

Participating scientists: *M. Bashir, M.M. Rai, R.K. Saini, A. Hassanali*

Assistants: *H.H. Korena, A.W. Bashir, J. Wawiye*

Work in progress

In a laboratory choice bioassay, solitarious gravid females were induced to oviposit in sand previously oviposited by conspecifics. This behaviour, however, is modified by the presence of certain host plants and gregarious eggpods. In cage studies, solitary females showed preference to oviposit in the vicinity of *Heliotropium*, followed by millet, over solitarious egg pods or other desert plant species, e.g. *Zygophyllum*. When provided with gregarious egg pods, froth or pods without froth, females preferred to oviposit in the vicinity of the whole egg pod or the froth, and only few attempts were made to oviposit in the vicinity of pods without froth and the empty sand bed. In choices between solitarious/gregarious egg pods and host plants, gregarious egg pods were preferred, followed by *Heliotropium* and millet. Only a few attempts were made in the vicinity of solitary egg pods or in empty sand beds. In the field, solitary egg pods and nymphs were predominantly found under *Heliotropium* and to a lesser extent in the vicinity of millet seedlings. With the advancement of the season and the drying up of the plants, nymphs tended to move from *Heliotropium* to millet. Egg pods were also found near millet seed and seedling beds. However on hatching, the nymphs tended to disperse and move to hide and feed on *Heliotropium*.

4. NEW INSIGHTS IN THE SEXUAL ATTRACTION OF THE SOLITARY DESERT LOCUST IN A WIND TUNNEL

Participating scientists: *H. Mahamat, A. Hassanali*

Assistant: *D.K. Kibuchi, P. Njiru*

Work in progress

The existence of long-range sex communication, involving reproductively active solitarious adults was earlier demonstrated in wind-tunnel assays (*ICIPE Annual Reports, 1992/3*). However, observations of male and female solitarious pairs in the field and in a screenhouse suggested that, although the insects eventually mate, the solitarious male responds somewhat lethargically to the female. We considered the possibility that active gregarising males (producing the aggregation pheromone), might respond to solitarious females more effectively. Accordingly, we made a detailed comparison of responses of males in different physiological states to mature solitarious females in a wind tunnel.

The results (Figure 4.1) show clearly that solitary-reared males crowded for varying periods (i.e. ones already demonstrating gregarious characters, particularly pheromone emission) from ecdysis, and gregarious males, were more strongly attracted to solitarious females, compared with solitarious males. These results suggest the operation of yet another mechanism of recruitment of solitarious insects into the gregarious or gregarising groups.

A number of candidate sex pheromone components already have been identified from the volatile emission of solitarious females, and their roles in sex attraction of males are being elucidated in a wind tunnel. The results are expected to lay the foundation for the development of a pheromone trap for detecting and monitoring desert locusts at early stages of population build-up, an important component of an early warning system.

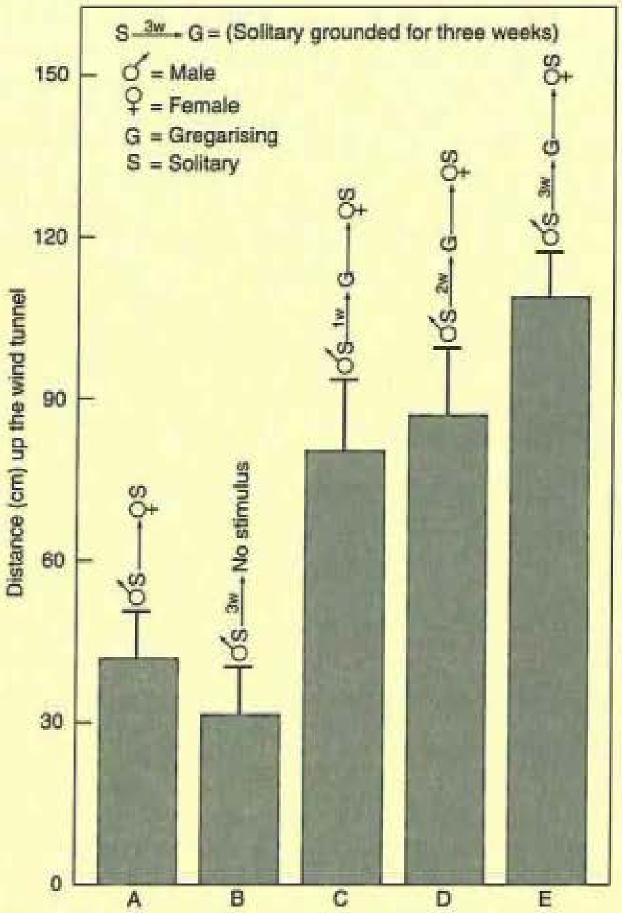


Figure 4.1. Progression of males in different physiological states (solitarious and solitarious which have been crowded for different periods, i.e. gregarising) to solitarious females in a wind tunnel

5. LOCUST–PLANT RELATIONSHIPS

Participating scientist: *M. Bashir*

Assistants: *H.T. Abd-El-Rahman, H.H. Korena, M.O.S. Mohamed, A.R.W. Bashir*

Work in progress

Analysis of data on previous infestations in the Red Sea area revealed that the desert locust when in plagues, causes substantial damage to pasture vegetation. These change the relative density and frequency of occurrence of the vegetation in the affected areas. Vegetation that is not palatable to small ruminants dominates. Hence, during plagues the insect becomes a serious competitor of small ruminants. Camels, being polyphagous, are not much affected.

Laboratory, semi-field and field trials indicated that the solitary phase has a limited list of preferred host plants. Out of over 30 host plants tested, compilation and analysis of life tables data for at least one generation, was possible on 4 species: *Heliotropium*, millet, *Crotalaria microphylla* and *Launaea capitata*. Rearing for more than one generation was only possible on *Heliotropium* and millet. Although relatively large and heavier adults were obtained from nymphs reared on *Lunaea capitata*, the females were not as fecund as those reared on *Heliotropium* and millet.

Feeding rates in paired plant and group tests indicated a clear preference for *Heliotropium* over most of the tested species, regardless of phase. Assessment of damage indicated that the nymphs cause damage by feeding and spillage. The solitary nymphs seemed to be efficient feeders. They tended to feed more and spill less compared to gregarious nymphs. Detailed data is now available on a number of pasture vegetation and cultivated crops, where nymphs of both phases are reared from the first instar to fledgling. As an example the gregarious 4th instar nymphs on two of the most important pasture trees *Acacia tortilis* and *Convolvulus hystrix*, removes 0.54 g/day (76% fed, 24% spilled) and 0.318 g (75% fed, 25% spilled) respectively. This is equivalent to 50 and 76.6% of its body weight, respectively. In comparison, the solitary 4th nymph instar removes 0.923 g/day (90% fed, 10% spilled) and 0.598 g (87% fed, 13% spilled) respectively. This is equivalent to 205 and 133% of its average body weight respectively. On *Heliotropium*, the gregarious 4th instar nymph, removes 0.307 g/day equivalent to 68.7% of its average body weight (69% fed, 31% spilled). The solitary one removes 0.98 g/day, equivalent to 218% of its average body weight (85% fed, 15% spilled).

There are seven *Heliotropium* spp. reported in the Red Sea area. *Heliotropium longiflorum*, *H. strigosum* (perennials) and *H. baccifrum* and *H. pterocarpum* (annuals) are more prevalent and proved to be the key species in the life system of the desert locust. The two perennial species are the first desert plant species to sprout at the advent of the first rain showers. They are very fast growers and are utilised as oviposition sites by solitary females.

The above data, together with the information now being compiled on the biomass production by the cultivated crops and the pasture flora important in the life system of the desert locust, will be assembled to develop host plant–locust models.

6. STUDIES ON THE EFFECTS OF ADULT PHEROMONE ON HOPPERS

Participating scientists: *M. Bashir, A. Hassanali, B. Torto*

Assistants: *H.H. Korena, M.O.A. Mohamed, A.R.W. Bashir, H. Amiani, I.M. El-Hassan, N. El-Tayab, A.M. Sayed*

6.1 TREATMENT WITH PHEROMONE ALONE

Under cage trials, the pheromone irrespective of concentration and method of delivery (spraying the nymphs, dipping or exposing to a swab of treated cotton hanging from the roof of the cage) solicited abnormal behaviour among individuals. This included increased cannibalism, change in the normal circadian rhythm and abnormal hyperactivity, revealed by the time devoted to moving around in relation to roosting and feeding. The consumption of the favoured food plant was significantly reduced in nymphs exposed to the pheromone compared to the control.

Under field conditions, marching bands sprayed with the pheromone showed the following abnormal behaviour:

(a) While still marching as a coherent band, the insects:
   (i) had frequent changes in the direction of displacement;
   (ii) had more than one leading edge;
   (iii) tended to mill around while marching and displacing randomly;
   (iv) tended to form significantly more roosting patches or groups.

(b) Marching as a coherent band, even with several leading edges, was soon terminated, compared to untreated bands.

(c) Treated nymphs tended to continue roosting and feeding on trees.

(d) Nymphs were hyperactive while on trees.

(e) Eventually, treated bands fragmented into smaller groups and individuals.

(f) There was evidence of increased night movement consistent with solitarisation.

(g) Due to fragmentation, individuals in these bands suffered more predation, principally by birds compared with the untreated bands.

6.2 COMBINED TREATMENT WITH CHEMO- AND BIOPESTICIDES

Exposure of gregarious nymphs to low doses of the adult pheromone increases their susceptibility to synthetic insecticides. Dilutions as low as 15-fold of some insecticides (e.g. propoxur) give higher mortalities compared with controls not treated with the pheromone.

Similar effects were found with oil formulations of the mycopesticides *Metarhizium anisopliae* and *Metarhizium flavoviride*, which were efficacious at relatively low doses on nymphs exposed to the pheromone.

These results indicate the potential use of semiochemicals in disrupting behaviour patterns vital in the life system of the desert locust. Further investigations are needed on formulations, dosages and delivery techniques on large hopper bands in the field.

Output

Publications

Assad Y.O.H., Torto B., Hassanali A., Njagi P.G.N., Bashir N.H.H. and Mahamat H. (1997) Seasonal variation in the essential oil composition of *Commiphora quadricincta* and its effect on the maturation of immature adults of the desert locust, *Schistocerca gregaria*. *Phytochemistry* 44, 833–841.

Assad Y.O.H., Hassanali A., Torto B., Mahamat H., Bashir N.H.H. and El Bashir S. (1997) Effects of fifth-instar volatiles on sexual maturation of adult desert locust *Schistocerca gregaria*. *Journal of Chemical Ecology* 23, 1373–1388.

Deng A.L., Torto B., Hassanali A. and Ali E.E. (1996) Effects of shifting to crowded or solitary conditions on pheromone release and morphometrics of the desert locust, *Schistocerca gregaria* (Forskal) (Orthoptera: Acrididae). *Journal of Insect Physiology* 42, 771–776.

Dakou D., Essuman S. and Raina S. K. (1996) Mise en évidence de facteurs humoraux dans la défense immunitaire du criquet pèlerin *Schistocerca gregaria*. *Science et technique*. Sciences naturelles Vol 22 Number 2.

Mahamat H., Hassanali A. and Ferenz H.-J. (1977) Vitellogenin titres in normal and accelerated maturation of gregarious-phase *Schistocerca gregaria*. *Comparative Biochemistry and Physiology* 116B, 447–451.

Mahamat H., Hassanali A. and Munyinyi D. (1997) Haemolymph pigment composition as a chemometric indicator of phase of the desert locust *Schistocerca gregaria*. *Insect Science and Its Application* 17, 199–204.

Njagi P.G.N., Torto B., Obeng-Ofori D. and Hassanali A. (1996) Phase-independent responses to phase-specific aggregation pheromone in adult desert locust, *Schistocerca gregaria* (Orthoptera:Acrididae). *Physiological Entomology* 21, 131–137.

Njagi P.G.N. and Torto B. (1996) Responses of nymphs of desert locust, *Schistocerca gregaria* to volatiles of plants used as rearing dies. *Chemoecology* 7, 172–178. (Publication released in Dec. 1997).

Rai M.M., Hassanali A., Saini R.K., Odongo H. and Kahoro H. (1997) Identification of components of the oviposition aggregation pheromone of the gregarious desert locust, *Schistocerca gregaria* (Forskal). *Journal of Insect Physiology* 43, 83–87.

Saini R.K., Rai M.M., Hassanali A., Wawiye J. and Odongo H. (1995) Semiochemicals from froth of egg pods attract ovipositing females *Schistocerca gregaria*. *Journal of Insect Physiology* 41, 711–716.

Tawfik A.I., Vedrova A., Li W., Sehnal F. and Obeng-Ofori D. (1997) Haemolymph ecdysteroids and the prothoracic glands in the solitary and gregarious adults of *Schistocerca gregaria*. *Journal of Insect Physiology* 43, 485–493.

Tawfik A.I., Osir E.O., Hassanali A. and Ismail S.H. (1997) Effects of juvenile hormone treatment on phase changes and pheromone production in the desert locust, *Schistocerca gregaria* (Forskal) (Orthoptera: Acrididae). *Journal of Insect Physiology* 43, 1177–1182.

Torto B., Njagi P.G.N., Hassanali A. and Amiani H. (1996) Aggregation pheromone system of nymphal gregarious desert locust, *Schistocerca gregaria* (Forskal). *Journal of Chemical Ecology* 22, 2273–2281.

Conferences attended

M.O. Bashir. The Association of Arab Research Councils and the Sudanese National Research Centre, University of Juba, Khartoum, 3–5 October 1995, Gaza. Two presentations given: (a) 'Natural enemies of locusts and their potential use as biocontrol agents'. (b) 'Preliminary investigations on the effect of a component of the desert locust adult gregarisation pheromone on gregarious nymphs'.

M.O. Bashir. ESA, Las Vegas, 17–22 December 1995. Poster on: Cannibalism among desert locust nymphs under adult pheromone stress.

M.O. Bashir. International Workshop on Sustainable Use of Rangeland and Desertification Control, Jeddah, Saudi Arabia, 3 November 1996. Gave a presentation on 'The effect of desert locust, *Schistocerca gregaria*, on the productivity of rangeland in the Red Sea Coast of Sudan and its population management through environment-friendly control tactics'.

A. Hassanali. International Meeting of the Orthopterists' Society, 26–30 October, 1997. Invited presentation on 'Desert locust gregarisation process: Insights from semiochemical research'.

A. Hassanali. The 42nd Regular Session of the DLCO-EA Council of Ministers, 7–8 August, Arusha, Tanzania. A brief overview of ICIPE's research on semiochemicals was given.

A. Hassanali. Locusts Research Strategy Meeting, IFAD, Rome, 25–26 September, 1995. The following two presentations made: (a) 'Gregarisation, the key mechanism in locust biology: Insights from semiochemical research'. (b) 'ICIPE's work on desert locust semiochemicals: An overview'.

M. Rai. International Behavioural Ecology Conference, 29 September to 4 October 1996, Canberra, Australia. Poster presentation on 'The identification of oviposition aggregation pheromone of the gregarious desert locust'.

Saini R. K. (1995) Semiochemicals from froth of egg pods, attract ovipositing females of the desert locust *Schistocerca gregaria*. International Ethological Conference, Honolulu, Hawaii USA 10–17 August, 1995.

B. Torto. International Chemistry Conference in Africa, Accra, Ghana, 31 July to 4 August 1995, 'Aggregation pheromones for the gregarious desert locust *Schistocerca gregaria*: Identification, bioassay and semi-field evaluation'.

B. Torto. 12th Annual meeting of the International Society of Chemical Ecology, 2–6 October 1995, Los Andes, Chile. 'Sex pheromone studies in the desert locust, *Schistocerca gregaria*'.

Proposals written

ICIPE/IITA collaboration proposal on 'A combined kairomone and aggregation pheromone bait system for the grasshopper pest of Africa, *Zonocerus variegatus*', to JICA and Nippon Foundation. 1995/6.

'The Locust Menace in Namibia and Botswana: Towards a Lasting Solution 1997. Also to Japanese institutions.

Capacity building

The following students completed their PhD studies:

Arop Leek Deng (Sudan) 1995. Title of thesis: Studies on some factors that influence phase dynamics of the desert locust, *Schistocerca gregaria* (Forskal) (Orthoptera: Acrididae).

Yousif Osman Hussein Assan (Sudan) 1995. Title of thesis: Effects of some inter- and intra-specific signals (kairomones and pheromones) on the maturation of the desert locust *Schistocerca gregaria* (Forskal) (Orthoptera: Acrididae).

Amer Ibrahim Tawfik (Egypt) 1995. Title of thesis: Interaction between pheromones and hormones in phase dynamics of the desert locust, *Schistocerca gregaria* (Forskal).

Hatem Abdel Fattah Mohammed (Egypt) 1996. Title of thesis: Morphometric and molecular comparisons of two isolated populations of the desert locust, *Schistocerca gregaria*, (Orthoptera: Arcididae).

Abdoulaye Niassy (Senegal) 1996. Title of thesis: Interactions between *Schistocerca gregaria* (Forskal) and *Locusta migratoria migratorioides*) (Reich and Fairmaire) in relation to phase polymorphism.

Impact

The semiochemical project has raised a lot of interest among scientists working in Orthoptera, chemical ecology and locust and grasshopper control the world over.

Plant Health

FOOD AND PERENNIAL CROP PESTS

IV. Biological Control of Cereal Stemborers in Eastern and Southern Africa (FOP-1)

Background, approach and objectives

This project is targeted against the exotic stemborer, *Chilo partellus*. Surveys from 1991–1997 revealed that *C. partellus* was by far the most abundant stemborer in several areas of Kenya, including the southern, lowland coastal area, the Eastern Province and the southwestern area bordering Lake Victoria. More recent surveys in Mozambique, Uganda and Zanzibar have also shown that *C. partellus* is the predominant stemborer over vast areas of East Africa. Moreover, there is evidence from Kenya and other countries, that the exotic stemborer has gradually displaced native stemborers over the past 30–40 years.

Based on the results of these surveys, ICIPE introduced a small parasitic wasp from the Indian sub-continent that attacks *C. partellus* in its native home. This parasitoid, *Cotesia flavipes*, was evaluated in the laboratory, and then released in the coastal area of Kenya in 1993, and later in other areas of Kenya. Surveys conducted during the long rains from 1995–1997 revealed that the parasitoid population was growing and the geographic distribution spreading. Beginning in 1996, efforts were made to develop collaborative programmes with other countries in the region to release *C. flavipes*. By the end of 1997, *C. flavipes* had also been released in Mozambique, Uganda and Somalia.

Classical biological control is the approach being followed. This strategy is based on the premise that introduced organisms often reach higher densities in the areas they have invaded than in their native homes. The reason for higher densities in the area of invasion is the lack of suppression by coevolved natural enemies. Classical biological control strives to establish the same ecological balances that occur in the native home, in the invaded area.

In recent years, the classical biological control approach has come under attack due to perceived potential negative impacts on non-target fauna. ICIPE is addressing these concerns by carefully conducting in-depth studies on the host range of introduced natural enemies, and by examining competition between exotic and introduced parasitoids.

The objectives of the project are twofold: increasing natural suppression of stemborer densities in East and southern Africa, and improving the capacity of national programmes to conduct biological control activities.

Participating scientists: *W. A. Overholt*, C. O. Omwega, A. J. Ngi-Song, S. W. Kimani-Njogu, M. N. Sallam, M. Bonhof, V. Ofomata, J. Songa, K. Takasu (*Project leader)*

Assistants: *J. O. Ongata, M. Majua, G. O. Ogola, J. O. Owaga, J. O. Ochieng', D. Mungai, B. Musyoka, M. O. Odoyo, S. P. Ojwanga, J. C. Olela, M. Mungai, P. Owuor.*

Donors: *Directorate General for International Cooperation (DGIS), The Netherlands, Rockefeller Foundation*

Collaborators: *• Wageningen Agricultural University • IITA • ICRISAT • CGIAR System-Wide IPM Initiative • NARS/Universities in Uganda, Ethiopia, Eritrea, Zanzibar, Zambia, Malawi and Mozambique*

Work in progress

1. STUDIES ON *COTESIA FLAVIPES* AND OTHER PARASITOIDS

1.1 ESTABLISHMENT AND EVALUATION OF *COTESIA FLAVIPES* IN KENYA

Cotesia flavipes was released at three locations in the coastal area in 1993, and surveys have been conducted every two weeks during the cropping season at about 30 sites each year to monitor the density and spread. *Cotesia flavipes* has been found at more sampling sites each year, and in higher densities. However, densities of the parasitoid across sampling sites at the coast have been highly variable, ranging from very rare, to seasonal parasitism of 7.5%. Parasitism on different sampling dates within a season has also been variable, ranging from 0 to as high as 50%. Future efforts will be focused on explaining the spatial and temporal variability in the abundance of the parasitoid population.

In addition to the work at the coast, a similar programme was initiated in the Eastern Province in 1996 in collaboration with KARI. *Chilo partellus* was found to be the most abundant stemborer and accounted for about 65% of the borers collected. In two areas, *C. flavipes* was found, with levels of parasitism of 5.3 and 1.9%, and at both locations it was the predominant larval parasitoid. As no releases of *C. flavipes* had been made in this area, it is assumed that the parasitoids gradually migrated from the coast, or were moved passively through the transport of infested plant material.

A study conducted in the southern Lake Victoria area of Kenya in 1994–96 also clearly revealed that *C. flavipes* was established in this area. However, parasitism was generally low ranging from 0 in the 1995 long rains to 6.1% in the long rains of 1996. *Cotesia flavipes* was recovered at 8 of 19 sites sampled, suggesting a fairly widespread distribution in the area. The lakeshore area is a medium elevation zone where both *Busseola fusca* and *C. partellus* are found. The presence of *B. fusca*, which is an attractive, but unsuitable host for *C. flavipes*, may negatively influence growth of the parasitoid population in this region.

To estimate the extent of the distribution of *C. flavipes* over all of southern Kenya, an extensive survey was conducted in mid-1997 that covered the area from the Indian Ocean in the east, to Lake Victoria in the west. *Cotesia flavipes* was recovered from all areas where *C. partellus* was the predominant stemborer. Parasitism at several sites was quite high (Figure 1.1), particularly in the semi-arid regions of southeastern Kenya. These results again demonstrate the dispersal ability of *C. flavipes* as no releases had been made in any areas outside the coastal strip.

1.2 DISTRIBUTION OF STEMBORERS AND ASSOCIATED PARASITOIDS IN WILD GRASSES IN THE EASTERN PROVINCE

This study was conducted in 1997 in two farms in each of six agroecological zones (AEZ) in the Eastern Province: UM2, UM3, UM4, LM3, LM4 and LM5. Results showed that the most common alternate wild host grasses of stemborers in UM2, UM3, UM4, LM3 and LM4 were *Pennisetum purpureum*, *Pennisetum trachyphillum*, *Panicum maximum*, whereas in LM5 *Sorghum versicolor* was the most abundant wild grass host. *Chilo partellus* larvae were sampled in LM5, where 9.1% were parasitised by *C. flavipes*. *Pennisetum trachyphillum* was the second most heavily infested grass species in the other five AEZs and *C. partellus* was the predominant stemborer. *Sesamia calamistis* was only recovered from *P. maximum* in UM3, and *Chilo orichalcociliellus* from *P. purpureum* in UM2. The hyperparasitoid *Aphanogmus fijiensis* was recovered from *Cotesia* sp. cocoons in LM3.

(See also Report V on the use of the wild habitat in stemborer management.)

Figure 1.1. Parasitism of *Chilo partellus* in southern Kenya

Location	*C. partellus*	*C. flavipes*	% Parasitism
South coast	387	0	0
North coast	206	31	15.0 (0–68.2)
Taita Taveta	21	7	33.3 (0–37.5)
Kibwezi	364	34	9.3 (0.7–21.2)
Machakos	23	2	8.7 (0–100)
Southwestern	372	4	1.1 (0–13.3)

1.3 POPULATION GENETICS OF *COTESIA* SPP.

Electrophoretic studies conducted on populations from different areas of the world indicated that populations from Karachi, Pakistan were most diverse, based on electrophoretic variation at three polymorphic loci, and the Indian population was the least diverse. Populations from the Sindh and Rawalpindi areas of Pakistan were intermediate. Electrophoretic data of *C. flavipes* recovered from field surveys suggested that the established population had maintained greater diversity than laboratory populations.

1.4 SUITABILITY OF *B. FUSCA* AND *S. CALAMISTIS* FOR THE DEVELOPMENT OF TWO GEOGRAPHICAL POPULATIONS OF THE LARVAL PARASITOID *COTESIA SESAMIAE*

The suitability of the African stemborers *S. calamistis* and *B. fusca* for the development of two geographical populations of the larval parasitoid *Cotesia sesamiae* was investigated. Results showed that both populations of the parasitoid could develop on *S. calamistis*. The inland population of *C. sesamiae* was able to successfully parasitise *B. fusca*, while the population from the coast was encapsulated. Mating studies revealed that the two populations were partially reproductively isolated. Uni-directional incompatibility, possibly caused by infection with *Wolbachia* bacteria, was observed when males from the *Wolbachia*-infected coastal population were mated with females from an uninfected inland population. Effect of parasitism by two geographical populations of *C. sesamiae* on the total haemocyte counts of *B. fusca* and *S. calamistis* indicated that from day 1 to 7 after parasitisation, there was a significant decrease in total haemocyte counts of larvae parasitised by *C. sesamiae*, compared to that of unparasitised larvae. This trend was observed for both hosts.

1.5 DISCRIMINATION OF PARASITISED AND UNPARASITISED STEMBORERS BY *C. FLAVIPES* AND *C. SESAMIAE*

A study on the ability of *C. flavipes* and *C. sesamiae* to discriminate between parasitised and unparasitised *C. partellus* and *S. calamistis*, was conducted in a Y-tube olfactometer using naive and experienced female parasitoids. Naive females had no oviposition experience, while experienced females had a previous experience in successfully attacking a stemborer. Neither naive nor experienced females of the two species exhibited an interspecific host discrimination ability. Both naive and experienced females of the two species accepted ovipositing in a host previously parasitised by the other species. Multiple parasitism is therefore expected to take place wherever the two species occur sympatrically. However, experienced females of the two species were significantly more attracted to healthy host larvae in fresh tunnels than larvae parasitised by conspecific females. Experienced females exhibited a clear tendency towards avoiding superparasitism, while this ability was absent in naive females.

1.6 INTRASPECIFIC AND INTERSPECIFIC COMPETITION BETWEEN *C. FLAVIPES* AND *C. SESAMIAE*

Studies were conducted to investigate competition between *C. flavipes* and its closely related African congener, *C. sesamiae*. Progeny production of *C. flavipes* on *Chilo partellus* increased gradually as the number of ovipositions increased, levelled off at three stings per larva, then decreased. Cocoon weight, sex ratio and emergence of the progeny were not affected by superparasitism. Prolonged immature development, shorter longevity of adult progeny and lower potential fecundity of female progeny were found as a result of increasing the number of ovipositions. Low progeny production and poor survival of *C. partellus* host larvae were found over the different numbers of ovipositions by *Cotesia sesamiae* (Table 1.1). When *S. calamistis* was the host, duration of immature stages of *C. flavipes*, parasitoid emergence, progeny

Table 1.1. Number of cocoons, adult progeny, cocoon weight, duration of immature stages, sex ratio, longevity, emergence rate and potential fecundity of *Cotesia flavipes* and *C. sesamiae* (means ± SD) as a result of different number of ovipositions on *Chilo partellus* fourth instar larvae

Number of stings	Parasitoid species	Cocoons	Adult progeny	Cocoon weight (mg)	Duration (Days)	Sex ratio (females/Total)	Longevity (Days)	% Emergence	Potential fecundity (No.eggs)
1	*C. flavipes*	38.8 (10.5) a	37.5 (12.6) a	0.085 (0.015) a	15.9 (1.12) a	0.65 (0.22) a	3.3 (0.4) a	95.4 (16.3) a	178.8 (12.4) a
	C. sesamiae	16.6 (5.62) b	14.4 (6.34) b	0.060 (0.027) b	16.9 (1.07) a	0.54 (0.21) a	2.7 (0.5) b	84.1 (20.9) a	136.0 (20.5) b
2	*C. flavipes*	57.2 (14.6) a	52.7 (13.6) a	0.069 (0.018) a	15.6 (0.72) b	0.65 (0.21) a	2.7 (0.6) a	92.6 (7.50) a	150.9 (18.1) a
	C. sesamiae	24.8 (4.35) b	20.8 (5.74) b	0.049 (0.023) a	18.8 (1.26) a	0.08 (0.15) b	2.8 (0.5) a	83.4 (17.1) a	120.1 (9.96) b
3	*C. flavipes*	58.5 (31.7) a	55.1 (30.3) a	0.064 (0.018) a	16.7 (1.79) a	0.73 (0.12) a	2.4 (0.5) a	94.3 (4.61) a	141.3 (25.2) a
	C. sesamiae	18.8 (11.8) b	11.0 (14.2) b	0.050 (0.033) a	19.3 (4.93) a	0.23 (0.35) b	2.3 (1.2) b	37.4 (44.8) b	103.5 (13.4) b
4	*C. flavipes*	31.1 (10.7)	27.4 (10.1)	0.068 (0.030)	18.1 (2.84)	0.59 (0.20)	1.8 (0.7)	88.1 (11.5)	122.4 (12.9)
	C. sesamiae	–	–	–	–	–	–	–	–
5	*C. flavipes*	25.4 (23.7)	22.1 (22.5)	0.033 (0.031)	19.3 (1.66)	0.51 (0.29)	1.7 (0.7)	82.1 (18.2)	116.8 (14.8)
	C. sesamiae	–	–	–	–	–	–	–	–

Means with the same letter within the same column and number of stings are not significantly different.

production and sex ratio were not affected by superparasitism, but cocoon weight, adult longevity and the potential fecundity of adult females were negatively affected. Superparasitism of *S. calamistis* did not affect emergence, longevity or sex ratio of adult progeny of *C. sesamiae*, but longer duration of immatures, lower cocoon weight and lower potential fecundity of adult females were recorded (Table 1.2). Multiple parasitism studies showed that *C. flavipes* is superior to *C. sesamiae* on *C. partellus*. Local displacement of *C. sesamiae* by *C. flavipes* is expected in areas dominated by this host.

1.7 STUDY OF MULTIPLE PARASITISM OF *B. FUSCA* BY *C. SESAMIAE* EX-KITALE AND *C. FLAVIPES*

Cotesia flavipes is established in western Kenya where *B. fusca* is commonly found. Previous work by the project, demonstrated that *C. flavipes* could not successfully parasitise *B. fusca*. However, *C. sesamiae* has been found to be a common parasitoid of *B. fusca* in western Kenya. A study was initiated to assess the outcome if *C. flavipes* and *C. sesamiae* oviposited in the same host. Preliminary results (Table 1.3) indicate that when both parasitoid species stung larvae about the same time or two hours apart, mixed progeny of both species generally emerged, with *C. flavipes* typically outnumbering *C. sesamiae*. With three days between ovipositions, mixed progeny were also obtained when *C. sesamiae* stung first. Few larvae produced only *C. sesamiae*. When *C. flavipes* stung first, only a few produced mixed progeny and the rest produced *C. sesamiae*, suggesting that *C. flavipes* eggs were killed before they were protected by substances from *C. sesamiae* that prevent encapsulation.

1.8 FUNCTIONAL AND NUMERICAL RESPONSES OF *C. FLAVIPES* AND *C. SESAMIAE* IN THE FIELD AND LABORATORY

Cotesia flavipes had a higher searching ability and attacked more larvae when *C. partellus* was the host. When the native stemborer *S. calamistis* was the host, there was no significant difference between numbers attacked by both parasitoids. Numerical response studies showed that *C. flavipes* produced more total progeny and female progeny per female parasitoid on *C. partellus* than *C. sesamiae*. No significant difference in progeny production was detected between the two parasitoids on *S. calamistis*. Functional and numerical responses tested in the laboratory, gave the same ranking of the two parasitoids on the two hosts as in the field. This study suggests that *C. flavipes* is a more efficient parasitoid to control both exotic and native stemborers in Kenya.

Table 1.2. Number of cocoons, adult progeny, cocoon weight, duration of immature stages, sex ratio, longevity, emergence rate and potential fecundity of *Cotesia flavipes* and *C. sesamiae* (means ± SD) as a result of different numbers of ovipositions on *Sesamia calamistis* fourth instar larvae

Number of stings	Parasitoid species	Cocoons	Adult progeny	Cocoon weight (mg)	Duration (Days)	Sex ratio (females/Total)	Longevity (Days)	% Emergence	Potential fecundity (No.eggs)
1	*C. flavipes*	34.3 (17.2) a	32.0 (17.6) a	0.106 (0.011) a	17.2 (3.0) a	0.53 (0.26) a	3.6 (0.7) a	92.9 (8.9) a	203.6 (8.7) a
	C. sesamiae	32.1 (12.6) a	26.8 (14.2) a	0.098 (0.023) a	16.5 (0.7) a	0.59 (0.32) a	3.1 (1.0) a	81.1(18.5) a	120.3 (8.4) b
2	*C. flavipes*	49.6 (24.8) a	45.9 (23.5) a	0.082 (0.007) a	17.1 (3.2) a	0.75 (0.21) a	3.6 (0.5) a	92.8 (5.3) a	188.2 (10.4) a
	C. sesamiae	66.0 (25.2) a	60.5 (28.1) a	0.068 (0.016) b	19.5 (4.8) a	0.49 (0.22) b	3.1 (0.8) a	88.2 (17.3) a	100.6 (7.4) b
3	*C. flavipes*	46.2 (22.3) a	41.3 (23.2) a	0.069 (0.017) a	15.7 (0.7) b	0.61 (0.26) a	2.5 (0.7) a	86.4 (9.8) a	179.3 (13.6) a
	C. sesamiae	59.6 (39.3) a	52.8 (39.7) a	0.069 (0.027) a	17.0 (1.3) a	0.57 (0.28) a	2.2 (0.8) a	79.1 (24.0) a	116.7 (21.7) b
4	*C. flavipes*	51.9 (20.9) a	47.8 (22.3) a	0.068 (0.029) a	16.0 (1.0) b	0.68 (0.22) a	2.3 (0.5) a	90.0 (10.9) a	161.1 (26.8) a
	C. sesamiae	56.7 (22.5) a	43.4 (19.4) a	0.086 (0.030) a	17.7 (1.4) a	0.67 (0.15) a	2.4 (1.2) a	76.2 (16.5) a	91.10 (14.7) b

Means with the same letter within the same column and number of stings are not significantly different.

Table 1.3. Percentage of *Busseola fusca* larvae from which *Cotesia flavipes*, *C. sesamiae* or both parasitoids emerged after parasitisation by both parasitoids at different time intervals

	Control		Time between first and second oviposition					
			0 hours		2 hours		3 days	
Parasitoid	CF	CS	CFCSK	CSKCF	CFCSK	CSKCF	CFCSK	CSKCF
C. flavipes	100	0	33	25	25	12.5	0	0
C. sesamiae	0	100	0	0	0	0	71	12.5
Both parasitoids	n/a	n/a	77	75	75	87.5	29	87.5

CF= *C. flavipes*, CS= *C. sesamiae*, CSK= *C. sesamiae* Kitale. CFCSK= *C. flavipes* oviposited first and later the larva was exposed to *C. sesamiae* Ex-Kitale (CSK) for oviposition. CSKCF= larvae was first exposed to *C. sesamiae* and then to *C. flavipes*.

1.9 DISPERSAL OF *C. FLAVIPES* IN A NEW ECOSYSTEM

A study on the dispersal of *C. flavipes* was conducted in a 100 m² maize field in northern Kilifi District in the coastal area of Kenya. It was shown that female parasitoids moved at least 64 m during their life span (2–3 days), and that parasitoid dispersal was dependent on wind direction. There was a significant dependence of parasitism on host location whether inside or outside the plant. The majority of parasitised stemborers (88.4%) were found inside the plant (stems and tassel stems), where 74.3% of the suitable hosts were found. Aggregation of parasitoids in response to plants with different host densities was not detected. It is anticipated that *C. flavipes* will continue to disperse and colonise areas where the dominant stemborer species is suitable for its development.

2. STUDIES ON *CHILO PARTELLUS* AND OTHER STEMBORERS

2.1 DISPLACEMENT OF NATIVE STEMBORER BY *C. PARTELLUS*

Chilo partellus occurs sympatrically in maize and sorghum with the native stemborer, *Chilo orichalcociliellus*, in coastal East Africa. There is clear evidence that the indigenous stemborer, *C. orichalcociliellus*, is being gradually displaced by the exotic stemborer, *C. partellus*. Previous studies revealed that these species have similar biologies and resource requirements, and are affected by the same biotic and physical mortality factors. The displacement has thus been attributed to unidentified characteristics that may favour *C. partellus* over *C. orichalcociliellus*.

Investigations on various ecological aspects of *C. partellus* and *C. orichalcociliellus* conducted in 1995–1997, revealed that *C. partellus* and *C. orichalcociliellus* have similar adult longevities, but *C. partellus* laid more eggs than *C. orichalcociliellus* at 25 and 28°C and 75, 84 and 96% relative humidities. However, at a higher temperature of 31°C, at all relative humidities, both species had similar fecundities. Also, higher numbers of *C. partellus* eggs survived to the first larval instar at all temperatures and relative humidities.

The dispersing abilities of *C. partellus* and *C. orichalcociliellus* were compared in the laboratory using a wind tunnel. Higher percentages of *C. partellus* larvae dispersed from the experimental plants, compared to *C. orichalcociliellus* in both maize and sorghum plants. Also, *C. partellus* larvae dispersed over longer distances than *C. orichalcociliellus* in maize and sorghum plants (Figure 2.1). Hence, the newly hatched larvae of *C. partellus* may have a higher chance of being able to escape the adverse effects of physical and natural mortality factors by dispersing in greater numbers at a fast rate to locate adjacent host plants suitable for their establishment for further feeding and development.

Field experiments were conducted to determine the establishment of *C. partellus* and *C. orichalcociliellus* in maize, sorghum, napier grass and wild sorghum plants. Equal numbers of first instar larvae of *C. partellus* and *C. orichalcociliellus* were recovered from all plants after 3 days of infestation (Tables 2.1 and 2.2). However, as the larvae developed, higher numbers of *C. partellus* larvae were recovered from all the plants except in napier grass, which had higher establishment of *C. orichalcociliellus* at 10 and 21 days after infestation. *Chilo partellus* and *C. orichalcociliellus* established and coexisted in the same plant at early larval instars, but competition and other mortality causing factors set in at the later instar stages, resulting in the drastic reduction of *C. orichalcociliellus* compared to *C. partellus*. These superior attributes of *C. partellus* may be involved in the displacement of *C. orichalcociliellus*.

2.2 IMPACT OF PREDATORS ON *CHILO* LARVAE AND PUPAE

During the short rains of 1995 and 1996, an experiment was conducted to estimate the impact of crawling predators on stemborer larvae by ringing the base of maize plants with a sticky material to exclude predators, and comparing densities of stemborers in these protected plants to densities in unprotected plants. In two of the 10 trials, more larvae were found in protected plants, whereas in the other 8 trials differences were not significant, suggesting that crawling predators did not have a large impact on

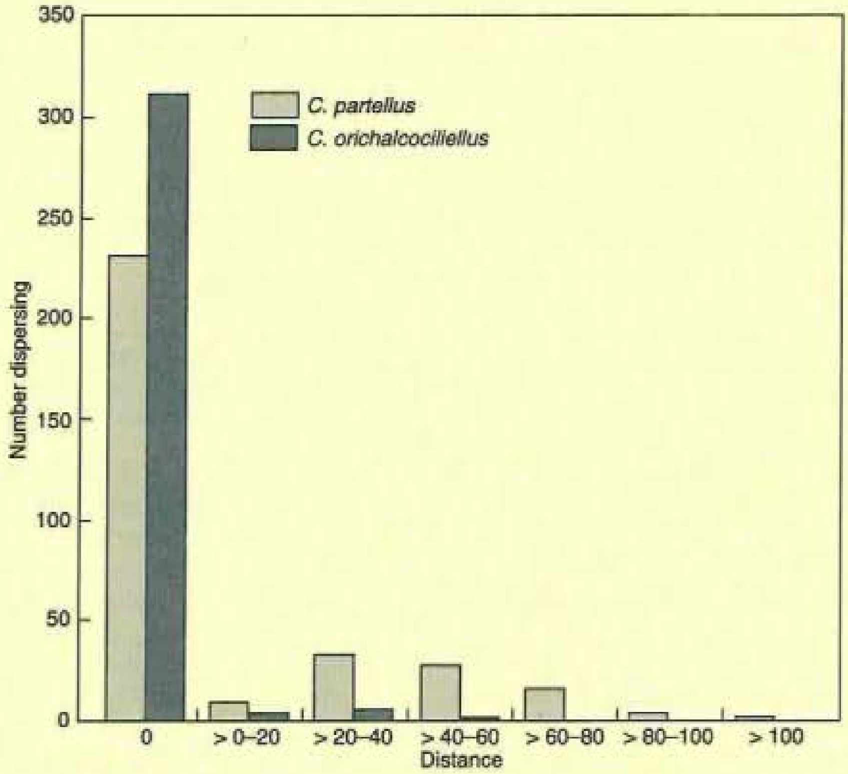


Figure 2.1. Distance dispersed by *Chilo partellus* and *C. orichalcociliellus* in a wind tunnel

Table 2.1. Larval establishment (percentage) of *C. partellus* (Cp) and *C. orichalcociliellus* (Co) in different host plants

Days after infestation	Maize Cp	Maize Co	Sorghum Cp	Sorghum Co	Napier grass Cp	Napier grass Co	Wild sorghum Cp	Wild sorghum Co
3	76.4 a	71.3 a	68.4 a	66.0 a	36.2 a	53.0 a	71.3 a	60.0 b
10	60.2 a	53.0 b	42.4 a	43.0 a	25.6 b	32.5 a	49.7 a	47.0 b
21	50.4 a	49.3 b	32.4 a	25.0 a	19.4 b	27.0 a	36.3 a	35.5 b

Host plants

For each host plant, means in the same row with different letters are significantly different at $P < 0.05$.

Cp = *C. partellus*
Co = *C. orichalcociliellus*

Table 2.2. Larval establishment (percentage) of *C. partellus* (Cp) and *C. orichalcociliellus* (Co) colonising the same plant in different host plants

Days after infestation	Maize Cp	Maize Co	Sorghum Cp	Sorghum Co	Napier grass Cp	Napier grass Co	Wild sorghum Cp	Wild sorghum Co
3	66.7 a	64.7 b	51.2 a	48.8 a	31.3 a	41.3 a	41.3 a	38.7 b
10	54.7 a	34.0 b	41.0 a	28.0 b	19.3 b	29.3 a	36.7 a	20.7 b
21	36.7 a	24.0 b	28.8 a	18.0 b	18.0 b	26.7 a	26.7 a	12.7 b

Host plants

For each host plant, means in the same row with different letters are significantly different at $P < 0.05$.

stemborer densities. In 1997, 60 maize plants were infested with 3 pupae per plant. Crawling predators were excluded from half the plants using a sticky material at the base of the stem. Three days after infestation, the numbers of pupae were counted. The results show that there were a slight trend towards more pupae in plants where predators were excluded, but the differences were only significant in 2 out of 4 replicates, again suggesting that crawling predators may not have a serious impact on stemborer pupae density.

2.3 MORTALITY OF *CHILO* EGGS IN MAIZE AND SORGHUM FIELDS AT THE KENYA COAST

Data on egg abundance and egg mortality were taken at two locations (Mtwapa and Kilifi) at the Kenya coast. Twice a week, 300 maize plants and 300 sorghum plants were checked for egg batches. The eggs were monitored daily, until their fate was known. The results indicated that infestation of the maize and sorghum crop started early, since on the first sampling day (circa 3 days after plant emergence), eggs were present in most fields. On maize, the main oviposition peak was found 6–9 weeks after emergence (w.a.e.), while smaller peaks could be observed around 2 w.a.e. and 13 w.a.e. In sorghum, a similar trend was found, with the highest number of eggs at 8 w.a.e., and smaller peaks at 2 w.a.e., 14 w.a.e. and 22 w.a.e. The abundance of *Chilo* eggs varied considerably between locations and between seasons. Infestations appeared to be higher at the Kilifi site than in Mtwapa, and infestation was also considerably higher during the short rains than during the long rains. In general, 3–5% of the sampled plants contained *Chilo* eggs. The majority of plants with eggs (78–98%) contained only one egg batch. The location of the egg batches varied per location and per season.

In most seasons, egg mortality was high. On maize, egg mortality varied from 19 to 78%, while on sorghum 45–69% of the eggs died. Parasitism was the most important mortality factor, accounting for 23–59% mortality. Predation was relatively unimportant (2–11% mortality), as was death by unidentified causes. Egg disappearance was 6 to 11%.

2.4 AGGRESSIVE BEHAVIOUR OF *C. PARTELLUS* LARVAE AGAINST *C. FLAVIPES*

Laboratory experiments in a glass tube arena were conducted to determine the effects of aggressive behaviour of *C. partellus* on oviposition success and mortality of *C. flavipes*. On contacting unparasitised hosts, female *C. flavipes* rapidly oviposited and retreated from the arena. Hosts exhibited no aggressive behaviour prior to oviposition. However, soon after being attacked, host larvae became aggressive by spitting and biting the parasitoids. When *C. flavipes* were introduced toward the head of the stemborer, the parasitoids stung the host near the head and were frequently bitten and killed. Parasitoids that were introduced at the posterior end of the abdomen, stung the abdomen and were often able to escape without being bitten. Regardless of the direction of introduction, parasitoids were more often killed by older hosts than younger hosts. Moreover, parasitised hosts were more aggressive than unparasitised hosts one hour after the initial oviposition, but not after 24 hours. Larval saliva of *C. partellus* was found to reduce survival of parasitoids. The aggressive behaviour of *C. partellus* was not an effective defence against parasitisation, but is likely to be an important mortality factor of *C. flavipes* in nature.

(For use of neem in control of stemborers, see the main report on neem, Report IX.)

3. FARMERS' PERCEPTIONS OF STEMBORERS, NATURAL ENEMIES AND CONTROL METHODS (IN COLLABORATION WITH THE ICIPE SOCIAL SCIENCES DEPARTMENT)

Farmers' knowledge and their perception of the stemborer problem was investigated in Kwale and Kilifi Districts on the Kenya coast. In each district, 120 farmers (household heads) in 12 villages were interviewed with the help of a questionnaire. Preliminary results indicated that in all villages, stemborers were considered to be the major problem in maize growing. All farmers were aware of stemborers and their damage, and many indicated that they had seen (*Chilo*) larvae and pupae. Eggs and adults were rarely observed by farmers.

Most farmers were unaware of the life cycle of stemborers, and none of the farmers knew where stemborers came from in the beginning of the growing season. The relation between wild hosts or residue management and stemborer infestation did not seem to be known to farmers. Almost all farmers said they left maize stems on the field after harvest to add soil fertility.

Only a few farmers took control measures, although stemborers were mentioned as an important pest in maize. Traditional control methods, such as the use of ash or leaf extracts of *Tephrosia vogelii*, were not commonly used. Insecticides were used by *ca.*30% of the farmers in Kwale District, while in Kilifi District the use of insecticides against stemborers was very low and restricted to one village. Only a few farmers indicated they had heard of 'good insects', and even fewer farmers could mention any 'good insect'. The majority of farmers recognised the predators, but mentioned only spiders and ants as consumers of stemborers. A reasonable number of farmers indicated that they had seen *Cotesia* cocoons, but none knew what they were.

4. FOREIGN EXPLORATION FOR ADDITIONAL NATURAL ENEMIES OF *C. PARTELLUS* IN ASIA

Sturmiopsis inferens is a common parasitoid of *C. partellus* in India, and often regarded as the second most important parasitoid after *C. flavipes*. *Sturmiopsis inferens* has a different life history and attack strategy than *C. flavipes*, and could thus provide complementary mortality of stemborers, rather than competing with *C. flavipes*. The Kenya Government granted ICIPE an import permit for *S. inferens* in July 1996, and an ICIPE scientist visited India for 6 weeks in late 1996 to collect *S. inferens*. Although fresh material of *C. flavipes* was collected from several locations, few *S. inferens* were found and none were shipped to Kenya. Efforts to renew exploration for *S. inferens* and other potentially useful natural enemies will be renewed in 1998.

5. REGIONAL ACTIVITIES

The project greatly expanded its activities in the East and southern Africa region beginning in 1996. Collaborative programmes with national research and extension organisations have been started in Mozambique, Uganda, Zambia, Somalia, Zanzibar, Zambia, Malawi, Ethiopia and Eritrea. In addition to earlier releases in Kenya, parasitoids have been released in Uganda, Mozambique and Somalia. In other collaborating countries, stemborer surveys have been initiated to identify locations where *Chilo partellus* is the predominant species as target sites for releases in 1998/99.

To support the release and survey programmes in collaborating countries, the project has hosted visitors for 2–10 days from national programmes in Somalia, Ethiopia, Uganda, Mozambique and Eritrea. In several countries, project activities have been completely or partially supported by funding sources external to the project. For example, much of the work in Mozambique has been supported by DANIDA. In Somalia, the International Committee of the Red Cross (ICRC) has provided most of the funding. The USAID IPM Cooperative Research Support Programme , IITA and the ICIPE project are working together on stemborers in Uganda. USAID funds may also be made available to support future activities in Eritrea.

Mozambique

The first releases of *C. flavipes* were made in Mozambique in November 1996. Surveys in early 1997 conducted by the Plant Protection Department revealed that the parasitoid had colonised maize fields in the area of release, and parasitism of 10% was reported in one field and 4% in a field 12 km from the release site. Further releases were made in several locations by the Department of Plant Health from a culture maintained in Maputo. Two staff members of the Department of Plant Health visited ICIPE in November 1997 to discuss progress on biological control of stemborers in Mozambique and make plans for 1998. Additionally, a collaborative grant proposal between Eduardo Mondlane University and ICIPE was submitted to the Rockefeller Foundation to provide support for the MSc studies of an instructor at the University. The focus of the study will be on the evaluation of *C. flavipes* in Mozambique.

Zanzibar

Project activities were initiated in Zanzibar in 1995/96 when an island-wide survey was conducted to identify stemborers and their natural enemies. However, plans to make releases of *C. flavipes* in Zanzibar were delayed pending government approval. In 1997, the project coordinator visited Zanzibar from 9–12 September and had further discussions with the Head of the Plant Protection Service. It was agreed that releases of *C. flavipes* would be made in Zanzibar beginning in the long rains of 1998 (March/April). In addition to the work of the project, a complementary grant proposal developed by Wageningen Agricultural University and ICIPE received funding from the Netherlands Foundation for Tropical Science (WOTRO). Beginning in 1998, this grant will fund a PhD fellowship to investigate the colonising ability of different genotypes of *C. flavipes* in Unguja and Pemba Islands.

Zambia

A visit was made to Zambia in February 1997 to initiate a collaborative programme on stemborer biological control with the national agricultural research institute at Mt Makulu. A workplan and budget were prepared to start a survey of stemborers in 1997. The survey started in September, and it is anticipated that it will be completed by the end of 1998. The survey will identify areas where *C. partellus* is the major stemborer for releases of *C. flavipes* in late 1998.

Ethiopia

The IPM coordinator at the Institute for Agricultural Research (IAR) in Ethiopia visited ICIPE in October 1997 to meet with project personnel and discuss the initiation of collaborative activities on biological control. A memorandum of understanding, workplan and budget were prepared and approved by the ICIPE and the IAR management. As part of the workplan, a technician from IAR spent a week at ICIPE in October 1997 for training on natural enemy identification and rearing of *C. flavipes*. The work in Ethiopia will include the involvement of an ARPPIS student who will begin field studies in 1998.

Eritrea

ICIPE was contacted by the Government of Eritrea in August 1997 regarding the possibility of establishing collaboration on stemborer biological control. A scientist from the University of Asmara visited ICIPE in November to develop a workplan and to identify stemborer natural enemies already collected. A stemborer survey is already being conducted in Eritrea with support from USAID, so the project may be able to rapidly move towards releases of *C. flavipes* in 1998 or 1999.

Uganda

In collaboration with IITA and a USAID-funded integrated pest management (IPM) project, stemborer distributions and natural enemies were mapped from 1994–96. A permit for the release of *C. flavipes* was given to ICIPE in June 1997, and the first shipment of *C. flavipes* to NARO were made in December 1997. Additional shipments will be made in 1998. An MSc student, funded partially by the project and partially by the USAID project, will begin to work with NARO on the release and evaluation of *C. flavipes* in 1998.

Malawi

A visit was made to Malawi in late 1997 to discuss the establishment of a collaborative programme on stemborer biological control with the Ministry of Agriculture, Department of Research. A memorandum of understanding, budget and workplan were prepared and approved by ICIPE and Malawi government. A country-wide survey of stemborers and natural enemies started in May 1998.

Somalia

The International Committee of the Red Cross (ICRC) approached ICIPE in early 1997 requesting assistance on stemborer management in the Hiran District of eastern-central Somalia. To initiate activities, a Somali agricultural extension agent received training on stemborer and parasitoid identification at ICIPE in March. A visit was made to Somalia by the project coordinator in May to determine the stemborers species present. Two stemborers, *C. partellus* and *Sesamia cretica* were found. The project began shipping parasitoids to the Hiran District on ICRC aeroplanes in June. Additional parasitoids were sent for release in October. A planned recovery survey planned for December 1997 was postponed due to civil unrest.

Output

Publications

Bonhof M. J., Overholt W. A., Van Huis A. and Polaszek A. (1997) Natural enemies of maize stemborers in East Africa: A review. *Insect Science and Its Application* 17(1), 19–35.

Hailemichael Y., Schulthess F., Smith J. W. , Jr. and Overholt W. A. (1997) Suitability of West African gramineous stemborers for the development of *Cotesia* species (Hymenoptera: Braconidae). *Insect Science and Its Application* 17(1), 89–95.

Khan Z. R., Ampong-Nyarko K., Chiliswa P., Hassanali A., Kimani S., Lwande W., Overholt W. A., Pickett J. A., Smart L. E., Wadhams L. J. and Woodstock C. M. (1997) Intercropping increases parasitism of pests. *Nature* 388 (6643), 631–639.

Kimani S. W. and Overholt W. A., (1995) Biosystematics of the *Cotesia flavipes* complex (Hymenoptera: Braconidae): Interspecific hybridization, sex pheromone and mating behaviour studies. *Bulletin of Entomological Resesarch* 85, 379–386.

Kimani-Njogu S. W. and Overholt W. A. (1997) Biosystematics of the *Cotesia flavipes* complex (Hymemoptera: Braconidae) parasitoids of gramineous stemborers. *Insect Science and Its Application* 17(1), 119–130.

Kimani-Njogu S. W., Overholt W. A., Woolley J. B. and Walker A. K. (1997) Biosystematics of the *Cotesia flavipes* Cameron complex (Hym: Braconidae): Morphometrics and morphology of selected allopatric populations. *Bulletin of Entomological Research* 87, 61–66.

Kioko E., Overholt W. A., Omwega C. O. and Mueke J. M. (1995) Taxonomic significance of isoenzymes in two pyralid stemborers of maize and sorghum in Kenya. *African Entomology* 3(2), 167–171.

Mbapila J. C. and Overholt W. A. (1997) Oviposition, development and searching behaviour *of Cotesia flavipes* Cameron and *Cotesia sesamiae* (Cameron) (Hymenoptera: Braconidae) in relation to aestivating and non-aestivating *Chilo* spp. (Lepidoptera: Pyralidae) larvae in maize. *African Entomology* 5(1), 35–39.

Ngi-Song A. J. and Overholt W.A. (1997) Host location and acceptance by *Cotesia flavipes* Cameron and *C. sesamiae* (Cameron) (Hymenoptera: Braconidae) parasitoids of African gramineous stemborers: Role of frass and other host cues. *Biological Control Theory and Application in Pest Management* 9, 136–142.

Ngi-Song A. J., Overholt W. A. and Ayertey J. N. (1995) Suitability of African gramineous stemborers for the development of *Cotesia flavipes* and *Cotesia sesamiae* (Hymenoptera: Braconidae). *Environmental Entomology* 24(4), 978–984.

Ngi-Song A. J., Overholt W. A., Njagi P. G. N., Dicke M., Ayertey J. N. and Lwande W. (1996) Volatile infochemicals used in host and host habitat location by *Cotesia flavipes* Cameron and *Cotesia sesamiae* (Cameron) (Hymenoptera: Braconidae), larval parasitoids of stemborers on graminae. *Journal of Chemicial Ecology* 22, 307–323.

Okech S. H. O. and Overholt W. A. (1996) Comparative biology of *Cotesia chilonis* (Hymenoptera: Braconidae) on selected African gramineous stemboers. *Biocontrol Science and Technology* 6(4), 595–602.

Omwega C.O., Overholt W.A., Mbapila J.C. and Kimani-Njogu S.W. (1997) Establishment and dispersal of *Cotesia flavipes* Cameron (Hymenoptera: Braconidae), an exotic endoparasitoid of *Chilo partellus* Swinhoe (Lepidoptera: Pyralidae) in northern Tanzania. *African Entomology* 5(1), 71–75.

Omwega C. O. and Overholt W. A. (1996) Genetic changes occurring during laboratory rearing of *Cotesia flavipes* Cameron (Hymenoptera: Braconidae), an imported parasitoid for the control of gramineous stem borers in Africa. *African Entomology* 4(2), 231–237.

Omwega C. O. and Overholt W. A. (1997) Progeny and sex ratios of field populations of *Cotesia flavipes* and *Cotesia sesamiae* reared from gramineous stemborers in coastal Kenya. *Insect Science and Its Application* 17(1), 137–142.

Omwega C.O., Kimani S. W., Overholt W. A. and Ogol C. K. P. O. (1995) Evidence of the establishment of *Cotesia flavipes* Cameron (Hymenoptera: Bracondiae) in continental Africa. *Bulletin of Entomological Research* 85, 525–530.

Overholt W. A., Ngi-Song A. J., Omwega C. O., Kimani-Njogu S. W., Mbapila J., Sallam M. N. and Ofomata V. (1997) A review of the introduction and establishment of *Cotesia flavipes* Cameron (Hymenoptera: Braconidae) in East Africa for biological control of cereal stemborers. *Insect Science and Its Application* 17(1), 79–88.

Potting R. P. J. , Overholt W. A., Danso F. O. and Takasu K. (1997) Foraging behaviour and life history of the stemborer parasitoid, *Cotesia flavipes*. *Journal of Insect Behaviour* 10, 13–29.

Potting R. P. J., Vet L. E. M. and Overholt W. A. (1997) Geographic variation in host selection behaviour and reproductive success in the stemborer parasitoid / *Cotesia flavipes* (Hymenoptera: Braconidae). *Bulletin of Entomological Research* 87, 515–524.

Takasu K. and Overholt W. A. (1996) Oviposition behaviour of *Cotesia flavipes* and *Goniozus indicus*, larval parasitoids of the lepidopteran stemborer *Chilo partellus*. *Japanese Journal of Applied Entomology and Zoology* 40, 308–310.

Takasu K. and Overholt W. A. (1997) Aggressive behaviour of *Chilo partellus* larvae against the larval parasitoid *Cotesia flavipes*. *Insect Science and Its Application* 17(1), 131–135.

Conferences attended

Hailemichael Y., Schulthess F., Smith J. W., Jr. and Overholt W. A. International workshop on tropical gramineous stemborers. Nairobi, Kenya, 15–18 May, 1996: Paper presented 'Suitability of West African gramineous stemborers for the development of *Cotesia* species'.

Kimani S. W. University of Nairobi, Faculty of Science, Zoology postgraduate seminar. 2–3 May 1995: Paper presented 'Morphological and biochemical characters with special reference to the *Cotesia flavipes* complex'.

Kimani-Njogu S. W. and Overholt W. A. International workshop on Tropical Gramineous Stemborers. Nairobi, Kenya, 15–18 May,1996: Paper presented 'Biosystematics of the *Cotesia flavipes* species complex (Hymenoptera: Braconidae), parasitoids of gramineous stemborers'.

Kimani-Njogu S. W., Overholt W. A., Woolley J. B. and Omwega C. O. Joint Congress of the Entomological Society of Southern Africa and the African Association of Insect Scientists. Stellenbosch, 30 June–4 July, 1997: Paper presented 'Biosystematics of the *Cotesia flavipes* complex (Hymenoptera: Braconidae): Electrophoretic and phylogenetic analyses of selected allopatric populations'.

Ngi-Song A. J. Annual conference of the Entomological Society of America, Las Vegas, Nevada, 17–21 December,1995: Paper presented 'Behavioural and physiological equivalence of novel and coevolved host-parasite associations'.

Ngi-Song A. J. Workshop on 'Insect pest control for small holders: Integrating biological control and host plant resistance' CTA-CABI/IAR, Addis Ababa, Ethiopia, October 1995. Paper presented 'Host selection by *Cotesia flavipes* Cameron and *Cotesia sesamiae* (Cameron) (Hymenoptera: Braconidae): An example of tritrophic relationship in a grass-stemborer-parasitoid system'.

Ngi-Song A. J.: Paper presented 'Immunological interactions between *Cotesia* spp. and stemborers'.

Ngi-Song A. J. Annual conference of the Entomological Society of America, Louisville, Kentucky, December,1996: Paper presented 'Suitability of the African stemborer, *Busseola fusca*, for the development of two geographic populations of the larval parasitoid, *Cotesia sesamiae*'.

Ngi-Song A. J. Joint Congress of the Entomological Society of Southern Africa and the African Association of Insect Scientists. Stellenbosch, South Africa, 30 June–4 July 1997: Paper presented 'Suitability of the African stemborer, *Busseola fusca*, for the development of two geographic populations of the larval parasitoid, *Cotesia sesamiae*'.

Ofomata V. C., Overholt W. A., Lux S. A. and Egwuatu R. I. Joint congress of the Entomological Society of Southern Africa and the African Association of Insect Scientists. Stellenbosch, South Africa, 30 June–4 July 1997 : Paper presented 'Possible mechanisms of partial competitive displacement of an indigenous stemborer (Lepidoptera: Pyralidae)'.

Omwega C. O. International Workshop on Tropical Gramineous Stemborers, Nairobi, 15–18 May 1996: Paper presented 'Progeny and sex ratios of field populations of *Cotesia sesamiae* and *Cotesia flavipes* from the Kenya Coast'.

Overholt W. A. Annual meeting of the Entomological Society of America. Las Vegas, Nevada, USA, 17–21 December, 1995: Paper presented 'An ecological approach to classical biological control of gramineous stemborers in Africa'.

Overholt W. A. HORTEC Horticultural Trade Fair, Nairobi, Kenya. 21 March, 1996: Paper presented 'Biologically intensive pest management in horticulture: the need for research'.

Overholt W. A. IAPC/OAU Meeting on 'Creating an African Understanding on the Safe Introduction of Natural Enemies, Collaboration in the Field of Biological Control, and Access to Biological Control Agents'. Kampala, 25–31 May, 1997: Paper presented 'Mass rearing of natural enemies for biological control'.

Overholt W. A. Annual Meeting of the Tanzanian Entomological Society. Zanzibar 9–12 September 1997: Paper presented 'Progress on biological control of stemborers in East and southern Africa'.

Overholt W. A. International Congress of Entomology, Florence, Italy August 31, 1996: Paper presented 'Release of exotic parasitoids against exotic and native stemborers in Africa and neighbouring Indian Ocean Islands'.

Overholt W. A., Kimani S. W., Ngi-Song A. J., Mbapila J., Omwega C. O., Lammers P. and Ogedah K. XIII International Plant Protection Congress. The Hague, Netherlands 2–7 July, 1995: Paper presented 'Classical biological control of cereal stemborers: a collaborative project between the International Centre of Insect Physiology and Ecology and Wageningen Agricultural University'.

Overholt W. A., Ngi-Song A. J., Omwega C. O., Kimani-Njogu S. W., Mbapila J. C., Sallam M. N. and Ofomata V. International Workshop on Tropical Gramineous Stemborers, Nairobi, 15–18 May, 1996: Paper presented 'A review of the introduction and establishment of *Cotesia flavipes* Cameron (Hymenoptera: Braconidae) in East Africa for biological control of cereal stemborers'.

Takasu K. and Overholt W. A. International Workshop on Tropical Gramineous Stemborers, Nairobi, 15–18 May 1996: Paper presented 'Aggressive behaviour of *Chilo partellus* (Swinhoe) larvae against the parasitoid, *Cotesia flavipes* Cameron'.

Project proposals

Biological control of cereal stemborers in subsistence agriculture in Africa. Submitted for funding to the Directorate for International Cooperation (DGIS). Funding ($3.83 million) was approved and made available for the period 1997–2000.

Temporal dynamics, economic importance and management of stemborers in maize production systems in eastern Kenya. Proposal written to support one PhD student. Submitted for funding to the Rockefeller Foundation and approved for $100,000 for the period 1996–99.

New associations and immunological interactions in host/parasitoid relationships for importation biological control. Submitted for funding to Rockefeller Foundation and approved for $35,900 for the period 1995–97.

Capacity building

Postgraduate training

The following students participated in the project:

Dr Adele Ngi-Song. (University of Ghana. PhD degree awarded in 1995). Parasitization of selected African stemborers by *Cotesia flavipes* and *Cotesia sesamiae* with emphasis on host selection and host suitability.

Dr Susan Kimani. (University of Nairobi. PhD degree awarded in 1995). Biosystematics of the *Cotesia flavipes* species complex, parasitioids of gramineous stemborers.

Dr Jacob Mbapila. (University of Dar es Salaam. PhD degree awarded in 1997). Comparative seasonal adaptation of *Cotesia flavipes* and *Cotesia sesamiae* to *Chilo partellus* on the Kenya coast.

Ms Vivian Ofomata. (PhD student, Nnamdi Azikiwe University, Nigeria. Research completed at the end of 1997). Factors involved in the displacement of *Chilo orichalcociliellus* by *Chilo partellus* on the Kenya coast.

Mr M. N. Sallam. (PhD student, Kenyatta University, Kenya. Research to be completed in early 1998). Comparative evaluation of certain aspects of the biology of *Cotesia flavipes* and *Cotesia sesamiae* (Hymenoptera: Braconidae) for the management of *Chilo partellus* (Lepidopera: Pyralidae) in Kenya

Ms Josephine Songa. (PhD student, Kenyatta University, Kenya. Research to be completed at the end of 1999). Temporal dynamics, economic importance and managment of stemborers in maize production systems of eastern Kenya.

Mr Kennedy Ogedah. (MSc student, Kenyatta University, Kenya, Research completed at the end of 1997). Evaluation of the impact of *Cotesia flavipes* Cameron (Hymenoptera: Braconidae) and indigenous parasitoids on stemborer populations in southwestern Kenya.

Mr Moses Ndile. (MSc student, Wageningen Agricultural Univeristy. Research completed in 1997; jointly supervised with Dr Arnold van Huis from Wageningen). A study on maize stemborers in Bukoba District, Tanzania: Species composition, population dynamics and parasitoids.

Ms Marieke Bonhof. (PhD student, Wageningen Agricultural University. Research to be completed in 2000). The impact of native predators on stemborer populations in coastal Kenya

Impact

The project has two objectives; suppression of stemborer densities in Africa through classical biological control, and increasing the capacity of national programmes in Africa to conduct biological control activities. It is premature to assess the biological impact reached under the first objective. An exotic natural enemy has been established and is spreading from several foci on the continent, and its population density has increased each year since release. However, overall levels of parasitism are still low, and are probably having a small, and as yet unquantified, impact on stemborer densities or cereal yields. It is anticipated that the final impact of the introduction will not be known for several more years. Impact with respect to the second objective has been high. Several graduate students have been trained and returned to their national programmes. Many other students from national programmes have received short-term training on stemborer biological control, and have initiated activities in their own countries. The results of the research conducted by the project has been disseminated widely in international journals and in non-refereed popular fora such as newspaper and radio.

V. Use of Wild Habitat in the Management of Cereal Stemborers (FOP-2)

Background, approach and objectives

This project was initiated in April 1994 as part of a novel programme in Africa for controlling stemborers in cereal crops. In view of the crucial importance of the cereal stemborers in reducing yields of maize and sorghum in Africa, in-depth studies are undertaken on the dynamic relationship between the population of stemborers and their natural enemies on wild hosts and cultivated crops.

The main objective of the project was to examine and understand the multiple interactions among cultivated crops, wild hosts, various stemborer species and natural enemies affecting the dynamics of pest populations and their pest status with a view to contributing to an integrated pest management package. The project is being undertaken in different agroecologies in Kenya.

During 1994–1995, the Project undertook studies to understand interactions among cultivated crops, wild hosts, various stemborer species, and natural enemies affecting the dynamics of pest populations. This information is now being used in the development of a sustainable integrated pest management approach through use of wild host and non-host plants.

The project relies on enriching the biodiversity of plants and the pests' natural enemies in and around the cropping environment. In particular, it has been demonstrated that several wild host plants buffer the crop against attacks by some stemborer species, and some plant species of economic importance could be used as 'trap plants' for management of stemborers. Based on the understanding of the volatile semiochemicals employed by the stemborers in locating suitable hosts and avoiding non-hosts, the project is developing a novel pest management approach utilising a 'push-pull' or stimulo-deterrent diversionary strategy. In this habitat management system, which involves combined use of trap and repellent plants, insects are repelled from the main crop, and are simultaneously attracted to a discard or trap crop.

This strategy fits in well with small- to medium-scale farmers in Africa practising mixed agriculture. It should also serve as a model for the management of other pests in Africa and beyond. Recommendations from this project are demonstrated to farmers through on-farm trials conducted in collaboration with the Kenya Agricultural Research Institute (KARI) and Ministry of Agriculture, Livestock Development and Marketing (MOADLM).

Several plants have been identified which, when planted in association with maize, lower the stemborer density. Particularly promising are the Napier grass, *Pennisetum purpureum*, the Sudan grass, *Sorghum vulgare sudanense*, the molasses grass, *Melinis minutiflora* and silverleaf, *Desmodium uncinatum*. Napier grass and Sudan grass are used as trap plants, whereas the molasses grass and the silverleaf repel the ovipositing stemborers. All the four plants are of economic importance to the farmers in eastern Africa as livestock fodder and have shown great potential in borer and striga management in on-farm trials.

Participating scientists: *Z. R. Khan*, W. Lwande, K. Ampong-Nyarko* (*Project Coordinator)

Assistants: *P. Chiliswa, O. Nyapela, G. Asino†, S. Ogechi, J. O. Ogoro†, A. Ndiege* († Died during March 1997)

Donor: *Gatsby Charitable Trust*

Collaborators: • *Kenya Agricultural Research Institute (KARI)* • *Ministry of Agriculture, Livestock Development and Marketing (MOALDM)* • *Government of Kenya* • *Integrated Approach to Crop Research (IACR)-Rothamsted, UK.*

Work in progress

1. ROLE OF THE WILD HABITAT IN THE INVASION OF CEREAL CROPS BY STEMBORERS IN AFRICA WITH SPECIAL REFERENCE TO *CHILO PARTELLUS* AND *BUSSEOLA FUSCA*

1.1 WILD HOST AND STEMBORER SURVEYS

In the *1994 Annual Scientific Report*, we reported the host range of various stemborer species. Since then, significant progress has been made on the knowledge of host range and population dynamics of various stemborers on cereal crops and wild hosts. Thirty-three species of wild hosts belonging to three families—Gramineae, Cyperaceae and Typhaceae were recorded as hosts to one or more stemborer species in various agroecologies (Table 1.1).

1.1.1 *Development of sampling plan*

Based on our destructive sampling survey data, statistically valid sampling plans for cereal stemborers on wild hosts were developed. Such sampling plans will be useful in modelling and ecological research. The number of plant samples required for enumerative and binomial samplings were determined for various wild host plants and stemborer species.

1.1.2 *Distribution patterns of stemborers*

To establish the relationships between wild host plants such as grasses and sedges and the level of stemborer infestation, each of the agroecologies was characterised according to the cropping system used, soil characteristics, and geo-climatic factors such as altitude and rainfall. The greatest diversity of grasses was found in the high altitude area of Trans Nzoia, with *Hyparrhenia rufa* and *H. cymbaria* the most important grasses in the region. At the Kenya coast, where stemborer damage is especially severe, there was the lowest plant diversity, with *Panicum maximum* the most common species. Wild sorghum, *Sorghum versicolor* was the most frequently encountered species at the lakeshore. Baseline data such as this will be used to determine how changes in the relative abundance of wild host species throughout the year affect stemborer infestation levels in the field. A highly significant relationship was found between *B. fusca* infestation in maize and the density of *H. rufa*. Also, for *S. calamistis* there was a highly significant relationship between *P. maximum* and *P. purpureum*. No significant relationship was found between *C. partellus* and *E. saccharina* and any of the alternate hosts.

Table 1.1. Wild hosts of cereal stemborers recorded from various agroecological zones of Kenya

	Insect species						
Plant species	CL	BF	SC	ES	PB	BS	PS
Graminae(Poaceae)							
Andropogon sp.	–	–	++	–	–	–	–
Cenchrus ciliaris L.	++	–	++	–	–	–	–
Coix lacryma-jobi L	++	–	++	–	–	–	–
Dactyloctenium bogdanii S. M. Phillips	++	–	–	–	–	–	–
Echinochloa pyramidalis (Lam.)	++	++	++	–	++	–	–
Echinochloa haploclada (Stapf)	++	–	++	–	–	–	–
Hyparrhenia cymbaria (L.) Stapf	–	++	–	–	–	–	–
Hyparrhenia filipendula (Hochst.) Stapf	++	–	++	–	–	–	–
Hyparrhenia pilgerana C.E. Hubbard	++	++	–	–	–	–	–
Hyparrhenia rufa (Nees) Stapf	++	++	++	–	–	–	–
Panicum deustum Thunb.	++	++	–	–	–	–	–
Panicum maximum Jacq.	++	++	++	++	–	–	–
Pennisetum macrourum Trin.	–	–	–	–	–	–	??
Pennisetum procerum W. G. Clayton	–	–	–	–	–	–	??
Pennisetum purpureum Schumach.	++	++	++	++	–	–	++
Pennisetum trachyphyllum Pilg.	++	++	–	–	–	–	??
Phragmites sp.	++	–	++	++	++	–	–
Rottboellia cochinchinensis W.D. Clayton	++	++	–	++	–	–	–
Setaria inrassata (Hochst.) Hack	++	++	–	–	–	–	–
Setaria sphacelata (Schumach.) Moss	–	++	++	–	–	–	–
Sorghum arundinaceum (Desv.) Stapf	++	++	++	++	–	–	–
Sorghum versicolor Anderss	++	++	++	++	–	–	–
Sorghum vulgare Pers. var. *sudanense*	++	++	++	++	–	–	–
Sporobolus pyramidalis P. Beauv.	–	++	–	–	–	–	–
Sporobolus marginatus auct. Hochst	++	++	–	–	–	–	–
Tripsacum laxum Nash.	–	++	++	–	–	–	–
Vossia spp.	–	–	++	–	–	–	–
Cyperaceae							
Cyperus distans	–	–	++	++	–	??	–
Cyperus immensis	–	–	++	++	–	++	–
Cyperus maculatus	–	–	–	++	–	??	–
Cyperus papyrus L.	–	–	++	++	–	??	–
Typhaceae							
Typha domingensis	–	++	++	–	–	–	–

++, recorded as host; –, not recorded as a host; CL, *Chilo* sp., BF, *Busseola fusca*; CS, *Sesamia calamistis*; ES, *Eldana saccharina*; PB, *Phragmataecia boisduvalii*; BS, *Bactra stagnicolana*; PS, *Poeonoma serrata*.

1.2 BEHAVIOURAL AND PHYSIOLOGICAL RESPONSES OF STEMBORERS ON WILD HOSTS

As part of our effort to demonstrate that wild hosts may or may not be important in population dynamics of stemborers, we have investigated how selected wild gramineous plants commonly present near maize and sorghum fields could support various stages of the establishment of *B. fusca*. Various behavioural and physiological responses involved in the establishment of maize stemborers on selected common African wild grass species were compared to a susceptible maize, a susceptible sorghum, a resistant maize, and a resistant sorghum variety in laboratory and greenhouse tests.

Wild sorghums were preferred over cultivated maize and sorghum for larval orientation and settling. In general, larvae fed better on the wild sorghums, and the efficiency of conversion of ingested food was higher on these wild hosts. In testing these and other parameters such as larval weight, longevity of adults, and ovipositional response, the data show that the wild sorghums are the most suitable for stemborer establishment. Such wild hosts can act as sources for stemborer colonisation on cereal crops, and could be good candidates as trap plants if managed properly.

Hyparrhennia rufa and *P. purpureum*, which were preferred for oviposition, were shown to be less suitable for larval orientation, settling, feeding and development. Hence, these species could be used to suppress insect infestation on cereal crops.

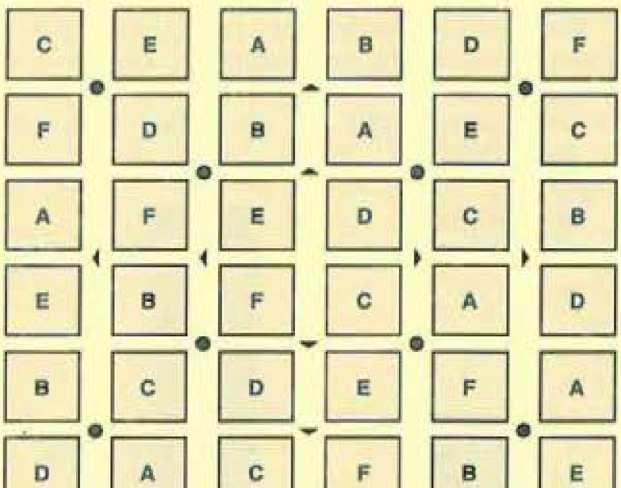
We discovered that different varieties of Napier grass differ in their attractancy to stemborers. Based on various behavioral and physiological responses involved in the establishment of maize stemborers on nine varieties of Napier grass, varieties suitable for stemborer oviposition but unsuitable for their development were selected. These varieties are now used as trap plants to suppress insect infestation on maize crops. One of the selected varieties, Bana Grass (Ex-Kitale), is well adapted to Trans Nzoia and is preferred by farmers as fodder, because of its smooth surface, high tillering and large biomass. Efforts are being made with KARI to multiply Bana Grass on a very large scale to distribute to participating and other interested farmers.

1.3 STEMBORER COLONISATION AND ESTABLISHMENT

Studies on colonisation and establishment of stemborers in different agroecological systems have revealed site-specific trap crop alternatives. To study stemborer colonisation processes on various host plants, field trials incorporating cultivated and selected wild host plants were undertaken in all the three ecological zones. The field plots consisted of 6 x 6 m plots arranged in a six by six quasi-complete latin square design (Figure 1.1). Observations were recorded for ovipositional preference, growth and development and parasitisation levels of stemborers on various host plants. The study revealed interesting aspects of multiple interactions among cultivated plants, wild hosts, various stemborer species and their natural enemies. Several wild hosts, such as *P. purpureum*, *H. rufa*, *Phragmites* sp., have high ovipositional preference, but low survival of stemborers, and were identified as trap plants. Similarly, host plants which have a high ovipositional preference and high survival of stemborers, such as *Sorghum arundinaceum*, *S. versicolor*, *S. vulgare sudanense* were also identified. Plants which also encourage multiplication of natural enemies, can be used as trap plants if managed carefully.

1.4 CONTROL OF STEMBORERS THROUGH TRAP PLANTS

Napier grass and Sudan grass, the two widely used commercial fodder grasses, can provide natural control to stemborers by acting as trap plants for stemborers, and as reservoirs for their natural enemies. Although the stemborers oviposit heavily on the attractive Napier grass, only very few larvae are able to complete their life cycles. Napier grass has its own



Mbita Point
A = Maize (susceptible)
B = Sorghum (susceptible)
C = *Pennisetum purpureum*
D = *Hyparrhenia rufa*
E = *Sorghum versicolor*
F = *Panicum maximum*

KARI, Mombasa
A = Maize (susceptible)
B = Sorghum (susceptible)
C = *Pennisetum purpureum*
D = *Phragmites* sp.
E = *Sorghum arundinaceum*
F = *Panicum maximum*

Field size = 6 x 6 m; plot to plot 2 m

KARI, Kitale
A = Maize (susceptible)
B = Sorghum (susceptible)
C = *Pennisetum purpureum*
D = *Hyparrhenia rufa*
E = *Sorghum versicolor*
F = *Echinochloa pyramidalis*

Field size = 8 x 8 m; plot to plot 2 m

● = *Chilo partellus* pheromone traps
▲ = *Busseola fusca* pheromone traps

Figure 1.1. A six by six quasi-complete latin square design for studying colonisation processes of stemborers on various host plants in a field

Table 1.2. Comparison of stemborer infestation and yield parameters from maize + Napier grass and maize mono field plots, in an on-farm trial, Lambwe Christian School for the Deaf, Suba District 1997+

Parameters	Maize + Napier	Maize mono	Difference
Stemborer infestation (%)	2.34	6.77	4.43*
Ear number	71.0	66.25	4.75 NS
Ear length	97.0	87.0	10.00*
Grain weight	10.4	7.7	2.70*
Percent moisture	19.1	18.6	0.50 NS
Yield (tonnes/hectare)	5.2	3.87	1.33*

+Data from other fields in Suba district could not be collected because of drought.
*Significant at $P < 0.5$; NS, not significant.

natural defence mechanism against crop borers. When the larvae enter the stem, the plant produces a gum-like substance, which causes the death of the pest. Stemborer infestation on maize mono was several times more than on maize crop surrounded by Napier grass or Sudan grass. However, stemborer infestation as well as larval parasitisation on Sudan grass was quite high, suggesting that Sudan grass can reduce stemborer infestation by buffering the crop against stemborer attack.

Sudan grass or Napier grass, when planted around maize fields, can decrease stemborer infestation on maize and can thus increase crop yield (Table 1.2). Planting Sudan grass around maize fields also increased efficiency of natural enemies. As compared

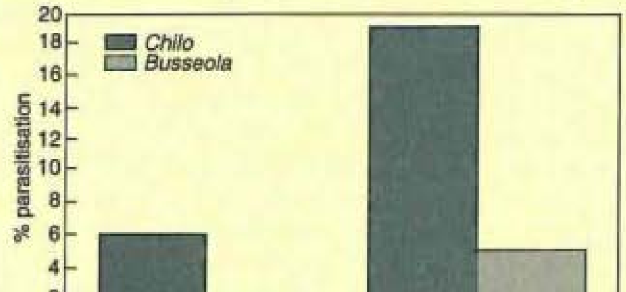


Figure 1.2. Parasitisation of stemborers (Sudan grass–maize experiment)

to the maize field where only 4.8% *Chilo* and 0.5 % *Busseola* larvae were parasitised, 18.9 % *Chilo* and 6.17 % *Busseola* larvae were parasitised in maize + Sudan grass field (Figure 1.2).

1.5 STEMBORER CONTROL THROUGH NON-HOST PLANTS

Intercropping maize with non-traditional hosts and non-host companion plants showed a marked impact in reducing stemborer infestation on maize. Planting maize into an already-established crop of molasses grass, *Melinis minutiflora* and silverleaf, *Desmodium uncinatum* at ICIPE and KARI (Kitale), fields gave dramatic reductions in stemborer incidence (Table 1.3). Studies are underway to determine the density of the non-host plants required to protect maize crops as well as to avoid interspecific competition.

1.6 WILD GRASSES AS REFUGIA FOR NATURAL ENEMIES

Several wild grasses such as *Pennisetum purpureum*, *Echinochloa pyramidalis*, *Panicum* sp., *Cyperus* sp. and *Phragmites* sp., commonly growing near farmers' fields, provide important refugia to natural enemies of stemborers such as *C. flavipes* and *C. sesamiae* after the cereal crops are harvested. Three species of borers, *Bactra stagnicolana*, *Phragmataecia boisduvalii* and

Table 1.3. Effect of intercropping maize with various host and non-host plants on damage by cereal stemborers

Treatment: Host/Non-host plants	Borer density per 10 plants[1]	Percent maize plants damaged
Maize + *Desmodium uncinatum*	0.0 c	11.2 bc
Maize + *Melinis minutiflora*	0.3 c	4.6 c
Maize + tomato	6.0 abc	29.7 a
Maize + cowpea	2.0 bc	24.5 ab
Maize + *Sorghum versicolor*[2]	9.0 ab	39.2 a
Maize monocrop (control)	14.8 a	39.2 a

Means followed by the same letter in each column are not significantly different ($P < 0.05$).
[1]Density of *Chilo partellus*.
[2]*S. versicolor* is a stemborer host.

Table 1.4. Alternative hosts of natural enemies of cereal stemborers present on wild hosts

Parasitoid	Pest	Alternative host	Wild host plants
Cotesia sesamiae	*Chilo partellus* *Busseola fusca*	*Phragmataecia boisduvalii*	*Echinochloa pyramidalis* *Phragmites* spp.
	Chilo partellus *Busseola fusca*	*Poeonoma serrata*	*Pennisetum purpureum* *Pennisetum macrourum*
Cotesia flavipes	*Chilo partellus*	*Bactra stagnicolana*	*Cyperus immensis* *Cyperus distans*

Poeonoma serrata, associated with these perennial wild hosts can be important hosts for *Cotesia* spp. and other natural enemies of crop pests (Table 1.4). These host plants can be very important reservoirs of natural enemies. None of these 'wild' stemborer species infest cereal crops.

1.7 INCREASED PARASITISM BY INTERCROPPING MAIZE WITH MOLASSES GRASS

We reported that molasses grass, *Melinis minutiflora*, when intercropped with maize reduced infestation by stemborers. Surprisingly, intercropping with *M. minutiflora* also increased parasitism particularly by the larval parasitoid, *C. sesamae*, and the pupal parasitoid *Dentichasmis busseolae* (Figure 1.3). The plant releases volatiles that repel stemborers, but attract parasitoids without being damaged. Live plants of *M. minutiflora* and its volatiles were shown to attract *C. sesamae* in Y-tube olfactometer. This study opens up a new and intriguing possibility of using intact plants with inherent ability to release these stimuli. Such plants will have a useful role in ecologically-based crop protection.

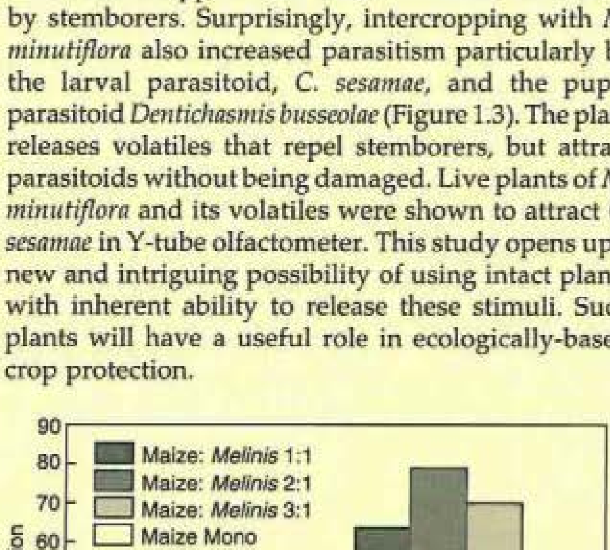


Figure 1.3 Parasitisation of stemborers in maize-*Melinis* intercrop

1.8 CROPPING SYSTEM ALTERNATIVES FOR STEMBORER AND *STRIGA* CONTROL

In a field trial at ICIPE, intercropping maize with silverleaf, *D. uncinatum* and greenleaf, *Desmodium intortum* significantly reduced infestation by *Striga hermonthica* by 40 times. We have reported that intercropping with *D. uncinatum* also reduced stemborer infestation on maize. Development of maize: *D. uncinatum* intercrop will reduce yield loss due to both stemborer and *Striga* and yet improve soil fertility. This farmer-preferable land management approach could replace traditional bush fallow rotation with a non-host nitrogen-fixing legume intercrop for *Striga* management. We are considering *Striga* germination-inhibitory effects of other species of *Desmodium*, and other food and fodder legumes. Efforts are now underway at ICIPE and IACR-Rothamsted to identify the allelochemicals produced by the root systems of *D. uncinatum* and *D. intortum*, which inhibit *Striga* in the soil.

2. GENETIC VARIATION IN STEMBORER POPULATIONS

Studies on isozyme variation in *C. partellus* and *B. fusca* were undertaken in close collaboration with Rothamsted Experimental Station. Data on eight mendelian enzyme loci: *Gluco-oxaloacetate transaminase* (Got), *Hydroxybutrate dehydrogenase* (Hbdh), *Hexokinase* (Hk), *Phosphoglucose isomerase* (Pgm), *Mannose-6-phosphate isomerase* (Mpi), *Glucose-6-phosphate dehydrogenase* (G6pd) and *Isocitrate dehydrogenase* (Idh), suggest that *C. partellus* populations from both Lake Victoria and coastal ecological regions are homogeneous. However, geographical differentiation in this species was evident.

Allele frequencies in *B. fusca* revealed significant geographic differentiation in both Lake Victoria and Trans Nzoia populations, with some fixed Got and G6pd loci. Genetic differentiation in relation to host plant influence was not evident in both *C. partellus* and *B. fusca*, suggesting that there is free movement of borer populations among different host plants within their ecosystems.

3. SEMIOCHEMICALS FROM HOST AND NON-HOST PLANTS

Significant progress has been made in the analysis of airborne volatiles of host and non-host plants, to discover the compounds responsible for attractancy or repellency to stemborers. The volatile oil obtained by hydrodistillation of the molasses grass, *Melinis* *minutiflora* deterred oviposition of *C. partellus*, demonstrating that the volatile semiochemicals play a major role in oviposition deterrence of the grass to stemborers (Table 3.1). Coupled CG-EAG of volatiles of *M. minutiflora* with *C. partellus* and *B. fusca* showed the presence of a number of electrophysiologically active compounds in the sample. Two of the five compounds identified from airborne volatile collections of *M. minutiflora* were electrophysiologically active against *C. partellus* by deterring oviposition. Non-host avoidance in *B. fusca* and *C. partellus* may be mediated by different compounds: α-terpenolene and β-caryophyllene. The repellency of α-terpenolene and β-caryophyllene at low concentrations indicates the potential of these compounds in the development of novel pest control strategies. (E)-β-ocimene, one of the electrophysiologically active compounds identified from *M. minutiflora*, did not deter oviposition of *C. partellus* at the doses tested. Only (E)-β-ocimene and α-terpenolene were found to be the major electrophysiologically active compounds in *M. minutiflora* airborne volatiles for *B. fusca*. Ovipositional bioassays against *B. fusca* are in progress. Significantly more eggs were laid by *C. partellus* on filter paper discs that were treated with eugenol and naphthalene, two electrophysiologically active compounds that were identified from the host plants, maize, sorghum and Napier grass. Nonanal, octanal, naphthalene, 4-allylanisole and eugenol are electrophysiologically active for *B. fusca*. In ovipositional bioassays, eugenol was found to stimulate oviposition by *C. partellus* and *B. fusca*, and in wind tunnel experiments, it was attractive to both *B. fusca* and *C. partellus*.

Table 3.1. Oviposition by *Chilo partellus* on filter paper discs treated with extracts and some of the electrophysiologically active compounds identified from host and non-host plants of stemborers

Test material	Dose (μg/disc)	Total number of eggs laid⁺ Treated	Control	Mean %OP	*P* (paired *t*-test)
M. minutiflora volatile oil	100	18	327	-89.6	0.005
α-terpenolene	100	0	991	-100.0	0.001
	10	35	632	-89.2	0.058
β-caryophyllene	100	0	331	-100.0	0.0001
Eugenol	100	376	96	59.3	0.127
	10	614	370	24.8	0.3103
Naphthalene	10	991	689	18.0	0.543
Ocimene	10	682	545	11.2	0.495

⁺Total from eight replications.

4. ON-FARM TRIALS ON MANAGEMENT OF STEMBORERS AND *STRIGA* THROUGH USE OF WILD HOSTS AND NON-HOST PLANTS

Farmer participatory trials on the management of stemborers and striga weed were initiated during January 1997 in Trans Nzoia and Suba districts of Kenya, supported by a special funding from the Gatsby Charitable Foundation. These trials are undertaken in collaboration with small and medium-scale farmers who are expected to benefit from ICIPE's IPM technologies. The on-farm approach is a highly interactive process, characterised by interdisciplinary, participatory and collaborative approaches. Scientists from Kenya Agricultural Research Institute (KARI) and extension staff from Ministry of Agriculture and Livestock Development (MOALDM) also work very closely with ICIPE scientists in implementing on-farm trials. The on-farm trials were scientist-managed and consisted of 11 farmers in Trans-Nzoia district and seven in Suba district. The farmers were selected through nomination by the farming community.

In Trans Nzoia, the project launched on-farm researcher-managed trials (OFRMT) in 1997 on the use of Napier grass as a method of stemborer control, in which it sought to involve farmers in field research activities. To achieve this, community mobilisation was undertaken with the help of KARI staff, agricultural extension agents and local administrative leaders. Meetings were convened at village levels in four villages. The primary objectives of these meetings were to create awareness on the use of the wild host for management of cereal stemborers and to organise and select farmers for participation in the OFRMTs. Those farmers who attended the meetings were given the criteria to use in selecting candidate participants.

In Suba District, the project launched OFRMT in 1997 on the use of *Desmodium uncinatum* as a method of stemborer and striga control, and the use of Napier grass for stemborer control. Similar selection processes were used to select trial farmers from three divisions of the district. Five farmers participated in the use of *D. uncinatum*, and two in the use of Napier grass.

In Trans Nzoia district, significant increase in maize yield was recorded in maize + Napier grass plots of all participating farmers. Unfortunately, because of the prevailing drought in Suba district during the 1997 long-rain cropping season, no reliable data could be collected except in one location where there was evidence of stemborer reduction and increase in yield (see Table 1.2).

A baseline diagnostic survey (embracing 150 subsistence farmers) in each of the two study areas is also being carried out to obtain a better understanding of socioeconomic circumstances of the farmers. This survey will be completed by December 1997. It is expected to provide the basis for the appropriate design of the farmer-managed trials and for the evaluation of the impact of the technology. Data are also being collected in collaboration with KARI on preliminary economic evaluation of the researcher-managed trials.

Output

Publications

Khan Z. R., Abenes M. L. P. and Fernandez N. J. (1996) Suitability of common graminaceous weed species as host plants for rice leaffolders, *Cnaphalocrocis medinalis* and *Marasmia patnalis*. *Crop Protection* 15, 121–127.

Khan Z. R. and Saxena R. C. (1997) Use of surrogate "stem" for eliciting ovipositional response of *Busseola fusca* (Lepidoptera: Noctuidae). *Journal of Economic Entomology* 90, 1426–1429.

Khan Z. R., Ampong-Nyarko K., Chiliswa P., Hassanali A., Kimani S., Lwande W., Overholt W. A., Pickett J. A., Smart L. E., Wadhams L. J. and Woodcock C. M. (1997) Intercropping increases parasitism of pests. *Nature* (London) 388, 631–632.

Khan Z. R., Chiliswa P., Ampong-Nyarko K., Smart E., Polaszek A., Wandera J. and Mulaa M. A. (1997) Utilisation of wild gramineous plants for management of cereal stemborers in Africa. *Insect Science and Its Application* 17, 143–150.

Conference papers and conferences attended

Chiliswa P., Khan Z. R., Loxdale H. D. and Brookes C. P. (1997) Allozyme variation in tropical cereal stemborers with particular reference to *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) and *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae), pp. 89–102. In *Focus on Agricultural Research for Sustainable Development in a Changing Economic Environment*. Proceedings of the 5th KARI Scientific Conference, 14–16 October 1996, Nairobi, Kenya.

Khan Z. R. (1997) A review of entomological techniques and methods used to determine mechanisms and bases of stemborer resistance in maize, pp. 62–67. In *Insect Resistant Maize: Recent Advances and Utilisation* (Edited by J. A. Mihm) Proceedings of an International Symposim held at the International Maize and Wheat Improvement Centre (CIMMYT), 27 November–3 December 1994 at CIMMYT, Mexico, D. F.

Khan Z. R. International Workshop on the Management of Tropical Gramineous Stemborers, ICIPE, Nairobi, 14–16 May 1996.

Khan Z. R. Annual Meeting of the Entomological Society of America, December 8–12, 1996, Louisville, USA.

Khan Z. R. International Conference on Ecological Agriculture: Towards Sustainable Development, November 15–17, 1997, Chandigarh, India.

Proposals written

Utilisation of Wild Host and Non-Host Plants for Management of Cereal Stemborers in Africa (1996–1998)—Funded by Gatsby Charitable Foundation.

New Integrated Stem Borer and *Striga* Management Systems in Subsistence Maize Farming for Africa' (1998–2001)—Funded by Gatsby Charitable Foundation.

Conservation of Gramineae and Associated Arthropods for Sustainable Agricultural Development in Africa. PDF-Block A. Funded by Global Environment Facility.

Capacity building

Training has been a very strong component of the Gatsby-funded Project. Several MSc and PhD students from different countries have worked or are working under the project.

J. J. Randriamananoro from Madagascar, a student at Rivers State University of Science and Technology, Nigeria, finished his PhD degree. The title of his thesis was 'Behavioural and physiological responses of cereal stalk borer, *Busseola fusca* Fuller (Lepidoptera: Noctuidae) to selected cultivated and wild host plants'.

Nicholas Hutter from UK, a student at the University of Newcastle-upon-Tyne, completed his MSc research project at Mbita Point on ovipositional preference and development of *Chilo partellus* on selected varieties of Napier grass, *P. purpureum*.

Mohamed Hassan Mohamud from Somalia, a student at Kenyatta University, completed his MSc degree on suitability of different wild graminaceous plants for the survival and development of *C. partellus*.

J. Patrick Mbugi from Kenya, is working for his PhD degree on the movement of *C. partellus* and *B. fusca* between cultivated and wild hosts.

Linnet S. Gohole from Kenya will be working for her PhD degree on effects of molasses grass, *M. minutiflora* on parasitisation of cereal stemborers in cereal-based cropping systems.

Muniru K. Tsanuo from Kenya will be working for his PhD degree on *S. hermonthica* seed germination stimulant/inhibitors exuded by roots of selected fodder legumes.

During the on-farm trials, the project also organised several training activities in Trans Nzoia and Suba districts. The main objective was capacity building in terms of knowledge, skills and ability to apply the technology. The training also involved visits to on-station technology trials. The views expressed by the farmers during the training session were taken into account and variations incorporated where appropriate. The following training workshops were undertaken in close collaboration with MOALDM and KARI. Some of the training workshops and exchange of MOALDM staff from the two districts was facilitated to allow exchange of experiences.

1. Workshop for farmers including participating farmers in April 1997 at KARI, Kitale (22 participants).
2. Workshop for extension staff of Trans Nzoia district in May 1997 at KARI, Kitale (30 participants).
3. Combined workshop for extension officers and farmers including participating farmers of Suba district in July 1997 at ICIPE Mbita Point Field Station (MPFS) (33 participants).
4. Combined workshop for secondary school agricultural teachers, area chiefs and district agricultural committee members at MPFS (60 participants).

In addition to the training sessions, field days were also held in each on-farm trial site of Trans Nzoia to give an opportunity to a large cross-section of farmers in the project areas to observe and assess the technology under evaluation. Over 200 farmers from the project sites took part in field days.

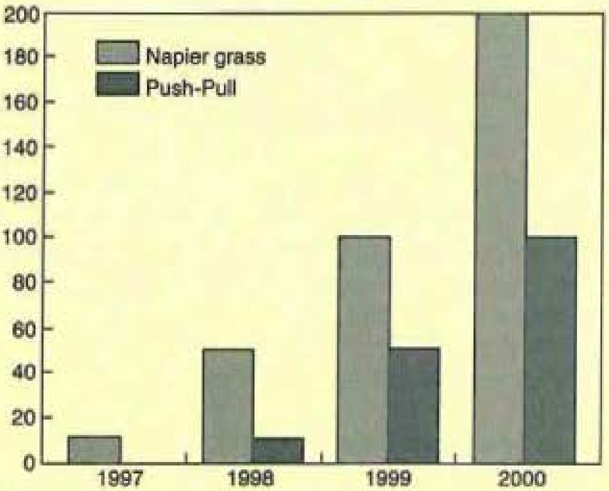
The majority of the farmers interviewed during the field days observed the effectiveness of using Napier grass as a stemborer control method, and indicated their willingness to take part in the farmer-managed trials (FMTs) during the 1998 season. Significantly, the farmers' impact rating of stemborer infestation in on-farm trials are consistent with biological data.

Impact

The Project has demonstrated the benefits of biodiversity of gramineous and leguminous plants in the cultivation of maize and sorghum and their management in order to reduce stemborer infestation and increase parasitisation by natural enemies. The research has provided a better understanding of the relationship between habitat diversity and habitat resilience to pest challenge, as well as scope for habitat modification to contain this challenge.

The proposed strategy of stemborer control, manifests important features which render it distinctively more advantageous than some other methods. In this proposal, the full integration of several crop protection approaches, i.e. trap crops and increased parasitism of pests, prevents high selection pressure on any single approach, thereby creating a sustainable system by obviating rapid development of resistance/ adaptation by pests, which is a feature common to single control measure, e.g. pesticides or genetically-based resistance.

The scaling up of the technology will involve both application of the technology in larger areas within the farm, as well as extension of the present on-farm trials to larger number of farms. Scaling up within the farm will involve scientist-managed trials in small pieces of land in the first year, farmer-managed trials on larger pieces of land (at least half of the maize area) in the second year, to application of the technology possibly to all the maize planted on the farm. For example, all the 10 farmers who participated in 1997 on-farm trials are interested in expanding the technology to more than half of the maize area in 1998. Similarly, the new farmers to be recruited in 1998 are expected to scale up the technology in 1999 and 2000 (see figure below).



Planned number of participating farmers using single component intervention based on Napier grass and fully-integrated push-pull strategy during years 1997 and 2000 in Trans Nzoia

5. SOCIOECONOMIC ASPECT OF UTILISING WILD HOST PLANTS FOR THE MANAGEMENT OF STEMBORERS IN AFRICA

Background, approach and objectives

The biological aspect of this project which has been under implementation in Trans Nzoia and Suba Districts aims *inter-alia* to investigate interactions between cultural crops and wild hosts of stemborers with a view to contributing to integrated pest management. The Social Sciences Department has been participating in the research project since early 1997.

The objectives of the research are to generate diagnostic information relating to the problem of stemborers, to develop a farmer participatory approach of technology evaluation, and to undertake socioeconomic assessment of the appropriateness of stemborer management by the use of wild host plants.

Participating scientists: *Z. R. Khan*, F. G. Kiros, Principal Investigator (*Project Leader)*

Assistant: *O. Nyapela*

Donor: *Gatsby Charitable Foundation*

Collaborators: *• Kenya Agricultural Research Institute (KARI) • Ministry of Agriculture, Livestock Development and Marketing (MOALDM)*

Work in progress

5.1 SOCIOECONOMIC DIAGNOSTIC SURVEY

A diagnostic survey methodology was designed in early 1997 and a questionnaire prepared for interview of randomly selected household heads, stratified by gender as well as farming communities. A total of 151 farmers were interviewed (Table 5.1). The data obtained by the interviews included information on household size and composition, land use and production, farming practices, pest problems, livestock production and various related factors. The data are currently being analysed with assistance of the Biostatistics Unit.

Table 5.1. Households interviewed in Trans Nzoia District

Community	No. of farmers Male	Female	Total
Yuya	53	26	79
Kiminini	8	5	13
Wamuini	36	4	40
Kisauni	16	3	19
Total	113	38	151

5.2 SELECTING PARTICIPATING FARMERS

A number of criteria were used for the selection of farmers for participation in the on-farm researcher-managed trials. The main criteria were: (a) total land size owned; (b) size of land offered for trials; (c) farmer's willingness to participate in the project; (d) number of heads of cattle owned; (e) production of Napier grass; and (f) the extent of stemborer problem faced.

Based on household data collected relating to these criteria, and by means of farmer participation, 50 farms were selected for the on-farm trials. Additionally, a total of 27 farmers were identified to participate in the technology evaluation process. The field trials have been completed and the analyses of the results are in the final stage of completion.

5.3 SOCIOECONOMIC EVALUATION OF TECHNOLOGY

Two types of evaluations were undertaken in 1997. The first was based on farmers' observations and perceptions of the on-going trials, and the second was an economic evaluation, based on data collected from researchers'-managed trials.

Preliminary results of farmers' evaluation indicate overwhelming interest in the project. About 95% of the farmers interviewed expressed their desire to participate in on-farm trials in 1998.

Farm input and output data were collected in collaboration with a KARI staff member, under the supervision of the principal investigator. Data analysis has been in progress, and a final report is expected from the KARI collaborator during the early part of 1998.

Capacity building

Several training activities were conducted for farmers and the extension staff. Initially, the emphasis of the training was to increase awareness and facilitate participation and collaboration. The training activities then focused on the methods of technology application and evaluation. The training activities have contributed significantly to stimulating interest and active participation by farmers and the collaborating institutions.

Output

Proposals written

A major project proposal has been prepared for research during 1998–2000. The proposal is entitled 'A Harvest of Biodiversity: Socio-Economic Evaluation of the Use of Fodder Plants in an Integrated Strategy of Stemborer Control and Livestock Management in Maize-Based Cropping System'. The objectives of the proposed research *inter-alia* include evaluation of farmers' managed trials and the potential for adoption and sustainability of the IPM technologies. The continuation of the socioeconomic research in Trans Nzoia District will critically depend on a grant in support of the proposed project.

VI. Understanding the Mechanisms of Maize Streak Virus Resistance of Maize Lines from Kenya, East and Southern Africa

Background, approach and objectives

Breeding projects in Nigeria, South Africa, Zimbabwe, Reunion and elsewhere have resulted in the selection of germplasm with a high degree of resistance to the maize streak virus (MSV). However, it continues to be a problem with many smallscale farmers. This project was initiated in October 1996 to address the MSV problem. ICIPE's role in the collaborative project is to study the vector's epidemiology, which is of major importance to disease spread.

Several studies were conducted to examine the spatial and temporal dynamics of *Cicadulina* species and maize streak virus in various ecologies in Kenya. Species composition was studied by sampling 10 project sites across Kenya. Long distance and local dispersal of leafhoppers were examined using yellow sticky traps and by successively planting to evaluate the spread of MSV from one crop to another. Alternate wild breeding hosts and their influence on MSV epidemics in maize were identified.

One objective is to understand the mechanism of resistance to MSV disease using maize germplasm from various sources. Additionally, the project will investigate the biology of MSV and its leafhopper vectors (*Cicadulina*) with a view to understanding the uneven spread of MSV disease in nearly uniform susceptible maize types grown in different agroecological zones of Kenya.

Participating scientists: *K. Ampong-Nyarko*, M. O. Odindo, Z. R. Khan, W. A. Overholt *(Project leader)*

Assistants: *M. Kithokoi, J. Obilo, D. Ojalla*

Donor: *Rockefeller Foundation*

Collaborators: *• Kenya Agricultural Research Institute (KARI) • John Innes Centre, UK • University of Cape Town, South Africa • International Service for the Acquisition of Agri Biotechnology Application (ISAAA)*

Work in progress

1. **UNDERSTANDING MSV VECTOR EPIDEMIOLOGY**

1.1 DISTRIBUTION AND COMPOSITION OF *CICADULINA* SPP.

Cicadulina species composition was studied by sampling ten project sites across Kenya twice during the maize growing season. The study has shown that MSV often occurs with maize dwarf mosaic virus (transmitted by the aphid *Rhapolosiphon maidis*), maize mosaic virus and maize stripe virus (both transmitted by *Peregrinus maidis*).

1.2 MONITORING OF *CICADULINA* SPP. POPULATIONS

Stationary yellow sticky traps mounted on poles using pulley mechanisms (called MPFS Pylon Trap) to hoist the sticky traps at 1-m intervals up to 12 m high, were deployed at Mbita Point Field Station, together with a malaise trap. The objectives of these studies were to monitor *Cicadulina* populations, determine the direction of flight and establish the importance of migration in MSV epidemiology. There is a general trend of decrease in number of leafhoppers caught over this period, probably due to changes in population or activity following some changes in weather parameters, such as rainfall.

Cicadulina chinai was the predominant species caught. The malaise trap was more efficient in catching *Cicadulina* up to 2 m above ground. It caught 238 *Cicadulina* compared with 37 from the yellow sticky trap over an 11 week period. The possibility of the 12-m high sticky trap intercepting migrating leafhoppers is yet to be demonstrated. The trap catches at each level will be correlated with the driving environmental variables after a full year trapping data has been accumulated and species identified.

1.3 SUCCESSION PLANTINGS OF IRRIGATED MAIZE

Maize H-511 was planted either as a monocrop or as a maize + cowpea intercrop in single alternate row arrangement at Mbita Point Field Station at three weekly intervals throughout the year. The first crop was planted on 14 April and it is in its 12th planting. This study was undertaken in part to determine the role in leafhopper epidemiology of source of infestation and local movement. There were four replications with plot size of 6 x 7 m. MSV diseased plants were counted weekly until tasselling.

As expected, the number of diseased plants increased from first planting until it reached a peak of 18.8 and 23.3% in maize mono and maize intercrop, respectively in the third crop, but rapidly declined after the third planting. A succession of plantings of maize may, therefore, not be a cause in increased streak infection in later plantings as has been earlier thought.

1.4 ALTERNATE BREEDING HOST OF *CICADULINA* SPP.

Sampling was carried out on the Gatsby wild host nursery *(See the previous project V report)* for establishing alternate breeding hosts of *Cicadulina*. Nymphs were recorded on *Setaria sphacelata* var *splendida*, *Echinochloa pyramidalis* (Lam), *Hyparrhenia rufa* (Ness) Staph, *Setaria incrassata* (Hochst.) Hack, and *Sorghum vulgare* Pers. var. Sudanese (Table 1.1).

1.5 RELATIONSHIP BETWEEN INVASION OF MAIZE AND ALTERNATIVE HOSTS

From maize fields surrounded by *Setaria*, Sudan grass, napier grass and maize in monocrop, counts were made and the spatial distribution of MSV-infected plants determined at 2 week intervals starting from the third week after planting. Spatial distribution of MSV infected plants and percent infestation in maize field surrounded by *Setaria sphacelata* was assessed at 2 week intervals from fixed quadrats in the second cropping season of 1997/98. The presence of the alternate host *Setaria sphacelata* did not increase MSV infestation compared to the maize crop without *S. sphacelata*. MSV infestation appeared to be randomly distributed.

1.6 EFFICIENCY OF TRANSMISSION OF VECTORS FROM DIFFERENT AGROECOLOGIES AND HOSTS

Efficiency of transmission of MSV by viruliferous *Cicadulina* from different ecologies and hosts, was initiated in 1997 using standard acquisition testing procedures. Each species was replicated 30 times. The indication is that species from different ecologies may differ in their transmission efficiency (Table 1.2).

Table 1.1. Alternate breeding hosts of *Cicadulina* spp.

Plant species	Presence/ absence of *Cicadulina* nymphs
Andropogon sp.	-
Cenchrus ciliaris L.	+
Coix lacryma-jobi L.	-
Dactloctenium bogdanai S. M. Philips	-
Echinochloa pyramidalis (Lam.)	+
Echinochloa haplociada (Stapf.)	-
Hyparrhenia cymbaria (L.) Stapf.	-
Hyparrhenia filipendula (Hochst.)	-
Hyparrhenia pilgerana C. E. Hubbard	-
Hyparrhenia rufa (Ness) Staph	+
Panicum deustum Thumb	-
Panicum maximum Jacq.	-
Pennisetum macrourum Trin.	-
Pennisetum orocerum W. G. Clayton	-
Pennisetum purpureum Schumach	-
Pennisetum trachphyllum Pilg.	-
Rottboellia cochinchinensis W. G. Clayton	-
Setaria incrassata (Hochst.) Hack	+
Setaria sphacelata var *splendida*	+
Sorghum arundinaceum (Desv.) Staph	-
Sorghum versicolor Anderss	-
Sorghum vulgare Pers. var. Sudanese	+
Sporobolus pyramidalis P. Beauv	-
Sporobolus marginatus auct. Fochst	-
Tripsacum laxum Nash	-
Vossia cupidata	-
Cyperus distans	-
Cyperus immensis	-
Cyperus maculatus	-
Cyperus papyrus L.	-
Typha domingensis	-
Phragmitis sp.	+

- Not recorded, + Nymphs recorded.

Table 1.2. Efficiency of MSV transmission by *Cicadulina* species from different ecologies

Leafhopper species	Ecology collected	Percent transmission
C. storeyi	Oyugis	70.0
C. storeyi	Mbita, *Pilgerana* host	30.0
C. mbila	Kitale	33.3
C. mbila	Mbita, Maize	53.3

2. REARING OF *CICADULINA* SPP.

The Kenya Agricultural Research Institute (KARI), Muguga, already has a *Cicadulina* rearing facility originally organised by Dr H. H. Storey nearly 60 years ago. A single colony of *C. mbila* has been maintained since. New insect rearing facilities were organised and successfully established at ICIPE's MPFS to rear type cultures of five species occurring in Kenya for virus transmission studies. The initial populations of leafhoppers were sampled from various wild as well as cultivated hosts. Single female leafhoppers were transferred to fresh cages, each insect in a cage. Eggs laid by each female were allowed to develop to nymphs, which were then transferred to a larger cage (50 x 50 x 70 cm). Hence, leafhoppers within each cage were offsprings of a single female. These pure single species formed starter cultures for each species. Pearl millet, *Pennisetum typhoides* was used for rearing the *Cicadulina*.

Output

Project proposals

Phase 2 (1999–2001) of the project at a higher funding level has been submitted to the Rockefeller Foundation.

Capacity building

The project organised a workshop from 24[th] to 28[th] November 1997 at ICIPE for KARI and ICIPE scientists on the project. This training workshop provided instruction on modern DNA diagnostic techniques, such as DNA extraction, PCR-DNA amplification and visualisation of DNA products for plants and insects so that the scientists would be better equipped for future activities.

VII. Sustainable Management of Insect Pests and Tsetse in Coastal Kenya: Kwale-Kilifi Adaptive Research Project—Crops Pests Component

Background, approach and objectives

In coastal Kenya, insect pests are a major constraint to food production. Stemborers on cereals and a range of insect pests on cowpeas cause substantial production losses and smallholder farmers do not have affordable means of minimising the pest damage. ICIPE was requested by the Kenya Agricultural Research Institute (KARI) to undertake the implementation role for the KKARP (Kwale-Kilifi Adaptive Research Project), involving the evaluation and demonstration of improved methods of management of major pests on maize, sorghum and cowpea in Kwale and Kilifi Districts of the Coast Province. The project also included tsetse trapping and socioeconomic components. ICIPE handed over the project to KARI upon completion of its role in late 1995.

The main approach was to test the scope for identifying locally adapted pest-tolerant genotypes/ cultivars as an inexpensive means of reducing the losses caused by pests. Additionally, early intercropping of cowpeas as a means of reducing stemborer severity in sorghum and maize was evaluated. Back-up testing of these components was undertaken at two sites: Mtwapa (KARI Research Centre) in Kilifi and Muhaka (ICIPE Research Station) in Kwale District. Farmer groups in two sites—Shimba Hills (high potential zone, Kwale District) and Vitengeni (medium potential zone, Kilifi District)—were mainly involved in the participatory activities, while limited activities were also undertaken with farmers in Kinango, a low potential zone in Kwale District.

The objectives were:

(i) to identify pest control technology options acceptable to and adoptable by smallholder farmers for reducing yield losses on food crops.

(ii) to build the capacity of KARI to conduct long term research in integrated pest management (IPM).

Participating scientists: *ICIPE: S. Sithanantham (Team Leader/ Coordinator), A. Oendo (Social Scientist); KARI: M. Kiarie (Entomologist), G. M. Kamau (Agronomist), B. Muli (Agronomist), E. Wekesa (Social Scientist), E. N. Wambugu (Lab. Technologist)*

Assistants: *G. Jira, G. Ambajo, D. Karuri, P. Mnyambu, J. Owuor, P. Kijana*

Donors: *UNDP, GoK*

Collaborators: *• Ministry of Agriculture—Kwale/ Kilifi Districts, Kenya • Farmers Groups— Shimba Hills and Kinango (Kwale), Vitengeni (Kilifi)*

Work in progress

1. FARMER-PARTICIPATORY IPM DEVELOPMENT

The activities in 1995 were focused on assessing the on-farm performance and farmers' attitudes towards the adoption of promising technologies. Efforts were also made to understand farmers' indigenous pest control, besides assessing the response of non-participating (neighbouring) farmers to the technologies being tested. The major results and their implications are discussed in the following sections:

1.1 ON-FARM ASSESSMENT OF YIELD BENEFIT OF PEST-TOLERANT CROP GENOTYPES

Two pest-tolerant maize genotypes (IC92M4, IC92M5) tested at three sites showed an overall yield advantage range of 12–21% over the check (Pwani Hybrid) (Figure 1.1). The yield benefit for the two pest-tolerant sorghum genotypes (Gaddam, ICS3) over the local check (Serena) was in the range of 8–16% from tests at two sites (Figure 1.2). These results demonstrated the potential for improving the yield under farmers' own management by shifting to the pest-tolerant varieties.

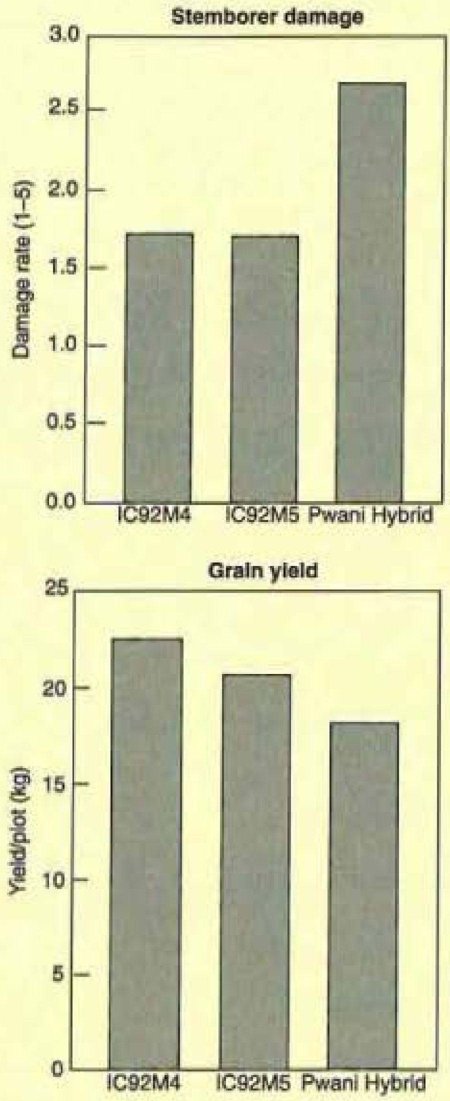


Figure 1.1. Stemborer damage severity and grain yield of maize genotypes under farmers' management, 1995 long rainy season

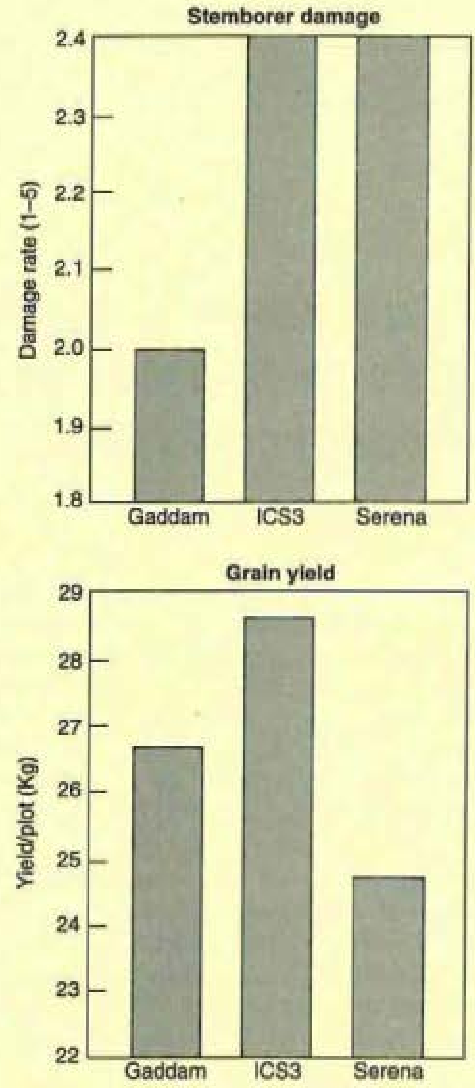


Figure 1.2. Stemborer damage severity and grain yield of sorghum genotypes under farmers management, 1995 long rainy season

1.2 FARMERS' RELATIVE RANKING OF PEST-TOLERANT GENOTYPES FOR FUTURE ADOPTION

Field days were conducted during harvest of the on-farm trial plots and the individual opinion of the participating farmers was assembled by recording the relative ranking preference for future adoption (Table 1.1). There was an overall greater preference ranking for growing of the pest tolerant genotypes, compared to the local checks. Apparently, the participating farmers were interested in shifting to the improved genotypes on the basis of their own appreciation of the potential yield benefits.

Table 1.1. Overall relative ranking by participating farmers among promising pest-tolerant genotypes for future adoption: Opinion survey, Jul–Aug 1995

		Number of farmers ranking as		
Crop	Genotype	Rank 1	Rank 2	Rank 3
Maize	IC92M4	22	5	0
	IC92M5	4	21	0
	Pwani Hybrid (Check)	0	1	8
Sorghum	Gaddam	13	7	6
	ICS3	15	14	4
	Serena (Check)	4	7	7
Cowpea	ICV3	11	4	2
	ICV11	9	13	0
	ICV12	4	8	11
	K.80+ (Check)	6	3	12

+Weighted estimate (extended from one site information).

Table 1.2. Participating farmers' attitudes to future adoption of pest resistant genotypes: Opinion survey among participating farmers, July 1995

	Number of farmers responding (%)			
	Shimba Hills (13)	Vitengeni (14)	Kinango (6)	Total (33)
Aspect				
Maize genotypes:				
Deciding to grow the pest tolerant genotypes on their own	13 (100)	14 (100)	6 (100)	33 (100)
Already cooked and tasted the chosen genotypes	13 (100)	12 (86)	5 (83)	30 (91)
Sorghum genotypes:				
Deciding to grow the pest tolerant genotypes on their own	13 (100)	14 (100)	5 (83)	32 (97)
Already cooked and tasted the chosen genotypes	13 (100)	9 (64)	5 (83)	27 (82)
Cowpea genotypes:				
Deciding to grow the pest tolerant genotypes on their own	13 (100)	14 (100)	6 (100)	33 (100)
Already cooked and tasted the chosen genotypes	13 (100)	12 (86)	6 (100)	31 (94)
Overall awareness/attitude				
Knowing the need to replace the seeds after every 3 seasons	9 (69)	10 (71)	2 (33)	21 (64)
Proposing to produce own seeds through local groups	13 (100)	14 (100)	5 (83)	32 (97)
Proposing to also buy from private seed producers if locally available	11 (85)	5 (36)	2 (33)	18 (55)
Proposing to preserve part of the harvest for planting in next year	12 (92)	14 (100)	6 (100)	32 (97)
Proposing to exchange seeds for grains and not divert seeds for food during food shortage	11 (85)	14 (100)	5 (83)	30 (91)
Confident of storing seeds for next season without insect damage	11 (85)	12 (86)	6 (100)	29 (88)

1.3 PARTICIPATING FARMERS' ATTITUDES TOWARDS THE ADOPTION OF PROMISING GENOTYPES

In an opinion survey conducted by the project in conjunction with the extensionists, it was observed that most or all the participating farmers had decided to grow the improved genotypes (of their choice) and had cooked and tasted them (Table 1.2). Most of them expressed interest to either purchase or locally produce and conserve the seeds with a view to growing the improved genotypes in the subsequent seasons.

1.4 RESPONSE OF NON-PARTICIPATING FARMERS TO THE TECHNOLOGIES BEING TESTED/ADOPTED BY PARTICIPATING FARMERS

A pilot survey was conducted among randomly chosen non-participating farmers in the testing sites in Kwale (74) and Kilifi (49) Districts, through individual interviews using questionnaire methodology (Table 1.3). It was found that a substantial proportion of them were aware of the technologies being tested. Some of them had also initiated voluntary evaluation of the technologies. Apparently, there was significant information flow within the community about the technologies between those who participated and their neighbours, to the extent that a few of the non-participating farmers were motivated to undertake testing in their fields voluntarily.

1.5 UNDERSTANDING FARMERS' INDIGENOUS PEST CONTROL KNOWLEDGE

A survey was also undertaken to understand the available local knowledge on locally practised pest control methods on agricultural crops among the participating farmers at the three sites. The results (Tables 1.4, 1.5) showed that parts of several local plants, especially neem, were known to be useful for crop pest control, including the maize stemborer. Other materials regarded as useful included ash, salt and paraffin, among others. This knowledge may be useful in future, for facilitating and validating the value of alternative local pest control practices.

Table 1.3. Diffusion of awareness and adoption/testing among non-participating farmers: A pilot assessment, Sept–Oct 1995

		Percent non-participating farmers reported				
		Pest tolerant genotypes			Intercropping	
Site	Number of participant farmers reporting	Aware	Voluntarily adopting/ testing	Awaiting seeds to test/ adopt	Aware	Voluntarily adopting/ testing
Shimba Hills	20	83	32	51	72	26
Vitengeni	20	82	42	40	64	18
Kinango	12	22	15	7	16	12
Overall	52	62	30	32	51	19

Table 1.4. Use of common plants for insect pest control as recognised by farmers, Kwale District. Survey of April–June, 1995

Plant (part)	Crop/target pest	% Farmers reporting Shimba Hills	% Farmers reporting Kinango	Details of use
Neem (seeds)	Maize stalkborer	96	80	0.5 kg seeds/ ground and soaked in water (15 l)
	Maize armyworm	23	0	0.5 kg seeds/ ground and soaked in water (15 l)
	Sorghum stalkborer	43	60	0.5 kg seeds/ ground and soaked in water (15 l)
	Sorghum armyworm	43	–	0.5 kg seeds/ ground and soaked in water (15 l)
	Sorghum shootfly	22	–	0.5 kg seeds/ ground and soaked in water (15 l)
	Cowpea aphids	52	10	0.5 kg seeds/ ground and soaked in water (15 l)
	Cowpea beetles	52	40	0.5 kg seeds/ ground and soaked in water (15 l)
	Kale aphid	4	–	0.5 kg seeds/ ground and soaked in water (15 l)
	Cabbage aphid	9	–	0.5 kg seeds/ ground and soaked in water (15 l)
	Cabbage grasshopper	4	–	0.5 kg seeds/ ground and soaked in water (15 l)
Neem (leaves)	Maize stalkborer	96	70	Leaves pounded, mixed in water
	Maize armyworm	23	–	Leaves pounded, mixed in water
	Sorghum stalkborer	43	60	Leaves pounded, mixed in water
	Sorghum armyworm	4	–	Leaves pounded, mixed in water
	Sorghum shootfly	22	–	Leaves pounded, mixed in water
	Cowpea aphid	52	–	Leaves pounded, mixed in water
	Cowpea beetles	52	10	Leaves pounded, mixed in water
	Kale aphid	9	–	Leaves pounded, mixed in water
	Cabbage grasshopper	4	–	Leaves pounded, mixed in water
	Maize weevils	–	10	Dry powder dusted
	Sorghum weevils	–	10	Dry powder dusted
Tobacco (leaves)	Maize stalkborer	–	22	20 leaves in 15 litres of water
	Maize armyworm	–	9	20 leaves in 15 litres of water
	Sorghum stalkborer	–	13	20 leaves in 15 litres of water
	Sorghum shootfly	–	4	20 leaves in 15 litres of water
	Sorghum aphids	–	9	20 leaves in 15 litres of water
Redpepper (fruits)	Maize stalkborer	–	4	Pounded and mixed with water

2. ON-STATION TESTING OF THE SUSCEPTIBILITY OF THE GRAINS TO STORAGE PESTS

Laboratory assessments were made of the relative susceptibility of the promising pest-tolerant genotypes to storage pests in collaboration with the KARI/ODA project (Dr Graham Farrel). Samples of grains from on-station trial plots were initially disinfested by fumigation and infested with storage pests under uniform conditions. The grains were sun-dried to bring the initial grain moisture level to about 12%. The grains were kept in plastic jars at 500 g each and replicated 4 times. Into each jar, 10 pairs of adults of selected postharvest pests were released and left undisturbed for 3 months. At the end, the number of adults found alive/dead were counted for each jar, as well as recording the difference in initial and final grain weight, and estimating the extent of loss in grain weight across the treatments.

In maize, the population of the maize weevil (*Sitophilus zeamais*) ranged from 545 to 912 in grains of the pest-tolerant genotypes, compared to 406–1091 among the check cultivars (Table 2.1). Among the

Table 1.5. Other indigenous materials/practices used in pest control, Kwale District, April-June 1995 survey

Material/practice	Crop/target pests (% farmers reporting)
Ash (as dust)	Maize stalkborer (74-100) Armyworm (30) Sorghum shootfly (17) Stalkborer (48) Aphids (57) Cowpea beetles (20-87) Aphids (87) Podsuckers (4) Kale aphids (4) Cabbage aphid (9) Stored grain: Maize (52) Sorghum (52) Cowpea (52)
Sand	Maize stalkborer (10-13) (into whorls) Sorghum stalkborer (10-13), Shootfly (9) Coconut rhinoceros beetle (17)
Cowdung (slurry)	Maize armyworm (20) Sorghum armyworm (20)
Paraffin (mix for stored seeds)	Maize weevils (30) Sorghum weevils (30)
Smoking (harvested cobs)	Maize weevils (90)

Table 2.1. Susceptibility of maize stemborer-tolerant genotypes to the maize weevil, *Sitophilus zeamais* in a laboratory study, Mtwapa 1995+

Maize genotype	Percent seeds infested	Number of weevils developed+ (per 500 seeds)	Seed weight loss %
Test entries:			
IC92-M1	89.7	571	34.9
IC92-M2	89.7	545	27.3
IC92-M3	92.0	702	26.4
IC92-M4	95.0	912	34.1
IC92-M5	85.3	641	20.5
Checks:			
Coast Composite	88.3	595	19.9
Pwani Hybrid	99.3	1091	54.6
Mdzihana	91.3	406	20.5
Mean	91.0	68.9	29.8
CV%	10.3	51.5	38.0
LSD (0.05)	15.8	593.4	19.1

+Mean of 4 replications.

promising genotypes, it was evident that IC92M4 tended to support a higher infestation than others. In terms of overall loss in grain weight, all the improved genotypes suffered significantly less loss than at least one of the checks (Pwani Hybrid).

In sorghum, the susceptibility of the improved genotypes to the maize weevil was found to be less than among the local cultivars (Table 2.2). The range in numbers of adult weevils that developed per jar over the storage period was 711–972 for the improved genotypes as against 703–1421 among the check cultivars. The respective range in grain weight loss was 34–47 and 48–58%.

In similar tests, promising pest-tolerant cowpea grain genotypes against the bruchid *Callosobruchus* sp., ICV12 was least susceptible among the improved genotypes. This genotype was on par with K.80, but much less susceptible than the other check (Local) (Table 2.3).

Table 2.2. Susceptibility of promising stemborer-tolerant sorghum genotypes to the storage weevil, *Sitophilus zeamais* in a laboratory study, Mtwapa, 1995+

Sorghum	Percent seed infested	Number of weevils developed+ (per 500 seeds)	Seed weight loss %
Test entries:			
Gaddam	86.7	711	34.1
ICS3	98.7	972	47.0
ICS4	92.3	823	42.1
Checks:			
Serena	98.3	1089	57.6
KAT	93.3	1421	56.3
Kacherina	98.3	703	47.9
Mean	94.6	954.1	47.5
CV%	9.3	59.0	38.6
LSD (0.05)	15.2	970.2	31.6

+Mean of 4 replications.

Table 2.3. Extent of susceptibility of grains of cowpea genotype to the storage bruchid. Laboratory study, Mtwapa, 1995 (4 months)

Cowpea genotype	Percent seeds infested	Number of bruchids developed+ (per 500 seeds)	Seed weight loss %
Test entries:			
ICV3	9.0	117	6.8
ICV11	67.0	74	19.8
ICV12	6.3	24	6.4
Check:			
K.80	6.3	20	6.0
Local	74.3	320	19.1
Mean	32.6	243.3	11.6
CV %	54.4	92.3	32.0
LSD (0.05)	31.03	393.3	6.51

+Mean of 4 replications.

The overall indications obtained in these trials were conveyed to the extensionists so as to alert farmers to take adequate precautions in storage of grains of the improved genotypes, which appeared to be not tolerant to the infestation by the storage pests concerned.

3. TRANSFER OF IMPLEMENTATION ROLE TO THE NATIONAL PROGRAMME

Upon completion of the joint implementation phase, ICIPE transferred the role of follow up activities to the national programme (KARI). The research-extension-farmer-linkage model developed in this project was commended by the Government of Kenya as highly successful.

To ensure a continued access to the seeds of improved genotypes that were tested in this project, ICIPE handed over the seeds of the cultivars (and their parents as appropriate) to the concerned scientists of KARI.

Based on the experience gained from the project activities including on-farm evaluations, a technology bulletin for extensionists was developed by ICIPE and KARI scientists.

Output

Publications

Odindo M. O., Nour A. M., Ajala S.O., Kiros F. G., Chitere P. O., Ampong-Nyarko K., Mohamed Ali M. A. and Ngalo Z. O. (1997) Integration of *Bacillus thuringiensis* with elite sorghum and maize genotypes to enhance productivity of small-scale farms in the coastal region of Kenya, pp. 144–153. In *Integrating Biological Control and Host Plant Resistance*. Proceedings of a CTA/IAR/IIBC Seminar, Addis Ababa, Ethiopia 9–14 October 1995. CTA Publication, The Netherlands.

Sithanantham S., Kamau G. M., Wekesa E. and Kiarie M. (Compilers) (1996) *Improved Insect Pest Management for Maize, Sorghum and Cowpea Production in Coastal Kenya. Technology Handbook for Extensionists*. ICIPE Science Press, Nairobi. 12 pp.

Wambugu E. N., Farrel G. and Sithanantham S. (1996) Evaluation of susceptibility of grains of some stalk borer tolerant maize and sorghum genotypes to maize weevil and larger grain borer, pp. 88–93. In *Crop Protection for Resource Poor Farmers in Kenya*. Proceedings KARI/ODA Crop Protection Conference, Nairobi, Kenya 27–28 March, 1996. KARI/ODA.

Conferences/ Seminars attended

Participated in the Research Advisory committee meeting and presented activities of the project, May 1995 (Mombasa).

Participated and presented a paper at the KARI/ ODA Crop Protection Conference Nairobi, Kenya, 1996.

Capacity building

Two KARI scientists (one breeder and one entomologist) were trained for the PhD under the ARPPIS programme in IPM-related research areas as follows:

Mr Kiarie Mwangi Kega, Kenyatta University. (In progress) Incorporation of stemborer resistance in maize genotypes along with streak virus resistance in maize.

Dr J.J. Randriamanoro, Rivers State University of Science and Technology, Nigeria. PhD awarded in 1996. Evaluation of neem for control of storage pests on maize.

Impact

- The project was recognised as a model for research-extension-farmer-linkage by the Government of Kenya.
- *Ex-ante* adoption studies indicated positive response from participating farmers as well as neighbouring farmers.

(See Report XIII under Animal Health Management for the ticks component of this project.)

VIII. Interactive Socioeconomic Research for Biointensive Pest Management (ISERIPM)

Background, approach and objectives

The ISERIPM project is an interdisciplinary, collaborative and participatory adaptive IPM research project which has been under implementation in Kenya since 1993 under the coordination of the ICIPE Social Sciences Department. The primary objectives of the project are to undertake adaptive and evaluative research on pest management technologies pertaining to selected staple food crops and livestock; and to develop interactive socioeconomic interface methodologies for crop and livestock pest management.

The project has two major components, (i) crop pests management, primarily stemborer management on maize and sorghum, which is implemented in the Coast Province; and (ii) livestock ticks management, implemented on Rusinga Island. This report pertains to the crop pests component. The report on the livestock ticks component is included under the Ticks Megaproject (Report XIII).

The main technological elements of crop pests management evaluated include pest-tolerant maize and sorghum cultivars, cultural practices (especially intercropping and strip cropping), and biological control with the application of *Bacillus thuringiensis*.

The core research activities were the following:

- Phase 1 (1993): On-station technology trials and evaluation by farmers.
- Phase 2 (1994): On-farm researcher-managed trials and evaluation by farmers.
- Phase 3 (1995): Farmer-managed trials.
- Phase 4 (1996): Farmer-managed trials based on technology modifications to enhance efficacy and profitability, and on-station verification trials in other parts of Kenya.
- Phase 5 (1997): Promotion of technology adoption and sustainability.

Integrated within each phase of the project are biological and socioeconomic studies, and GIS activities related to technology adaptation and evaluation processes. The socioeconomic studies were designed not only to ensure the effective adaptation of the technologies, but also to contribute to the development of interactive research methodologies involving multidisciplinary, participatory and collaborative approaches.

The implementation of the project during 1996/1997 necessitated revision of the earlier planned activities. This was due to funding constraints and the fact that the planned cooperative research with the African Highlands Initiative did not materialise.

The main research activities carried out during 1995–1997 were focused on the evaluation and modification of the promising technologies, assessment of the potential of adoption and sustainability, and capacity-building of farmers and extension staff in the management of the technologies.

Participating scientists: *F. G. Kiros* P. Chitere (Sociologist), Field Coordinator (1995); K. Ampong-Nyarko, Agroecologist; A. Odulaja, Biostatistician; S. Sithanantham, Entomologist (1994–1996); G. T. Lako (1995) (*Project Leader)*

Assistants: *P. E. Ragama, G. O. G. Nyambane, P. N. Kizito, Biostatistics (1996), H. Meena, Biostatistics (1995), B. A. Omolo, O. Nyapela, O. O. Okello, Biostatistics (1995), G. Nengo, S. Oluoch, N. Dibogo, M. Mungai*

Donor: *Rockefeller Foundation*

Collaborators: *• Kenya Agricultural Research Institute (KARI) • Ministry of Agriculture Livestock Development and Marketing (MOALDM) • Provincial Administration • Farmers*

Work in progress

1. TECHNOLOGY EVALUATION BY RESEARCHERS AND FARMERS

1.1 ECONOMIC EVALUATION OF FARMERS' MANAGED TRIALS

The collection and analysis of economic data was given particular attention during the farmer-managed trials of 1995. The main reason for this emphasis is the fact that during this phase, IPM options were selected by the farmers themselves for implementation under their own management. Hence, the economic results of these trials are of particular interest as they reflect the initial stage of technology adoption.

The alternative technology trials consisted of those specified below:

1.1.1 *Maize trials treatment*

(i) Researcher-recommended technology:
   1. Cultivar ICZ-5 or IC92-M5;
   2. Strip relay cropping:
      • 2 rows of cowpea (ICV2)
      • 4 rows of maize (ICZ-5 or IC92-M5)
      • 3 rows of cassava;
   3. *Bt*.

(ii) Farmers' practice—Practice with his/her own cultivar, cropping pattern and method of insect pest control.

(iii) Researcher-recommended technology as modified by farmers:
   1. Maize cultivar ICZ-5 or IC92-M5 or Coast Composite;
   2. Strip relay cropping (modifications on row-ratios of different crops, spacing, time of planting cowpea/legume variety);
   3. *Bt* (choice to buy for application).
   4. Neem.

1.1.2 *Sorghum trials treatments*

(i) Researcher-recommended technology
   1. Sorghum cultivar Gaddam El Hammam or DRIV-1;
   2. Strip relay cropping:
      • 2 rows of cowpea (ICV2)
      • 4 rows of sorghum(Gaddam El Hammam or DRIV-1)
      • 3 rows of cassava;
   3. *Bt*;
   4. Neem.

(ii) Farmers' Practice—Practice with his/her own cultivar, cropping pattern and method of insect pest control.

The main inputs, including maize, sorghum and cowpea cultivars, cassava cuttings, *Bt* and neem powder were provided to the farmers free of charge. It was assumed that this would encourage them to undertake as many of the trials as possible. Land and labour for the trials were provided by the farmers. The farmers allocated an average of 0.125 hectares of land for the researcher-recommended trials based on maize and sorghum.

However, due principally to the low rainfall which prevailed particularly in Kilifi District, only 77 farmers out of the expected 100 carried out most of the trials and these only during the long-rains period. No trials were undertaken during the short-rains period due to the almost total failure of the rains at the research sites.

Detailed economic data were collected in 1995 from a representative sample of 50 farmers covering the different research villages. In 1996, data were entered into a Lotus 123 worksheet and analysed using SAS.

1.1.3 *The analytical model*

The main objective for undertaking the economic analysis of the farmer-managed IPM technology trials was to determine whether the new technology or intervention is economically viable from the farmers' point of view. In other words, do the new technologies result in increased benefits to farmers or not, given the variable costs that they have to incur? (It is assumed that farmers will be concerned about the costs and benefits of any technology recommended for adoption.)

Given the above assumption, this study is based on the application of two tools of economic analysis, i.e. *the partial budget* and *marginal analyses*. The choice of these techniques does not obviously preclude the use of others.

The *partial budget analysis* enables comparison of the costs and benefits which result from the planned change in the cropping system with those of the existing practice. In other words, the tool enables us to establish the net benefits (NB) of the various practices in the trials. To obtain these, the total variable costs (TVC) are to be subtracted from the gross benefits (GB).

Thus, NB = GB - TVC

where GB = gross benefits (quantity of crop harvested times the farm-gate price at harvest time);

TVC = total variable costs incurred; and

NB = the net benefits obtained.

Marginal analysis essentially entails the calculation of the marginal rate of return (MRR), which is an economic rate of return on the extra unit of money invested in the new technology or experiment. As mentioned earlier, farmers are more likely to adopt a technology which yields the greatest benefit or highest MRR and not any other.

The MRR is calculated by dividing the marginal net benefits (i.e. the change in net benefits) by the marginal cost (i.e. the change in the marginal cost), expressed as a percentage.

Thus,

$$MRR = \frac{NB_N - NB_O}{TVC_N - TVC_O} \times 100$$

Where, MRR = the marginal rate of return of practice N compared to practice O;

NB_N = the net benefits of practice N;
NB_O = the net benefits of practice O;
TVC_N = the total variable costs of practice N; and
TVC_O = the total variable costs of practice O.

The researcher-recommended practice on maize and sorghum and the companion crops (cassava and cowpea) resulted in higher average yields compared to farmers' own practice on these crops (Table 1.1). In terms of total gross benefits, the researchers-recommended practice on both maize and sorghum also yielded higher returns compared to the farmers' own practice on these crops.

Average input costs and average cost of labour have in both cases been higher for the researcher-recommended practices for maize and sorghum as compared to the farmers' own practices for the same. This is likely, because of the fact that farmers did not apply *Bt* in their fields in all cases and they also did not apply neem in the case of their sorghum-based fields.

In terms of net benefits, the researcher-recommended practices on maize resulted in higher net benefits than the farmers' practice. It should be noted that two of the Kilifi villages, Pingilikani and Lutsangani were adversely affected by very low rainfall and farmers in these villages tended to pay more attention to their own practices than the experimental ones.

As in the case of maize, the researcher-recommended sorghum practices had higher total

Table 1.1. Results of partial budget analysis for the various practices in all the villages for the whole sample—1995

	FPM	RRPM	FPS	RRPS
Average yield kg/ha				
Maize	750.41	860.89	13.33	0
Sorghum	0	0	186.43	250.34
Cassava	3379.41	8076.65	1553.51	5171.36
Cowpea	1.89	15.97	0	7.89
Average gross benefits Kshs/ha				
Maize (@ 11.00 Kshs/kg)	8254.51	9469.79	146.63	0
Sorghum (@ 25.00 Kshs/kg)	0	0	4660.75	6258.5
Cassava (@ 2.14 Kshs/kg)	7231.94	17284.03	3324.51	11066.71
Cowpea (@ 26.50 Kshs/kg)	50.09	423.21	0	209.09
Total (Kshs/ha)	15536.54	27177.03	8131.89	17534.3
Average input costs Kshs/ha				
Maize seeds	473.03	439.07	59.89	0
Sorghum seeds	0	0	197.6	240.74
Cassava cuttings	1332.3	1905.44	1047.65	1527.67
Cowpea seeds	37.19	332.7	22.66	226.34
Bt. applied	0	882.2	0	870.49
Neem applied	232.2	2832.99	0	2402.72
Total (Kshs/ha)	2074.72	6392.4	1327.8	5312.96
Average cost of labour (Kshs/ha)				
Land preparation	1955.88	1995.88	1452.95	1886.76
Planting	2284.38	2822.44	1638.49	2304.32
Weeding	3269.96	4018.58	2677.05	3352.9
Thinning	0	230.17	50.07	455.04
Bt application	0	411.42	0	371.37
Neem application	34.29	695.45	0	648.94
Harvesting	370.57	565.78	204.78	332.52
Total (Kshs/ha)	7915.08	10739.72	6023.34	9351.85
Total variable costs (Kshs/ha)	9989.8	17132.12	7351.14	14664.81
Net benefits (Kshs/ha)	5546.74	10044.91	780.75	2869.49

FPM — Farmers' own practice on maize.
RRPM — Researchers-recommended practice on maize.
FPS — Farmers' own practice on sorghum.
RRPS — Researchers-recommended practice on sorghum.
0 entries — Activity not carried out and hence no cost incurred nor yield obtained.

variable costs compared to the farmers' practices, but again researchers-practice yielded higher net benefits in all, except the two Kilifi villages referred to above. The results also show that in all the Kwale villages, farmers lost money on their sorghum-based practice. The reason appears to be that these farmers did not intercrop sorghum with cowpea and cassava. It should also be recognised that birds, which are a major pest of sorghum in the area, consumed much of the crop. Bird damage of sorghum was also high in the researchers-recommended practice in Kilifi villages.

It is worth noting at this point that farmers who intercropped cassava and cowpea with maize or sorghum tended to realise greater benefits than those who did not intercrop.

Considering the maize based trials, the marginal rate of return for farmers who applied the researchers-recommended practice was found to be 0.63 or 63% . This means that for every shilling (Kshs 1) per hectare that the farmer invested in his/her farm using the researchers-recommended practice as compared to the situation in the farmers' practice, he/she obtained net benefits of Kshs 0.63 over and above the Kshs 1 invested.

The MRR for the sorghum-based trials was similarly calculated and gave a figure of 0.29 or 29%, which is less profitable for farmers than the maize-based practice.

1.1.4 *Concluding remarks*

The results need to be further scrutinised based on the analysis of the yields and input costs on the different trials in the various villages. It is, however, still possible to make some general observations based on the overall results:

(a) In general, it appears that the researcher-recommended IPM technologies offer greater opportunity for increased benefits in spite of their higher costs than the farmers' practices;
(b) The gross benefits from cassava on the researcher-recommended trials significantly exceeded those from maize and sorghum. However, the relatively higher benefits of cassava do not necessarily mean that the benefits from maize and sorghum are insignificant;
(c) The average yields and variable costs differed between the two Districts; the yield differences are seen to be largely due to environmental factors, which would need to be further analysed.
(d) The average yields and variable costs were also found to vary among the trials within each District; it appears that differences in management practices account for much of the variations. There is need to look into the specific factors which account for the variations.

1.2 EVALUATION OF IPM TECHNOLOGIES BY FARMERS

A survey was conducted to obtain information on the farmers' evaluation of the IPM technologies. Most of the participating farmers were interviewed based on a questionnaire designed to capture their views of the various technology components. The main results of the survey are summarised below.

1.2.1 *Preferences for maize and sorghum cultivars*

Maize cultivars

About 53% of respondents indicated that they preferred ICZ5 maize variety, while about 47% said that M-5 was their preference. The farmers who expressed preference for the recommended maize cultivars gave different reasons, viz: early maturity (94.4%), high yield (73.0%), pest resistance (14.6%), drought resistance (5.6%) and marketability (3.4%).

The reasons given by the majority of the farmers who indicated no preference of the recommended maize cultivars were that the cultivars require a lot of fertiliser (27.0%), are not tolerant to drought (14.6%), require a lot of rain (11.2%), are susceptible to insect pest attack (7.9%) and are easily attacked by birds (3.4%).

It is noteworthy that a large number of the farmers do not appear to readily associate the high yields observed to pest tolerance.

Sorghum cultivars

The sorghum cultivar planted by most of the farmers was Gaddam El Hammam. The reasons given for preferring this cultivar were its high yield (45.5%), pest tolerance (6.1%) and good colour (6.1%). Again, it appears that the farmers do not readily associate high yield with pest tolerance.

Those who did not prefer the cultivar said that this was due primarily to its susceptibility to both bird attack (45.5%) and insect pest infestation (18.3%).

1.2.2 *Preferences for researcher-recommended cropping pattern*

About 40% of the respondents indicated that they preferred the original researcher-recommended practices (1995), because they resulted in high yields and, according to 19.7% of the respondents, these practices also controlled pests better. A very small number of the respondents (3.6%) indicated that they preferred the researcher-modified practices (1996) because they resulted in high yields. Some farmers did not prefer the researcher-modified practices because labour intensive (25.2%) and do not allow ox-ploughing (5.4%).

1.2.3 *Perceptions of the effectiveness of* Bt (Bacillus thuringiensis) *in controlling pests*

Farmers were asked to evaluate the effectiveness of *Bt* in controlling insect pests. The proportion of farmers who indicated that *Bt* was effective was 37.1%, very effective 29.2%, effective (5.6%) and ineffective (2.2%). A large number of the respondents (68.5%) indicated that they did not encounter problems when preparing and applying *Bt*, a few (3.4%) indicated that its application was labour intensive, some (1.1%) indicated that lack of sugar and ability to remember calibrations were problems faced during preparation.

About 65% of the respondents indicated that they were prepared to buy and use *Bt* in the future. The farmers were willing to spend total amounts ranging between Kenya Shillings 20 and 700 (Kshs 60=US$1) for *Bt*. A few could not afford *Bt* (10.1%) and a small number preferred to use neem instead of *Bt* (2.2%).

1.2.4 *Perception of the effectiveness of neem in controlling insect pests*

The results of the survey of farmers' perception of the effectiveness of neem in controlling insect pests showed a range: effective (14.6%), very effective (6.7%) and fairly effective (1.1%).

The evaluation of neem in the control of cowpea pests was as follows: fairly effective (37.1%), effective (20.2%), ineffective (15.7%) and very effective (3.4%).

About 60% of the respondents indicated that they did not encounter problems in preparing and applying neem. However, disagreeable choking smell (10.1%), difficulty in pounding (7.8%) and mixing with saw dust (1.1%), were reported as posing problems during the preparation by the rest of farmers. Problems encountered during application were: blocking of the sprayer (4.4%), lack of sprayer (3.4%) and the ineffectiveness of applying neem using a broom (1.1%).

About 61% of the respondents were willing to buy and make use of neem in the future, and indicated that they were willing to spend total amounts ranging between Kenya Shillings 20 and 150 (Kshs 60=US$1) for this input. The respondents who were not willing to buy neem indicated that they had their own neem (7.9%), that neem was not effective (6.7%) or that they lacked money (4.5%).

1.3 OVERALL EVALUATION OF THE PROJECT BENEFIT

About 90% of the farmers indicated that they benefited from the ISERIPM Project. They indicated that they benefited from the education and the use of insect pest control measures, including stemborers, other farming techniques (33.7%), use of ICIPE's early maturing cultivars (33.7%), and use of *Bt* and neem (6.9%).

Asked for their suggestions on how to improve the IPM technologies, about 27% suggested the continuation of farmer-training, 16% the provision of 'soft loans' to purchase ox-ploughs, and about 7% the extension of the benefits of the technologies to other farmers. Most farmers had no suggestions to offer.

It should however be stressed that based on their experiences during the on-farm trials and evaluation of the results (1995), the farmers have introduced numerous modifications to the recommended technologies (1996), not all of which have been documented. In many cases, the modifications introduced were changes in companion crops, spacing of plants, reduction of the number of rows of some plants and increasing those of the others, and crop protection measures. A better understanding of the reasons for the particular modifications would require detailed investigation. There is, however, little doubt that the modifications have been made in response to food and cash requirements of each farming household, limitations of resource endowments such as land, labour and other factors, as well as environmental considerations.

1.3.1 *Evaluation of IPM technologies by collaborators*

In accordance with the project's objective of collaboration between the project team, KARI researchers and MOALDM's extensionists, a consultative meeting was held at ICIPE's Muhaka Field Station following the farmer-managed trials (1995). The meeting was attended by 12 MOALDM's extensionists located in the ISERIPM project sites, 1 KARI researcher and 2 participating farmers' representatives. The collaborators were briefed by the project's field team of progress made in the implementation of the project and problems that had been experienced.

The observations made by the consultative meeting on the farmers-managed trials were: (a) too narrow spacing of crops in the trials which is incompatible with the MOALDM's recommendations; (b) farmers' inability to afford inputs such as fertilisers; (c) need for further research to help establish the efficiency of neem in controlling the target pests; (d) need to involve more farmers of the project villages in growing sorghum in order to minimise the effect of bird damage of the crop on the household level; (e) sorghum not being a common staple of the Kenyan Coast, need to carry out demonstrations of food preparation for the benefit of the farm families; and (f) the need in collaboration with KARI and the MOALDM to investigate a suitable mode of production and distribution of *Bt*.

The biological and social scientists endeavoured to take certain steps and introduce some modifications to the technologies, in response to some of these observations as well as the farmers' evaluations.

2. PROMOTION OF TECHNOLOGY ADOPTION AND SUSTAINABILITY

2.1 CAPACITY-BUILDING ACTIVITIES

2.1.1 *Farmers' leaders' workshop*

This workshop was held in 1995 by the project team at the District Training Centre, Matuga. The workshop was aimed at training a group of leaders from among the participating farmers who would provide a link between the project team, MOALDM's staff and other farmers, and help in the promotion and sustainment of the IPM technologies. It was attended by 24 participating farmers who were chosen by the rest of the farmers on the basis of their leadership capability and their effective management of the on-farm trials. The training was coordinated by the project team assisted by some staff of MOALDM and KARI collaborators, as well as 3 trainers from the University of Nairobi and Kenya Institute of Management. The contents of the training were in the form of presentations and discussions by resource persons on topics which included: (a) agriculture at the Kenyan coast with emphasis on insect pest problems; (b) leadership in farm organisations; (c) importance of farm organisations in small-scale farming; and (d) project management with emphasis on farm resources, their uses and constraints.

2.1.2 *Training of farmers on community organisation*

A follow-up training workshop was conducted in 1996. It was specifically designed to increase farmers' understanding of the role that can be played by community organisations in technology promotion, and the need for identifying or forming such organisations by participating farmers. The workshop was attended by about 30 representatives of farmers' as well as women's groups and divisional and frontline extension officers.

The focus of the workshop was the lecture by Prof. Fassil G. Kiros on 'Formation and functions of community organisations', which addressed the following aspects: (a) need for community organisations; (b) characteristics of organisations; (c) functions of organisations; (d) setting goals; (e) division of labour; (f) planning activities; (g) supervision of work; and (h) need for participatory management and decision-making.

Dr Kwesi Ampong-Nyarko, the agroecologist on the research team also gave a presentation on the 'Methods of seed production, storage and distribution'.

The participants in groups discussed alternative approaches of community organisations, constraints to community organisations and suggestions for overcoming them, and specific ways of collaboration between the community and the extension services.

At the conclusion of the training workshop, the participants resolved either to identify existing community organisations or to form new ones in their respective villages. Particular frontline extension agents were then identified and assigned responsibility for follow-up on the collaboration of ICIPE's field assistants, to ensure that this is achieved by mid-October 1996. The organisations would then begin the implementation of the functions proposed by the consultative group.

2.1.3 *Community organisations identified or created in the various villages*

In accordance with the resolution reached during the training workshop, community organisations were identified or created in all eight participating villages (Table 2.1).

Table 2.1. Community organisation in different districts and villages

District/Village	Community Organisation
Kwale	
Mamba	Mawazo Women Group
Makambani	Mwakoyo B Group
Mwalewa	Mwangaza Wa ICIPE Group
Tsuini	ICIPE Hatua Group
Kilifi	
Silala	Tushauriane Youth Group
Pingilikani	Pingilikani ICIPE Self-Help Group
Lutsangani	Bahati ICIPE Self-Help Group
Tandia	Hika-Hika Group

These organisations initiated the planning of their communal activities in 1996 and were fully operational in 1997.

2.1.4 *Training of subject-matter specialists*

The training of subject-matter specialists was organised in response to the suggestion of the ISERIPM Consultative and Planning Committee (which includes as members, ICIPE's research staff, KARI and MOALDM officials). Ten participants were identified for the training in consultation with the local MOALDM and KARI officials. The trainees included district crops officers, district and divisional extension coordinators and farm management officers from both Kwale and Kilifi Districts.

The training led by Dr Ampong-Nyarko covered the following topics: (a) Use and abuse of pesticides; (b) IPM technology, benefits and constraints to adoption; and (c) Components of the ISERIPM technology, application and sustainability. Following the lectures and discussions, the participants took part in field demonstrations where they observed the application of technologies by farmers and exchanged views with them.

2.1.5 *Field days*

With collaboration of MOALDM's frontline extension agents and staff of the Provincial Administration, four field days (one at each site—Jego, Mrima, Pingilikani and Sokoke) were held during the long rains, 1995 season. The field days were aimed at creating awareness among non-participating farmers both within and outside the project sites, about IPM technologies being adapted in the ISERIPM project. The participants included both men and women farmers. At Mrima site a number of pupils from a neighbouring primary school attended the field day.

2.1.6 *Educational visit of participatory farmers to ICIPE's other field stations*

At the request of the farmers themselves, a visit to various on-going research projects was organised for the ISERIPM participating farmers in 1996. The educational visit aimed to encourage farmer-to-farmer interaction and sharing of experiences, and stimulate greater interest in ICIPE's research activities and technology adoption. The farmers' representatives from Kwale and Kilifi Districts accompanied by frontline extension agents from the two Districts visited research activities in both on-station and on-farm sites. They visited Mbita Point Field Station (MPFS), Rusinga Island, Lambwe Valley and Oyugis. At MPFS, scientists demonstrated the vegetable IPM research project. The farmers familiarised with the neem awareness project activities, biological control of ticks using chickens, the project on community-managed tsetse trapping by the KISABE farmers' group in Lambwe Valley and were also briefed on the Oyugis-based banana research project activities.

As a result of the five-day visit, the ISERIPM farmers resolved to continue exchanging ideas with their counterparts in western Kenya and to establish community-managed working groups such as the one they visited in Lambwe Valley.

2.2 PROMOTION OF TECHNOLOGY TRANSFER

The ISERIPM Consultative and Planning Committee had decided in 1996 that the extension staff should take more leadership responsibility to promote adoption and sustainability, that farmers should from 1997 pay for inputs at production cost, and that they should be encouraged and supported to produce by themselves the pest resistant varieties of maize and sorghum seeds, which had been introduced to them. One of the principal activities in 1997 was, therefore, to enable farmers' organisations already created, to undertake seed multiplication and evaluate their performance. Farmers were given training on the methods of seed production in 1996 and were expected to carry out this task during the 1997 long rains season.

The research team visited all the participating villages of Kwale and Kilifi Districts during the onset of the main season in 1997 in order to ensure that adequate preparations were being made by farmers. These included the identification of suitable sites for seed multiplication and organising for land preparation and other field activities. During the visits, it was found necessary to provide further advice to farmers in performing these tasks and additional guidance on the need for quality control in seed production.

As decided by the Consultative and Planning Committee, the farmers were also reminded that they would need to agree to pay the cost of seeds and other inputs provided. This was intended to encourage the farmers to be self-reliant.

Arrangements were then made for MOALDM extension agents, assisted by ICIPE field staff, to continue to monitor closely the activities of the farmers and to provide advice as needed.

A second monitoring visit of the various communities was made in July 1997. The primary purpose of this visit was to ensure that the seed multiplication activities were being carried out and to evaluate the performance of the farmers' organisations in managing seed multiplication and their potential for the promotion of adoption of the technologies. Indeed, it was found that the leaders of the farmers' organisations were with few exceptions doing an outstanding job in managing the seed multiplication plots. It was clear that with some support from the extension services, the farmers' organisations offer much promise toward the promotion of the effective application and sustainability of the technologies in their respective communities. A significant indicator of the success of the farmers was that they were able to achieve satisfactory harvests and to pay the cost of seeds advanced to them.

The results of the monitoring visits were reported to the Consultative and Planning Committee which concluded that the IPM technologies were ready for wide diffusion in Kwale and Kilifi Districts. It, therefore, decided that the MOALDM in 1997 should conduct demonstrations in all 8 divisions of the two Districts with the assistance of ICIPE staff. The Committee further decided that:

- Demonstration plots be organised on farmers' fields;
- the Ministry assign extension staff to plan and manage the demonstrations;
- the Project supply maize seeds, *Bt* and fertiliser for the demonstrations;
- the Extension staff ensure that land and labour are provided by farmers; and
- a training workshop to familiarise the IPM technologies to divisional extension staff be planned and carried out by ICIPE in collaboration with the Ministry and KARI, and those trained be made responsible for training frontline extension agents.

Final arrangements were made by the close of 1997 for technology demonstrations to be carried out by MOALDM extension staff in 80 locations in all 8 divisions of Kwale and Kilifi during the main season of 1998. This stage marks a significant achievement of the collaborative approach of technology adaptation and promotion.

3. STUDY OF PATTERNS OF ADOPTION OF TECHNOLOGIES

Individual farm households were allowed to adopt the technology, if need be, with their own modifications as they saw fit. A survey was then carried out (1997) based on questionnaire interviews to monitor and document the farmers' chosen practices. The following is a report of the main results of interviews of 112 farmers.

3.1 PRACTICES ON MAIZE-BASED PLOTS

About 23% of respondents planted pure stand maize; only 15% used the original researcher-recommended practice, while the others varied both rows of maize and type of intercrops. Reasons for modifying the researcher-recommended practice reported were that the practice required relatively more seed (9.2%), respondents did not need additional cassava as they had enough (2.8%), had labour shortage (11.9%), and various other reasons (about 13%). However, a large proportion (about 63%) gave no particular reasons for modifying the recommended practices.

Asked whether the respondents would continue using the IPM technologies, about 80% answered in the affirmative. Among the reasons given were to control insect pests (24%), increase yields (24%), and the advantage of planting on the same piece of land twice (11%). About 20% who answered in the negative indicated as a primary reason that the practice was labour intensive (about 17%) and others gave a variety of other reasons. About 19% of (21) respondents planted okra as an intercrop because of its expected high yield and early maturity (61.9%), marketability (9.5%), control of insect pests and increased yields (9.5%) and for other reasons (9.5%).

3.1.1 *Use of* Bt

About 78% of the respondents used *Bt*. About 84% of the respondents said they would continue using *Bt* in subsequent seasons, because it controls insect pests, resulting in increased yield (82.6%). The main reasons for not using *Bt* given were that there was too much rain (16.5%), low pest infestation (22.0%), it is labour intensive, and it may not be available in the market. (12.8%) Not a single respondent applied neem to his/her crop, because it was not readily available for use.

3.1.2 *Plant spacing*

About 86% of the respondents used 75 cm inter-row spacing. Reasons for not using the recommended spacing were that it was too narrow for the traditional ox plough planting and weeding (8.3%), and for various other reasons (6.5%). About 64% of the respondents indicated they would continue using inter-row spacing of 75 cm and 34% said they would not.

About 45% of the respondents said they would continue using intra-row spacing of 32 cm while 55% said they would not. The reasons for not using the spacing were that it results in congested plants (35.8%), makes planting and weeding by ox plough difficult (12.8%) and for other reasons (4.6%).

3.2 PRACTICES ON SORGHUM-BASED PLOTS

About 21% of respondents planted pure stand sorghum, and only about 5% followed the original researchers-recommended practice.

Reasons given for modifying the researchers-recommended practice were lack of seed (10.5%), and others (10.5%). However, about 89% said they would use the recommended practice during the subsequent season, the main reason expected being better insect pest control and hence high yield (52.6%). Those who said they would discontinue sorghum-based IPM technology (11%) gave as their main reasons that it was labour intensive (5.3%) and that birds damage the crop (5.3%).

3.2.1 *Plant spacing*

About 27% reported that they used intra-row spacing of 32 cm in planting sorghum, two-thirds of these indicating that the spacing resulted in congested plants. The same proportion indicated that they would continue using 32 cm intra-row spacing, because it gives optimum yield. About 93% of respondents used inter-row spacing of 75 cm and the same number said they would continue using this spacing during the subsequent season.

Very few respondents planted cassava in sorghum-based plots, the reasons being that they lacked cassava cuttings (42%), that they had enough cassava (16%), that the crop is eaten by wild animals (16%). However, 89% of the respondents said they would in future continue planting cassava in sorghum-based plots. About 47.4% felt that cassava does help control insect pests, 31.6% that it has high yield, 5.3% that it is resistant to drought and the rest giving no explanation.

3.2.2 *Use of* Bt

Only 26.3% applied *Bt* on their sorghum crop, the others did not due to too much rain (15.8%), and low pest infestation (42.1%). About 95% would in future continue using *Bt* on sorghum, because according to them it controls insect pests and increases yield.

Respondents did not use neem on the sorghum crop, about 21% indicating that it was not effective, 36.8% that it was not available locally, 10.5% that it is made ineffective by too much rain, 5.3% that it was labour intensive, and 15.8% for other reasons. However, about 58% reported they would in future use neem on sorghum.

3.3 CONCLUDING REMARKS

The findings of the 1997 survey indicate that the pattern of initial adoption of the IPM technologies varied between the farmers reflecting the differences in household circumstances and changing agro-ecological factors. However, many of the farmers indicated their intention to continue making use of the different technology components in spite of the various problems and constraints identified by them during the 1997 season. Clearly, the challenge for the extension services would be to take advantage of the expressed receptivity of the farmers and endeavour to facilitate adoption and sustainability, specifically by overcoming some of the constraints encountered by them.

4. FARMERS' MANAGED TRIALS

Background

The components of the ICIPE technology variously contributed to reduced stemborer infestation and increased yield in the 1994 on-farm scientist-managed trials. Strip relay cropping reduced borer infestation, increased multiple cropping index and land use intensity. Sorghum Hyd-6 and maize ICZ5 were tolerant to the stemborers. *Bt* gave significant reductions in insect infestations.

Two types of farmers-managed trials were carried out in 1995 and 1996. The 1995 trials consisted of the scientists' recommended practices resulting from the 1993/94 technology evaluation. The 1996 trials were designed to incorporate technology modifications by farmers as well as the scientists. In addition to the farmers' trials, on-station back-up testing of technological components was carried out. The results of these trials are presented.

4.1 FARMERS' MANAGED TRIALS OF RECOMMENDED PRACTICES

The 1995 on-farm farmer managed trial was a straight comparison of ICIPE's technology with current farmer practice under a wide range of farmers' conditions. Farmers were also encouraged to modify the ICIPE technology (cropping pattern, cultivar, *Bt*/neem application) on a third plot for maize trials. Farmer management was included as a variable in monitoring the focus on socioeconomic aspects. Plot size was 25 x 25 m, large enough for farmers to compare the demands made by the new technology with their usual practice. Neem extract (10%) was introduced as part of the ICIPE technology for the control of multiple pests in cowpea. The treatment details were presented earlier.

About 90 farmers were involved in the study. Each farmer was expected to have experiments for both maize and sorghum. The experiments were planted between 30 March and 30 April 1995 in Kwale District, and between 19 April and 1 June 1995 in Kilifi District. Late planting, combined with erratic rainfall during crop growth, adversely affected crop yield. It also meant that most of the second cowpea crop could not be planted. The mean plant damage due to stemborers in maize was 16% in the farmers control compared to 4% in the ICIPE technology in Kwale and 10 and 5% respectively in Kilifi.

4.2 MODIFIED TECHNOLOGY TRIALS

On-farm trials were conducted in 1996 to modify IPM components based on the experiences of 1995, to enable a fine tuning of recommendations. The specific objective were:

(a) To introduce technological options for the control of the main pests of maize, sorghum and cowpea; and
(b) To improve efficacy, profitability and sustainability of IPM technologies by introducing different companion crops.

Without initiating another cycle of on-station testing, farmers were encouraged to modify the technologies. This was a straight comparison of researchers-recommended technology that had been tested in the previous two years with current farmer practice under a wide range of farmers' conditions. Farmers were encouraged to modify the technology (cropping pattern, cultivar, *Bt*/neem application) on their own plot for maize trials. The average plot size was 25 x 25 m.

As part of farmer modification of technology, farmers were encouraged to plant companion crops of their choice, instead of cassava and cowpea used in earlier years. Farmers also made their own decisions on plant spacing of their crops and they had the option to use either neem or *Bt* for stemborers protection in their maize and sorghum crops. In addition, those farmers who planted cowpea could use neem against the multiple pests of cowpea. Maize cultivars ICZ-5, IC92M5 and Coast Composite were provided for the farmer to make a choice.

The project technicians advised farmers to plant early in the season. Project technical staff were also at hand during planting to offer assistance during planting experiments. In addition to farmer modification of technology, there were two controls that were planted by some farmers who had additional land to spare. Those were the initial proposed technology, and modification of that technology.

The IPM menus were also tested in 1996 in other agroecological zones of Kenya.

4.2.1 *Treatments*

(a) Researcher-recommended practice on maize (RRPM)

1. Cultivar ICZ-5 or IC92M5;
2. Strip relay cropping:
   - 4 rows of maize (ICZ-5), 2 cowpea, 3 rows of cassava: within row 32 cm, between rows 75 cm, 2 plants per hill;
   - 3 rows of cassava spacing (75 x 50 cm);
   - 2 rows of cowpea (within row spacing 20 cm);
3. *Bt* or neem.

(b) Modified researchers-recommended practice on maize (MRRPM)

1. Cultivar ICZ-5/M5;
2. Strip relay cropping;
   - 4 rows of maize (ICZ-5/M5); spacing: within row 40 cm, between rows 75 cm, 2 plants per hill;
   - 3 rows of cassava spacing (75 x 50 cm);
   - 1 row of cowpea (within row spacing 15 cm);
3 *Bt* or neem.

(c) Modified farmers' practice on maize (MFPM)

1. Maize cultivar (ICZ-5) IC92M5 or Coast Composite to be provided by Project);
2. Strip relay cropping (modifications on row-ratios of different crops, spacing, time of planting cowpea/legume, cowpea/legume variety);
3. *Bt* or neem application;

(d) Farmer's practice—practice with his/her own cultivar, cropping pattern and method of insect control.

4.2.2 *Data analysis*

Since many farmers' control plots were monocrops, for comparison, strip yields were converted to the monocrop equivalent. Also, because of multiplicity of spacing modification by farmers, only the resulting plant density were used in the analysis.

The yield density relationship was converted to density-revenue data. From these data can be determined the amount of space (density) that can be replaced to give an equivalent maize yield. Total revenue from maize alone was maximised when maize was planted at 55,000 plants. Total revenue from cassava was maximised when cassava was planted on 64% of the land. However, contribution of maize to total revenue in maize–cassava intercrop was maximised when maize occupied 64% of the area at a plant density of 35,200/ha and cassava occupied 36 % of the land at a density of 7200 plants/ha. Based on very low yields of cowpea, total revenue is optimised when maize was planted as a monocrop.

The main treatment of researchers-recommended maize IPM technology, and the farmers' practice were subjected to modified stability analysis (Hildebrand, 1984).

From the analysis, there is evidence that the farms fall into two recommendation domains. Farms did not produce more than 1800 kg/ha in the drier north of Kilifi District. In Sokoke Location the local maize technology was found to be superior to the IPM technology. In the other category of farms, IPM technology out-performed the farmers' practice in the Mrima and Jego sub-locations (better environment). Interventions that are appropriate in the drier environments would include cassava in the technology, or appropriately the introduction of sorghum. The poor performance of IPM in this harsh environment could be due to the non-adaptability of the varieties and many other factors being investigated.

Sorghum was also adversely affected by the poor environment; the maximum monocrop yield in the better environment was 1498 kg/ha compared to that of 100 kg/ha in the poor environment of Silala. The drought tolerant ability of sorghum was thus not manifested.

5. ON-STATION BACK UP TESTING OF TECHNOLOGIES

Background

One of the components of pest management being evaluated in this project is 'early' intercropping of cowpeas in maize, towards reducing the severity of stalkborer in the latter crop. This practice involves a shift from the locally common 'relay' intercropping of cowpeas. The extent of avoidable losses due to insect pests among cowpea genotypes when planted 'early' and the scope for minimising the losses by neem sprays were required to be determined as a back-up for the on-farm testing of this technology component. This section deals with the back-up studies undertaken at Muhaka Field Station during the long rain season.

5.1 RESULTS

5.1.1 *Efficacy of neem seed extract spray against cowpea leaf beetle*

Three-week-old cowpea plants were transplanted in pots and the leaves sprayed with three concentrations of neem seed kernel extract (NSKE), at 5, 10 and 20%. One set of plants was sprayed with cypermethoin (synthetic pysithoid at the recommended dose) and another set kept unsprayed (as check) for comparison in four replications. The plants were caged with 15 cm tall transparent cylinders (ca 7.5 cm), having a ventilation vent of muslin cloth at the top. Field collected adults of the leaf beetle, *Ootheca beningseni* were prestarved overnight and caged on the plants daily for 12 h. Foliar damage was recorded by visual ratings following a rating score of 0–5 cm (0 = no feeding, 1 = less than 10% area fed; 2 = 11–25%; 3 = 26–50% area fed; 4 = 51–75% area fed; 5 = more than 75% area fed). The observations were terminated at 6 days after spraying.

The results showed that even at the lowest dose of neem spray (5%), the feeding by beetles was very meager (within 25% area) up to five days after spraying. At higher doses (10 and 20%) the leaf feeding by adults was significantly less than in the unsprayed plants even at 6 days after protection. These results confirmed that there was good justification for spraying 10% neem seed extract for protecting the cowpea plants from leaf beetle damage.

5.1.2 *Evaluation of yield loss reduction by neem seed extract sprays in 'early' planted cowpea*

An on-station trial was conducted to assess the benefit of neem sprays against the major cowpea insect pests. Since the leaf beetle (*Ootheca*) infestation was too low (less than one per plant), the spraying was limited to thrice during the flowering stage and the effect of the sprays was assessed on flower infestation by thrips and *Maruca*, besides measuring the grain yield.

At higher concentrations of neem spraying (10 and 20%), the thrips and *Maruca* infestations were significantly reduced. The grain yield enhancement due to spraying of neem was the greatest in the medium (10%) concentration. At the highest neem spray concentration, there was perhaps some adverse or phytotoxic effect, expressed as mild to moderate browning in leaves, which may have also affected the yield potential of the plants. The medium concentration (10%) appeared to be the optimum, with the least avoidable yield loss of 16%. This finding clarified the scope for neem spray in protecting the cowpeas. The farmers have been reluctant to plant cowpea early in the long rains in coastal Kenya, because of the relatively higher pest challenge experienced from *Ootheca*, thrips and *Maruca*. Since the use of neem was clarified, the on-farm technology evaluations were backed up by demonstrations on the preparation and application of neem sprays for protecting the early planted cowpeas.

5.1.3 *Effect of neem seed extract sprays in cowpea on the non-target arthropods*

During the course of field testing of neem seed extract sprays on cowpea for protection from flower/pod infesting pests at Muhaka, an assessment was also made of the effect of the sprays on pollinating bees.

Counts of bees (mainly the African honeybee) visiting the cowpea flowers was made by walking carefully along each row (12 row plot of 5 m each) for about 10 minutes, at 1, 3, 5 and 7 days after spraying.

The results showed that neem sprays at all the concentrations, tended to significantly reduce the bee visits to cowpea flowers only in the first day after spraying, but not beyond this period. Even during this initial period, the number of bees visiting the neem sprayed plots was greater than that of plots sprayed with the synthetic pyrethroid. This indicated that though neem tended to initially deter the bee visits, it was apparently less deterrent than the synthetic pyrethroid, and so could still be preferred. Field studies have also been initiated on the effects of neem sprays on the relative abundance of other beneficial arthropods, especially spiders and predatory ants.

5.1.4 *Evaluation of yield loss during long rains in coastal Kenya*

In order to be able to choose among cowpea varieties for early planting during the long rains in coastal Kenya, three genotypes from ICIPE (ICV2, ICV3, ICV11) and one from IITA (IT82D) were compared with two locally available cultivars (K.80, CatEye) in two sets of plots—one protected by insecticide sprays (three times) during flowering and the other without insecticidal protection.

It was found that ICV2 yielded more grains than the others when grown without insecticidal protection. The Project multiplied the seeds of ICV2 for further on-farm planting by the participating farmers.

6. GIS ACTIVITIES

Databases and maps of the biophysical, social and economic factors were already developed during the earlier phases of the project.

The following activities were in progress in 1995 and followed up in 1996:

(a) Compilation of digital maize and population distribution data in the study area. These data were obtained after much effort in late 1995.
(b) Incorporation of these data into existing database.
(c) Compilation of pest distribution data in the study area.
(d) Development of socioeconomic parameters maps.
(e) Incorporation of Kilifi soil data recently obtained into the database.

The main activity in 1996 was to develop maps revealing the crucial biophysical and socioeconomic factors related to adoption by farmers of the introduced technologies.

These factors are:

- Annual rainfall
- Long rains
- Short rains
- Long rains reliability
- Short rains reliability
- Soil type
- Soil texture

- Soil pH
- Soil rooting depth
- Population density
- Social and economic centres
- Maize distribution
- Agroecological zones
- Land use pattern.

The field sites of all farmers were geo-positioned using the global positioning system (GPS). In each district, the farmers were in two categories—the participating farmers and those farmers who adopted the technologies voluntarily. This information was represented on the maps of the two districts, Kwale and Kilifi.

Table 6.1 shows the number of farms geo-positioned according to district, highlighting key characteristics.

All farms in the same district fall into the same rainfall reliability zone, agroecological zone, land use pattern zone and maize distribution. Hence, only the soil type, population density, social and economic centres and maize distribution can be overlaid on the farms' geo-positions, to reveal how these factors are related to adoption by farmers of the introduced technologies. The maps developed are available in Biostatistics Unit and the Social Sciences Department.

7. MAIN PROJECT BENEFITS

The implementation of the project was a challenge to the Social Sciences Department and collaborating departments. It was rendered more difficult by staff restructuring before the completion of the second phase of the project. The project was also affected by logistical and climatic factors. Nevertheless, every effort was made to implement the project albeit with some revisions. As a result, the planned objectives of the project have substantially been accomplished. The main project benefits are the following:

(a) It was demonstrated that arthropod pest levels can be reduced on-farm within the project communities to manageable/tolerable limits without adversely affecting the farming environment. Reductions would vary, however, between the research sites and particular farms, reflecting environmental and management differences.

On maize, a reduction of 19.3% of stemborer damage was achieved, attributed to strip cropping (9.4%), maize cultivar ICZ5 (4.1%) and *Bt* (5.8%).

Neem appears to offer some promise for the reduction of stemborer and other pest damage, but its effectiveness would need to be further evaluated.

In general, it is concluded by the researchers that the IPM technologies appear to be more suited to Kwale than the drier areas of Kilifi.

(b) Potential for increased agricultural production and food security, improved nutrition and level of living, has been enhanced in the project communities. The results of the economic analyses show that the researcher-recommended practices could result in total yields, which in

Table 6.1. Farms geo-positioned by district and village

District	(Sub-location)/ village	Farmer status	Sex	Applying technology	Not applying technology
Kwale	(Jego)	sp	Female	4	0
	Tsuini		Male	24	0
	Mwalewa	vp	Female	3	0
			Male	6	0
	(Mrima)	sp	Female	6	0
	Mamba		Male	10	0
	Makambani	vp	Female	1	0
			Male	4	0
Kilifi	(Mwarakaya)	sp	Female	6	0
	Lutsangani		Male	12	0
	Pingilikani	vp	Female	2	0
			Male	1	0
	(Magogoni)	sp	Female	6	1
	Tandia		Male	14	3
	Silala	vp	Female	1	0
			Male	1	0

sp= Farmers selected for participation.
vp=Farmers participating voluntarily.

maize-equivalent amounts, could feed several additional persons in the average household.

(c) Knowledge and understanding of farmers and extension agents of IPM have been enhanced; this is evident not only from the intensive participation of the farmers in the research activities, but also from the results of socio-economic studies.

(d) Collaborative working relationship with institutions such as KARI and MOALDM have been strengthened; this is expected to facilitate future collaborative activities of ICIPE as a whole. Yet, it should be stressed that the ISERIPM experience has shown that a satisfactory level of collaboration can be achieved only with proactive and sustained effort on the part of the researchers.

(e) Training brochures for extension agents and farmers that can be used as prototypes for subsequent IPM technology interventions and training, were prepared and used in the various training activities.

(f) Methodologies for interfacing between social scientists, biologists, extension workers and farmers have been applied and documented to serve as a basis for other projects. These include interdisciplinary methods of characterisation of farming systems and technological needs, integrated methods of technology evaluation, methods of selection of representative farmers for participation in technology trials, the use of training as a tool for stimulating farmers' participation and effective technology management.

(g) A major achievement of the Project was the acceptance of the MOALDM extension services in the Coast Province to conduct demonstrations of the IPM technologies in 1998 in all eight divisions of Kwale and Kilifi. This is a significant step in the transfer of IPM technologies adapted to the region.

Output

Publications

Chitere P. and Kiros F. G. (1996) Farmers participation in the adaptation of IPM technologies in sub-Saharan Africa: Experiences from Kenya. *African Crop Science Journal* 4, (1) 115–126.

Kiros F. G. (1995) Toward typologies of agricultural producers in sub-Saharan Africa. *Eastern African Social Science Reseach Review* Vol. XI, No. 2, pp. 1–15.

Kiros F. G. (1996) The silent violence of insect pests and disease vectors in sub-Saharan Africa: Facing up to the challenge. *Bulletin of African Insect Science*, Vol. 16.

Odulaja A. and Kiros F. G. (1996) Modelling agricultural production of small-scale farmers in sub-Saharan Africa: A core study in western Kenya. *Agricultural Economics* **14**, 85–91.

Omolo E. O., Ssennyonga J. W., Ngugi A., Kiros F. G. and Okali C. (1995) Community mapping exercise: An evaluation. *Agricultural Administration (Research and Extension) Network 52*. Overseas Development Institute, London.

Sithanantham S., Otieno Z. N. and Nyarko K. A. (1997) Preliminary observations on the effects of neem sprays on some non-target arthropods in cowpea ecosystems, pp, 643–664. In *Proc. International Conference on Pests in Agriculture*, 6–9 Jan. 1997, Montpellier, France. ANPP, Paris.

IX. Natural Pesticides from Neem

A. AWARENESS BUILDING AND FACILITATING THE USE OF NEEM AS A SOURCE OF NATURAL PESTICIDES AND OTHER USEFUL PRODUCTS IN SUB-SAHARAN AFRICA (AGEC-2)

Background, approach and objective

Sub-Saharan countries, characterised by extremes of climate and a high proportion of eroded or degraded land, are facing an uphill task in producing sufficient food for their rapidly growing populations. A high percentage of people therefore suffer from malnutrition and other ailments, many of which are arthropod-borne. The challenge is to increase yields in production systems, reduce post-harvest losses, and improve human health, animal health, and the environment based on technologies which are economically efficient, ecologically sound, equitable, and ethical. The neem tree, *Azadirachta indica*, a botanical cousin of mahogany, has come under close scientific scrutiny as a source of environmentally 'soft', novel pest control materials. Neem derivates neutralise the pests in the subtlest manner by affecting their behaviour and physiology. The tree is widespread in Asia and Africa and has multiple uses in herbal medicine, toiletries and pharmaceuticals, as a source of timber and fuel, in reforestation programmes, and possibly in contraception.

The use of simple formulations or mixtures of bioactive components in the neem seed is an attractive option for pest management, especially for the resource-poor farmers in Africa.

This pot-pourri of novel chemicals has diverse behavioural and physiological effects on insect pests: repellency, feeding and ovipositional deterrency, growth inhibitory, mating disruption, chemosterilisation, and reduction of adult longevity, fecundity, and egg hatchability, thereby impairing pests' overall fitness, without affecting ecological services rendered by pests' natural enemies, pollinators, and other non-target organisms. Nearly 500 pest species worldwide, including insects, mites, ticks, and nematodes, have been found to be sensitive to various neem products and now several neem-based materials are being used for pest management in Asia, Europe and North America.

In Africa, lack of awareness of neem's potential and a paucity of information on methods of seed processing, extraction and formulation of bioactive constituents, and application, have been major constraints to its use for pest management in food and horticultural crops and stored grains. The objective of this project is to increase awareness of the use of neem materials as natural pesticides and other useful products in seven countries in eastern Africa, to safeguard the environment. Neem would replace synthetic pesticide use and promote multipurpose forestry for improving incomes, nutrition and health. Rural poverty would be alleviated through training, field trials, demonstrations, interaction and collaboration with national, regional and international programmes.

Since 1994, under the Finland–UNEP-funded Project, ICIPE has been demonstrating the potential of simple neem products such as azadirachtin-rich seed powder, cake, oil and aqueous extracts, against major pests of food crops and stored products in Kenya. ICIPE has also been training several NARES and farmers' groups on how to grow and use neem as natural pesticides.

ICIPE has been building and extending this awareness in other East African countries: Eritrea, Ethiopia, Malawi, Tanzania, Uganda and Zambia. Efforts are underway for largescale collection of seed and processing of neem materials for use in pest management through enhanced participation of scientific and farming communities and entrepreneurs.

Laboratory studies and field trials were conducted during the long rains (LR) and short rains (SR) cropping seasons at the ICIPE's Mbita Point Field Station, ICRAF Research Station at Machakos, on-farm near Machakos in Kenya and Shinyanga and Tabora in Tanzania, KARI's trial site at Machanga in Eastern Kenya, and farmers' fields at Mbita and Oyugis. The trials were directed primarily against stemborers affecting maize and sorghum, weevils and nematodes affecting bananas, the diamondback moth affecting kale crop, termites in maize and root-knot nematodes in sesbania in agroforestry, 'kiwi weevil' affecting cowpea and green gram, and the maize weevil in stored maize.

(See also the report on 'Development of a Smallscale Industry for Neem-Based Insecticides' in part B following. For the use of neem in controlling ticks and mosquitoes, see under those reports (XIII and XIV). For reports on development of botanicals for use in pest control, see under the Behavioural and Chemical Ecology Department.

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Donors: *Government of Finland, UNEP*

Collaborators: *• ICRAF • KARI • University of Nairobi • Society for Hospital and Resources Exchange (SHARE), Kenya*

Work in progress

1. NEEM FOR FOOD AND PERENNIAL CROP PESTS

1.1 NEEM CAKE IN STEMBORER CONTROL

The effectiveness of neem cake (NC) applications against *Chilo partellus* infestations in maize and sorghum crops was evaluated in field trials conducted at Mbita. During 1995, ICZ5, a maize cultivar moderately resistant to stemborers, was planted at the Experiment Station. When the crop was 3 weeks old, each plant was artificially infested with stemborer egg masses at the blackhead stage. Application of powdered NC @ 1 g/plant to the 4-wk-old crop or to the 8-wk-old crop, significantly reduced the foliar damage, stem tunnelling and the number of *Chilo* larvae on par with Dipterex. However, growth of larvae, as measured by the width of their head capsules at one week after treatment, was significantly less on neem-treated plants (Table 1.1). Grain yield with neem equalled that obtained with insecticide and was significantly higher than in the untreated plot. Also, in LR 1996, in fields planted to 'Serena' sorghum, similar results were obtained with NC application (Figure 1.1, Table 1.2) In a trial conducted in 1996, application of NC at 1 g/plant also effectively controlled *Busseola fusca*. Compared with expensive insecticides, the net gain in income was always higher with low-cost neem cake.

We also compared the efficacy of NC prepared by directly crushing the unhusked seed with that of NC made by reconstituting the crushed kernel with 10, 30 or 40% husk for stemborer control at the same rate of 1 g/plant. Compared with untreated control, all NC materials tested significantly reduced the plant damage and correspondingly increased the grain yield on par with Dipterex. Chemical analysis showed that even directly prepared NC had ~5500 ppm of azadirachtin-A thus obviating the need to reconstitute kernel and husk into cake with a standardised ppm of azadirachtin.

1.1.1 *Growth, development and reproduction of maize stemborers on semi-synthetic diet containing azadirachtin-rich 'neem bitters' (NB)*

To determine the cause of poor establishment of stemborers and low plant damage on neem-treated maize or sorghum plants, we studied the growth and development of neonate *B. fusca* larvae on a standardised diet containing 10, 100, 500 or 1000 parts per billion (ppb) of NB with 10% azadirachtin-A; diets with acetone (solvent) or without acetone served as controls.

Larval growth was significantly reduced and the developmental period prolonged on a diet containing NB at 100 ppb; at 500 ppb growth and development was totally inhibited (Table 1.3). Fecundity of females developing on the diet with NB at 100 ppb was reduced when they were mated with males reared on standardised diet (Table 1.4). Also, egg hatchability was reduced when females were reared on diet containing NB, indicating that azadirachtin-rich NB had a pronounced IGR effect.

1.2 NEEM AGAINST KIWI WEEVIL IN COWPEA

The kiwi weevil, *Piezotrachelus varium*, has become an important pest of cowpea and green gram in eastern Kenya. In trials conducted in collaboration with KARI at Machanga, a high volume spray application of neem seed extract controlled the pest as effectively as dimethoate and significantly increased the number of pods per plant, compared with the untreated control.

1.3 *STRIGA* CONTROL

The witchweed, *Striga hermonthica* is parasitic on maize and sorghum roots and seriously limits the yield of these important food crops in Africa. We discovered that striga infestation was insignificant in fields planted with maize and sorghum and treated with neem cake. The mechanism of striga inhibition by neem is being investigated.

Table 1.1. Infestation and plant damage by *Chilo partellus* larvae and grain yield in plots planted with the moderately resistant ICZ5 maize cultivar and treated with powdered neem cake (NC) once at 4 weeks after crop emergence (WE) or twice at 4 and 6 WE, or with an insecticide. ICIPE Mbita Point Field Station, short-rains cropping season 1995[1]

Treatment	Damage[2] 9 WE	Plant height (cm) 15 WE	Tunnel length (cm) 9 WE	Tunnel length (cm) 15 WE	*Chilo* (no.)[3]	Head capsule width (mm)[4]	Yield (kg/ha)
NC once	2.7 a	187 a	1.6 a	2.9 a	0.8 a	0.55 a	6143 a
NC twice	2.7 a	190 a	0.4 a	3.2 a	0.0 a	0.53 a	6250 a
Dipterex	2.2 a	188 a	1.2 a	2.4 a	0.8 a	1.28 c	6179 a
Untreated (control)	3.7 b	164 b	12.4 b	19.0 b	8.4 b	0.87 b	5286 b

[1] Within a column, means followed by the same letter are not significantly different at $P = 0.05$ by LSD test; averages of 5 replications.
[2] Foliar damage scored visually on 1–9 scale (1 = no damage, 9 = completely damaged).
[3] Larvae recorded at 9 WE.
[4] Head capsule widths recorded at 5 WE.

Table 1.2. Infestation and plant damage by *Chilo partellus* larvae and grain yield in plots planted with stemborer-susceptible 'Serena' sorghum cultivar and treated with powdered neem cake (NC) once at 4 weeks after crop emergence (WE) or twice at 4- and 6 WE, or with an insecticide. Mbita Point Field Station. Short-rains cropping season 1996 [1]

Treatment	Damage[2] 9 WE	Plant height (cm) 9 WE	Tunnel length (cm) 7 WE	Tunnel length (cm) 9 WE	*Chilo* (no.)[3]	Head capsule width (mm)[4]	Yield (kg/ha)
NC once	3.1 a	120 b	1.5 b	3.1 a	3.0 a	0.95 a	5178 b
NC twice	2.8 a	121 ab	1.6 b	1.6 c	1.4 a	0.94 a	5763 a
Dipterex	2.6 a	126 a	0.3 a	1.4 a	2.0 a	1.14 c	5421 ab
Untreated (control)	3.7 b	107 b	4.7 c	9.7 b	8.4 b	0.23 b	4395 c

[1] Within a column, means followed by the same letter are not significantly different at $P = 0.05$ by LSD test; averages of 5 replications.
[2] Foliar damage scored visually on 1–9 scale (1 = no damage, 9 = completely damaged).
[3] Larvae recorded at 9 WE.
[4] Head capsule width recorded at 5 WE.

Figure 1.1. Comparison of sorghum grain yield sampled from plots treated with 1 g of powdered neem cake per plant at various times of plant emergence. Application of the neem cake once (Neem 1) (far left) or twice (Neem 2) during the growing season, gave a grain yield comparable to the application of dipterex (*2nd right*) a synthetic pesticide, at a fraction of the cost. The untreated control is on the far right

2. NEEM FOR HORTICULTURAL CROP PESTS

2.1 NEEM SEED DERIVATIVES AGAINST DIAMONDBACK MOTH (DBM)

Diamondback moth, *Plutella xylostella*, a major pest of cabbage and kale crops, has become resistant to virtually all commercial insecticides, including *Bacillus thuringiensis*. In laboratory studies, we found that kale leaves treated with neem seed kernel extract repelled the larvae and deterred feeding (Figure 2.1). Also, insect growth and development was impaired and the few moths that emerged were deformed.

In heavily infested kale fields at MPFS and in a farmer's field in western Kenya, ultra-low volume spray applications of 20% neem seed extract at 10 l/ha at 10-day intervals controlled the pest within 3 weeks, resulting in increased harvest of marketable foliage. In contrast, untreated and cypermethrin-treated plants continued to be damaged by the pest.

Table 1.3. Growth and development of neonate *Busseola fusca* larvae reared on a standardised diet treated with acetone or 'neem bitters' (NB) at varying concentrations[1]

NB concn (ppb)	Larval period (d)	Survival to pupation (%)	Growth index	Pupal period (d)	Total dev. period (d)	Pupal weight (mg) Male	Pupal weight (mg) Female	Adult emergence (%)
10	41.6 b	82.5 a	2.0 a	14.4 a	56.8 b	186.2 a	222.5 a	82.5 a
100	82.6a	35.0 b	0.4 b	13.8 a	96.3 a	106.0 b	135.0 b	25.0 b
500	–[2]	-	-	-	-	-	-	-
1000	–[2]	-	-	-	-	-	-	-
Acetone	40.1 b	82.5 a	2.1 a	14.5 a	55.2 b	192.1 a	249.4 a	80.0 a
Untreated	45.6 b	87.5 a	2.0 a	14.0 a	54.8 b	181.0 a	215.1 a	70.0 a

[1]Within column means followed by a common letter are not significantly different at $P = 0.05$ level by Tukey's Test; avg. of 4 reps., each rep. had 20 insects reared individually.
[2] Died.

Table 1.4. Fecundity of *Busseola fusca* adults developing from neonate larvae reared on a standardised diet treated with acetone (A) or with 'neem bitters' (NB) at varying concentrations[1]

Pair from[2] NB (ppb) Female x Male	Replicates (no.)	Egg batches (no.)	Eggs/batch (no.)	Eggs/female (no.)	Hatchability (%)
0 x 10	19	2.9 ab	112 a	299 ab	72 ab
0 x 100	14	3.4 ab	76 ab	270 ab	77 a
10 x 0	33	3.3 ab	88 ab	300 ab	64 ab
100 x 0	15	2.3 b	53 b	147 b	49 b
0 x 0	46	3.9 a	84 ab	307 ab	66 ab
0 x 0A	21	3.9 a	95 ab	369 a	76 a
0A x 0	36	3.7 ab	78 ab	287 ab	63 ab

[1]Within column means followed by a common letter are not significantly different at $P = 0.05$ by Tukey's test; total eggs laid by a female constituted a replication.
[2] A = standard diet with acetone (solvent) only.

Figure 2.1. *Plutella xylostella* larvae fed little on kale leaf discs treated with 1, 2, or 3% neem seed kernel extract (NSKE), and untreated disc (control) was almost eaten up within 24 h

Figure 2.2. Difference in body sizes of *C. sordidus* larvae recovered from untreated and neem-treated banana pseudostems

2.2 EFFICACY OF NEEM SEED DERIVATIVES AGAINST BANANA WEEVIL AND BANANA NEMATODES

In laboratory tests, growth and development of banana weevil, *Cosmopolites sordidus*, larvae was adversely affected when 2nd-instar larvae were confined for 2 weeks to pseudostems of 'Nakeyetengu' (AAA-EA), a susceptible banana cultivar, treated with neem seed derivatives (Figure 2.2).

Also, soil applications of powdered neem seed or neem cake at 100 g / plant at planting and subsequently at 3-month intervals, reduced the populations of *Pratylenchus goodeyi* and *Meloidogyne* spp. on par with Furadan 5G (carbofuran), applied at 40 g / plant at planting and then at 6-month intervals to banana plants grown in 100-l containers with controlled levels of banana nematode infestations (Table 2.1). Eight months after planting, banana plants treated with powdered neem cake, seed, kernel or neem oil, had 7 to 95 times less parasitic nematodes than the untreated control. However, only neem cake powder or neem seed powder applied to unpared banana plants kept the nematode population below the economic threshold (10,000/ 100 g of roots). The predominant species, *P. goodeyi* and *Meloidogyne* infesting banana plants, were highly sensitive to treatment with neem cake or seed powder. In comparison with untreated banana plants, neem-treated plants produced greater plant biomass and vigorous suckers. Also, banana plants with greater biomass tended to have fewer nematodes (r = -0.137).

Table 2.1. Effect of soil application of neem seed powder (NSP), neem cake (NC), neem kernel powder, or neem oil (NO) on populations of banana nematodes at 2 and 8 months after treatment of pared or unpared suckers planted in 100 l capacity drums. Mbita Point Field Station, 1996–1997

Treatment	Nematode population (no./100 g of roots)+ after 2 months	after 8 months
Pared	1200 a	22,200 a
Pared + Furadan	0 a	16,800 a
Pared + NC	0 a	12,000 a
Pared + NSP	0 a	22,500 a
Pared + NKP	0 a	81,600 b
Unpared + NC	300 a	1200 a
Unpared + NSP	300 a	3600 a
Unpared + NKP	125 a	27,600 a
Unpared + NO	0 a	5700 a
Unpared (untreated)	25,050 b	114,000 b

+Within column means followed by a common letter are not significantly different at $P = 0.05$ by Tukey's test; average of 4 replicates.

3. NEEM FOR AGROFORESTRY AND TOBACCO

Insects and nematodes also affect trees and crops in agroforestry. In collaborative trials conducted by ICRAF at Shinyanga in Tanzania in 1995–1996, application of powdered neem cake at 2 g/plant to a hybrid maize, Cargil at 4 and 6 weeks after sowing, registered a 30% yield increase over the untreated control. Single application of neem cake or thiodan did not significantly increase the yield. Application of powdered neem cake at 135 kg/ha also reduced the termite damage and significantly increased the grain yield of the hybrid maize over the Furadan-treated or untreated crop (Table 3.1). In a long-term trial conducted at ICRAF Field Station at Machakos, it was observed that when neem cake was applied at 15 g/grevillea seedling, the tree mortality after 15 months was 60%, compared with 52% tree mortality in Furadan treatment and 72% in the untreated control.

In field trials conducted in Tabora, Tanzania, although application of powdered neem seed or neem cake at 15 g/m^2 was not as effective as ethylene dibromide at 62 ml/m^2 in reducing the root-galling index in tobacco plants, the tobacco yield increased significantly with neem treatments (Table 3.2).

4. BUILDING NEEM AWARENESS

Neem had been introduced in Kenya at the beginning of the 20th century. However, it was a neglected species. From 1995 to December 1997, more than 650 agricultural extension personnel, foresters, health workers, teachers, researchers, journalists, and representatives of NGOs, youth, and women groups from Eritrea, Ethiopia, Kenya, Malawi, Mozambique,

Table 3.1. Effect of application of powdered neem cake on termite damage to maize crop and the grain yield. Shinyanga, Tanzania, 1995-1996+

Treatment	Termite damage (%)	Grain yield (kg/ha)
Neem cake (45 kg/ha)	36.4	1340
Neem cake (90 kg/ha)	32.2	1560
Neem cake (135 kg/ha)	27.2	1650
Furadan 5G	41.1	1220
Untreated (control)	49.9	1240
SED	3.5	150

+Average of 5 replications.

Table 3.2. Effect of neem treatments in comparison with ethylene dibromide on root galling index and tobacco yield. Tabora, Tanzania, 1996+

Treatment	Root galling index at days after planting 72	107	142	Yield (kg/ha)
Neem cake powder (5 g/m^2)	5.9	5.0	4.6	422
Neem seed powder (10 g/m^2)	4.3	3.8	4.7	467
Neem seed powder (15 g/m^2)	3.0	2.7	3.8	578
Neem cake powder (10 g/m^2)	4.1	3.6	5.3	511
Neem cake powder (15 g/m^2)	3.1	3.6	4.6	517
Ethylene dibromide (62 ml/m^2)	1.8	2.1	3.3	456
Untreated (control)	6.2	5.8	5.1	378
SE ±	0.59	0.64	0.61	77

+Root-galling index: 0 = no damage, 10 = severe damage. Average of 4 replications.

Figure 4.1. Resource speakers and participants of the 5th Training Workshop on 'How to Grow and Use Neem' held at Mbita Point Field Station, June 1997

Somalia, South Africa, Sudan, Tanzania, Uganda, and Zambia were trained on 'How to Grow and Use Neem' in six major and four satellite workshops held at MPFS (Figure 4.1).

Special seminars on neem were conducted on request from farmers, schools, churches and local administration. Also, a special seminar was organised at ICIPE Headquarters in Nairobi to inform and inspire senior administrators, policymakers, entrepreneurs, and donor agencies for taking steps to encourage production, commercialisation and use of neem in Africa. The Project coordinator also delivered invitational lectures on neem in Ethiopia, Kenya, Zambia, India, Pakistan and Thailand.

Output

Publications

Kiarie M. and Saxena R. C. (1996) Exploratory evaluation of neem extract sprays on maize for control of stalk borers in coastal Kenya, pp. 571–573. In *Neem and Environment*, Vol. 1 (Edited by R. P. Singh, M. S. Chari, A. K. Raheja and W. Krauss). Proceedings of the World Neem Conference, India, 1993. Oxford & IBH, New Delhi.

Musabyimana T. and Saxena R.C. Efficacy of neem seed derivatives against banana parasitic nematodes *Phytoparasitica* (in press).

Raguraman S., Jayaraj S. and Saxena R. C. (1996) Effect of neem extracts on brown planthopper, *Nilaparvata lugens* and its symbionts, pp. 375–380. In *Neem and Environment*, Vol. 1 (Edited by R. P. Singh, M. S. Chari, A. K. Raheja and W. Krauss). Proceedings of the World Neem Conference, India, 1993. Oxford & IBH, New Delhi.

Saxena R. C. (1995) Biological effects of neem and their modes of action. Homoptera: Leaf and planthoppers, aphids, psyllids, whiteflies and scale insects, pp. 268–286. In *The Neem Tree* Azadirachta indica *A. Juss. and Other Meliaceous Plants: Sources of Unique Natural Products for Integrated Pest Management, Medicine, Industry and Other Purposes* (Edited by H. Schmutterer). VCH, Weinheim, Germany.

Saxena R. C. (1995) Neem products for integrated pest management: Pests of stored products , pp. 418–432. In *The Neem Tree* Azadirachta indica *A. Juss. and Other Meliaceous Plants: Sources of Unique Natural Products for Integrated Pest Management, Medicine, Industry and Other Purposes* (Edited by H. Schmutterer).VCH, Weinheim, Germany.

Saxena R. C. (1996) Sustainable development—Beyond 2000. *Global Neem Update* 1(2), 3–5, and 11–12.

Saxena R.C. (Ed.). (1997) *Directory of Neem Workers in Eastern and Southern Africa.* ICIPE Science Press, Nairobi. 30 pp.

Saxena R.C. and Kidiavai E.L. (1997) Neem seed extract spray applications as low-cost inputs for management of the flower thrips in the cowpea crop. *Phytoparisitica* 25, 99–110.

Conferences attended and papers

Kega K. M. and Saxena R. C. (1996). Neem derivatives for management of *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae). International Neem Conference, Queensland, Australia, 4–9 February 1996.

Premaratne Bandara, K. A. N. , Vijaya Kumar and Saxena R. C. (1996). *Grewia mirocos* (Tiliaceae)—A plant with anti-insect properties. International Neem Conference, Queensland, Australia, 4–9 February 1996.

Premaratne Bandara, K. A. N., Vijaya Kumar and Saxena R. C. (1996) An insect ovicidal compound from *Zingiber purpureum* (*Z. cassumunar*) (Zingiberaceae). Symposium on Bioactive Natural Products, Kandy, Sri Lanka, 11–15 November 1996.

Saxena R. C. (1996) Neem seed derivatives as low-cost inputs for insect pest management in cowpea, maize and sorghum crops. International Neem Conference, Queensland, Australia, 4–9 February 1996.

Saxena R. C. (1996) Agricultural technologies for 21st century: Neem for sustainable agriculture and environmental conservation. Annual Sustainable Development Conference, Islamabad, Pakistan, 4–9 Aúgust 1996.

Saxena R. C. (1996) Neem seed derivatives as low-cost inputs for pest management in food crops. International Symposium on Biopesticides: Toxicity, Safety, Development and Proper Use. Phitsanulok, Thailand, 27–31 October 1996.

Saxena R. C. (1996) Neem treatments for insect management in cowpea, maize, and sorghum crops. Annual Meeting of Entomological Society of America, Louisville, KY, 8–12 December 1996.

Saxena R. C. (1997) Botanical pest control. Roundtable on Ecological Agriculture for the Small Holder in Southern Africa, Siavonga, Zambia, 28 May–4 June 1997.

Saxena R. C. (1997) 'Green revolutions' without blues: Botanicals for pest management. International Conference on Ecological Agriculture: Towards Sustainable Development, Chandigarh, India, 15–17 November 1997.

Saxena R. C. (1997) Neem seed extract spray applications as low-cost inputs for management of *Megalurothrips sjostedti* in cowpea crop. Annual Meeting of Entomological Society of America, Nashville, Tennessee, 14–18 December 1997.

Saxena R. C. and Onyango F. O. (1995) Growth, development, and reproduction of *Chilo partellus* on diet containing neem seed powder. Annual Meeting of Entomological Society of America, Las Vegas, Nevada, 17–21 December 1995.

Saxena R. C. and Onyango F. O. (1996) Growth, development and reproduction of *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae) on semi-synthetic diet containing 'neem bitters' concentrate. International Neem Conference, Queensland, Australia, 4–9 February 1996.

Project proposal

Saxena R. C. (1997) Awareness Building and Facilitating the Use of Neem As a Source of Natural Pesticides and Other Useful Products for Promoting Rural health and Prosperity in Sub-Saharan Africa (Phase 2). Submitted to Government of Finland and UNEP, November 1997.

Capacity building

Approximately 550 persons from seven East African countries, and non-target countries such as South Africa, Mozambique, the Sudan and Somalia (on special request or sponsorship), have been trained in six regular and four satellite training workshops. A special seminar was organised for over 50 senior government officers, policymakers, and others in Nairobi in September 1997. Another 200 persons were trained on uses of neem in one-day seminars held during the same period. One student has completed his PhD thesis on 'Management of the maize weevil with neem' and others are about to complete. Also, a number of students from technical schools completed their non-degree training programmes under the Project.

Impact

As a result of the awareness created under the Neem Project, planting of neem trees and production and use of neem derivatives for pest control are gaining popularity in many countries in sub-Saharan Africa.

Awareness of neem is growing in the eastern and southern Africa region, in large part, due to ICIPE's Neem Awareness Project. Since 1994, more than 50,000 seedlings and about 200 kg of viable seed have been distributed among farmers, schools, churches, NGOs and other interested groups in Kenya. Since inception of the Neem Project at Mbita, awareness of neem's potential has already been created and the communities have planted more than 2000 neem trees; the Rusinga United Development Group, a local women's organisation, has raised a nursery of 6000 neem seedlings from the seed provided by the Project. This has stimulated the establishment of numerous private nurseries in Kenya and its neighbours. At Kwimba Afforestation Project site in Tanzania, neem is being planted at 0.5 million seedlings annually.

Commercial production of selected standardised neem-based control preparations by a private Nairobi firm, is another encouraging sign that demand for this ecologically safe pesticide is growing. Pilot scale production of neem-based pesticides is also underway as part of ICIPE's Technopark initiative.

(See the following report in Part B.)

Videos

Six videos covering neem awareness work at ICIPE, have been made. In 1996, the Neem Awareness Project was featured for its environmental impact under the Rolex Awards. Also, the Project was widely covered by the media in Africa, and featured in two segments of the Reuters 'Africa Journal' programme.

1. *Neem—Wondertree* (52 min),
2. *How to Use Neem* (12 min),
3. *Neem—A Tree of Wonder: A Lecture by R. C. Saxena* (55 min) [by I. Vehkalahti, Pori, Finland].
4. *The Neem Tree* (25 min) [by G. Bradbury, Reuters International, Nairobi, Kenya].
5. The Neem Awareness Project was featured for its environmental impact in the book, *'Spirit of Enterprise: The 1996 Rolex Awards'*.

B. DEVELOPMENT OF A SMALLSCALE INDUSTRY FOR NEEM-BASED INSECTICIDES

Background, approach and objectives

The careless and indiscriminate use of synthetic pesticides has led to widely known problems such as environmental contamination, toxic residues, side effects on non-target organisms, increase of pest resistance to pesticides, secondary pests, and pest resurgence. Moreover, the advent of Maximum Pesticide Residue Limits in horticultural products for export has prompted an intensive search for natural insecticides and fungicides in Kenya. The neem tree, *Azadirachta indica* (A. Juss) has been known for a long time for its medicinal and pesticide properties. The potential use of the various tree components as natural pesticides has been intensively researched worldwide in the last 20 years. Home-made pesticides from the leaves and seeds have been the most widely used.

In Africa the tree is used as a shade tree and as a source of fuelwood. Knowledge of neem's efficacy as a traditional medicinal plant is widespread. However, its potential for use as a natural pesticide is little known. Pesticides formulated on neem are being widely used in India. Some industrialised countries are also working intensively on formulating neem-based pesticides. Besides being environmentally friendly, these have the advantage of controlling a wide range of pests without leaving dangerous residues.

Kenya has a high potential for growing neem. Based on climatic classifications, it is estimated that over 25% of the land in Kenya is suitable for growing neem. The tree is currently found in Lamu, Taita/Taveta, Kilifi and Mombasa Districts in Coast Province as well as the semi-arid areas of northeastern Kenya.

The main problems hindering use of neem by growers include poor dissemination of neem-related knowledge and the fact that in those regions where neem could be used successfully, such as vegetable growing areas, there are not enough neem trees or none at all. Another reason is the lack of professional marketing strategies.

This project aims to produce simple, standardised, neem-based pesticides, which can be purchased on the market at competitive prices. It also encourages seed collection as an alternative source of income generation, especially in areas of marginal agricultural activities.

Two feasibility studies were done by the GTZ-IPM Horticulture Project (IPMH) in 1994–1995. In 1995 approximately 300 kg seeds were collected and transported to Nairobi for analysis and processing. A pilot processing unit was established by testing and adaptation of locally available machinery. During the first half of 1996, SAROC Ltd, a private local company under contract with the project GTZ-IPMH, organised collection, preparation and extraction of oil from neem seeds. After the successful completion of this pilot activity, IPMH solicited a grant from GTZ for the development of a smallscale industry for neem based insecticides. The contract was awarded to ICIPE in mid-1996. The project is being conducted in collaboration with SAROC Ltd.

Participating scientists: *A. M. Varela, Dorian Rocco (SAROC)*

Assistants: *S. O. Okoth, M. Muli, N. Kuesters, K.K. Stanley, D. Pacho*

Donor: *Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ)*

Collaborators • *GTZ IPM-Horticulture Project (IPMH)* • *KARI* • *Homegrown, Kakuzi Ltd., Shalimar Flowers (Kenya), Hortitech (K) Ltd and other fruit, vegetable and cut flower growers in Kenya*

Work in progress

5. NEEM COLLECTION AND FORMULATION

5.1 DEVELOPMENT OF NEEM PRODUCTS

Neem seed collection was organised by SAROC Ltd. The peak fruiting season in coastal Kenya and Tanzania is between March–May. During this period seeds were collected, dried and cleaned, delivered at collection points and sent to Nairobi. In 1996 slightly over 7 tonnes neem seeds were collected. About 17 tonnes of neem seeds were collected and delivered in Nairobi in 1997.

The seeds were processed in the propotype unit at ICIPE as follows: The seeds were first disinfected to avoid fungal growth and aflatoxin contamination. The seeds were then put through a sheller to break the outer shells and liberate the kernels. Thereafter the kernels were separated from the shells and put through a mill to extract the oil. The byproduct after extracting the oil is the neem kernel cake.

Pesticides for seed treatment, soil treatment and foliar spray are being developed based on neem kernel cake and neem oil. These products can be used directly for plant protection, but further processing is necessary to obtain a standardised product. The products are being standardised on the amount of the main active ingredient azadirachtin (aza), which may vary greatly among different trees and regions or countries. The aza content is measured by high performance liquid chromatography (HPLC) in the chemistry department at ICIPE.

The following formulations have been developed and are being tested:

(i) Neemros: Neem cake powder standardised at 0.5% a.i. by reconstituting the neem cake with neem seed shell in adequate proportion.
(ii) Neemroc EC oil: A water miscible oil with 0.03% a.i.
(iii) An alcoholic extract with 1% a.i.
(iv) An enriched oil at 0.5% a.i.

5.1.1 *Registration of produced neem-based pesticides*

Applications for the registration of the first two products, Neemros and Neemroc were presented to the Pest Control Products Board (PCPB) in 1996. This certificate is needed to enable the marketing of any pest control product.

To fulfill the requirements of PCPB efficacy, field and laboratory trials on key pests of several crops were started. These trials were also directed to determine frequency of application and effective concentrations which are economically competitive with available pesticides.

Results on the efficacy of two neem products, Neemros (NCP 0.5%) and Neemroc (neem oil EC 0.03%) against important pests such as the diamondback moth (DBM) and aphids on cabbage; aphids and thrips on French beans; leafminers on tomato were presented to the PCPB in December 1997.

6. NEEM PRODUCTS FOR MANAGEMENT OF PESTS IN HORTICULTURE

6.1 MANAGEMENT OF THE DIAMONDBACK MOTH (DBM) *PLUTELLA XYLOSTELLA* (L.) ON CABBAGE

The effects of amendments with neem cake powder (NCP) in the nursery bed and at transplanting, and foliar sprays with neem cake water extracts (NCP-WE) on DBM were studied in screenhouse experiments. Cabbage plants were artificially infested with second-instar DBM larvae, or DBM moths were periodically released.

6.1.1 *Amendment with NCP in the seedbed*

Amendments with NCP in seedbeds at rates equivalent to 83 g, 1667 g/m^2 were tested in a series of experiments against an untreated control by adding 10, 12.5, 20, 25, 30, 40, 50, 100 and 200 g NCP to 7 kg in trays of 45x30x5 cm. One hundred cabbage seeds were sown per tray. The experiments had three replications in a randomised complete block design (RCBD).

Concentrations of 40 g and above had a negative effect on larval growth and survival. Some adults emerging from treated plants were deformed. One week after transplanting in the field, the effect on larva had almost ceased, and half of the emerged adults were deformed. This effect lasted for about one week after transplanting. However, amendments with 40 g NCP and above were phytotoxic and affected seed germination. At safe concentrations to the plants (below 40 g), there was no significant difference in larval development and feeding between treatments and control. However, wing deformation was observed in some adults from plants grown in soil amended with 12.5 and 25 g. No differences in fecundity were observed.

6.1.2 *Amendment with NCP at transplanting*

NCP was added to the planting hole when transplanting cabbage seedlings at rates of 1.7, 3.5 and 7.0 g per plant. Twenty second instar DBM larvae per treatment were infested at 5, 11 and 18 days after treatment. Each treatment was replicated four times.

Larval survival to adult was reduced by neem treatments when compared with the control. Adult deformation, mainly of wings, was observed in adults from larvae from all neem treatments, while those from control were all normal. The percentage of deformed adults was dose-dependent (Table 6.1). Only the two highest concentrations (3.5 and 7.0 g), significantly reduced larval growth and feeding compared with control (Table 6.2). The effect of amendment with 7.0 g was manifested on larvae infested at 5, 11 and 18 days after treatment, whilst the effect of amendment with 3.5 g was significant only 11 days after treatment (Table 6.2).

6.1.3 *Application of NCP-WEs as foliar spray*

The effect of foliar applications with three different concentrations of NCP water extracts (NCP-WE) (12.5 25 and 50 g / l) on DBM were compared with a control in a randomised complete block design (RCBD) with 3 replicates. Plants were treated 5 days after transplanting. Control plants were treated with water.

Table 6.1. Survival to adult of DBM larvae on cabbage plants planted in soil amended with NCP. Batches of 20 larvae were infested at 5, 11 and 19 days after treatment

	Infestation 5 days after treatment		Infestation 11 days after treatment		Infestation 18 days after treatment	
Treatment	Survival to adult (%)	Deformed adults (%)+	Survival to adult (%)	Deformed adults (%)+	Survival to adult (%)	Deformed adults (%)+
Control	45	0	57	0	90	0
1.7 g NCP	25	40	20	25	60	25
3.5 g NCP	15	67	20	50	55	38
7.0 g NCP	5	100	30	30	65	45

+Based on total number of emerged adults.

Table 6.2. Effect of amendment with NCP on larval growth and damage caused by DBM larvae on cabbage plants planted in soil amended with NCP. Plants were infested with batches of 20 larvae at 5, 11 and 19 days after treatment

	Mean* larval length (mm)			Mean* leaf damage (cm^2)		
Treatment	5 days	11 days	18 days	5 days	11 days	18 days
Control	7.6 a	7.9 a	7.9 a	0.8 a	1.6 a	1.4 a
1.7 g NCP	7.9 a	6.5 a	7.6 a	0.8 a	1.3 a	1.2 a
3.5 g NCP	6.0 a	5.2 b	6.8 a	0.6 a	0.7 b	1.0 a
7.0 g NCP	4.5 b	4.2 b	6.6 a	0.2 b	0.6 b	0.8 b

*Means followed by the same letters in the same column are not significantly different at $P = 0.05$ according to Duncan's multiple range test.

Table 6.3. Survival to adult and fecundity of moths from 20 DBM larvae infested on plants sprayed with NCP-WE at different concentrations. Plants were infested with batches of 20 larvae at 5, 11 and 19 days after treatment

	Infestation on the treatment day		Infestation 1 week after treatment			Infestation 2 weeks after treatment		
Treatment	Survival to adult (%)	Deformed adults (%)	Survival to adult (%)	Deformed adults (%)	Eggs laid+	Survival to adult (%)	Deformed adults (%)	Eggs laid+
Water	70	0	70	0	60.9 a	75	0	59.7 a
12.5 gl^{-1}	0	–	35	29	42.0 b	70	0	56.0 a
25.0 gl^{-1}	0	–	35	29	40.4 b	65	0	57.3 a
50.0 gl^{-1}	0	–	25	80	23.5 c	65	0	48.8 a

+Per female. Means followed by the same letters in the same column are not significantly different at $P = 0.05$ according to Duncan's multiple range test.

One block was infested on the treatment day. A second and a third block were infested 1 and 2 weeks after treatment, respectively.

NCP-WE at the three tested concentrations significantly reduced larval growth, feeding and survival (Tables 6.3 and 6.4). These effects lasted from 1 week at the lowest concentration to 2 weeks at the highest concentration. The moths (29–80%) from larvae infested 1 week after treatment, emerged into deformed adults in the neem-treated plots. Moths from neem-treated plants laid significantly fewer eggs than moths from untreated plants. Reduction in fecundity was dose-dependent (Table 6.3).

In a second experiment, weekly applications of NCP-WE at two concentrations (25 and 50 g) were compared with Dipel, (0.5 g/l) a biopesticide recommended for DBM control. Each treatment was applied to 10 plants replicated three times in a randomised complete block design. One hundred DBM moths were released weekly into the screenhouse. Plant damage was measured by an index based on the percentage leaf damage from 0 (no leaf damage) to 7 (more than 60% leaf damage). Untreated plants had significantly more DBM larvae per plant than plants treated with Dipel and NCP-WEs. Throughout the experiment, plants treated with Dipel had the lowest number of DBM larvae per plant (Figure 6.1). However, 7 weeks after the first applications, the number of DBM on NCP-WEs was comparable to those on plants treated with Dipel.

Table 6.4. Development and feeding of 20 DBM larvae on plants sprayed with NCP-WE at different concentrations. Plants were infested with batches of 20 larvae on the treatment day (0), and 1 and 2 weeks after treatment

	Mean* larval length (mm)			Mean* leaf damage (cm^2)		
Treatment	0	1 week	2 weeks	0	1 week	2 weeks
Control	8.5 a	8.40 a	6.95 a	3.69 a	3.59 a	3.23 a
12.5 gl^{-1}	5.6 b	7.40 a	7.49 a	0.43 b	2.39 a	2.83 a
25.0 gl^{-1}	4.9 b	6.75 b	6.01 a	0.58 b	1.68 b	2.80 b
50.0 gl^{-1}	4.8 b	5.20 b	5.33 b	0.25 b	1.28 b	2.36 b

*Means followed by the same letters in the same column are not significantly different at $P = 0.05$ according to Duncan's multiple range test.

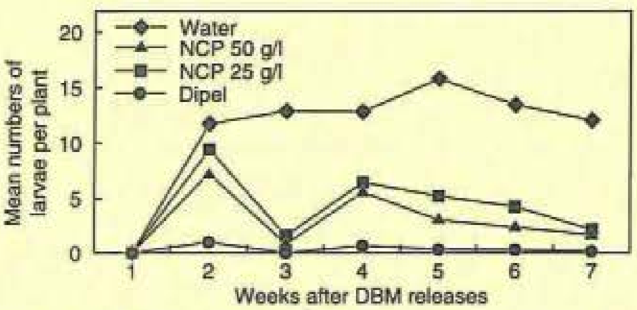

Figure 6.1. Fluctuations of DBM larvae on cabbage plants with different treatments after weekly releases of DBM moths in a screenhouse

Both neem treatments and Dipel performed comparably well in reducing leaf damage. However, yield from neem-treated plants was much higher than from plants treated with Dipel and control plants (Table 6.5). This was due to an accidental aphid infestation. Dipel treated plants suffered heavier infestation than all other treatments and by the end of the fourth week most of the plants were stunted. This shows the value of neem as a broad spectrum biochemical.

6.2 MANAGEMENT OF THE APHID, *BREVICORYNE BRASSICAE* (L.) ON CABBAGE AND KALE

These trials were carried out from June to November 1997.

6.2.1 *Effects of neem treatments on* B. brassicae *on cabbage under field conditions*

The effect of foliar applications with neem oil at 2% and NCP-WE at 50 and 100 g a.i. per ha on aphid populations was compared to a synthetic insecticide, Karate and a control. This was done in a field trial on artificially infested cabbage plants at Mai Mahiu in the Rift Valley of Kenya. The experiment was done using a RCBD with four replicates. Plants were sprayed four times at weekly intervals. Aphid infestations were recorded by using a scoring system from 0 (no aphids) to 7 (more than 300 aphids).

Plants treated with the insecticide Karate presented significantly lower aphid infestation than neem

Table 6.5. Mean numbers of larvae per cabbage plant and damage seven weeks after transplanting, and mean cabbage head weight at harvesting (2.5 months after planting)

Treatments	Mean number of larvae per plant	Mean* damage rating	Yield (g)
Control	12.0 a	3.57 a	72.9 b
25 gl^{-1} NKCP-WE	2.0 b	1.30 b	132.8 a
50 gl^{-1} NKCP-WE	1.7 b	1.32 b	161.6 a
Dipel 2x	0 b	1.00 b	39.4 b

Means followed by the same letters in the same column are not significantly different at $P = 0.05$ according to Duncan's multiple range test.

treatments and control, during the growing period. Aphid infestation increased during the first 3 weeks in all treatments except Karate. Thereafter, aphid infestations decreased in all treatments due to the onset of heavy rains. Plants treated with neem oil and NCP-WEs had lower aphid infestations than control plant (Figure 6.2). However, these differences were not significant, with the exception of NCP-WEs at 50 g/ha, where the initial infestation of the plants before the treatment was already lower that on the other plants.

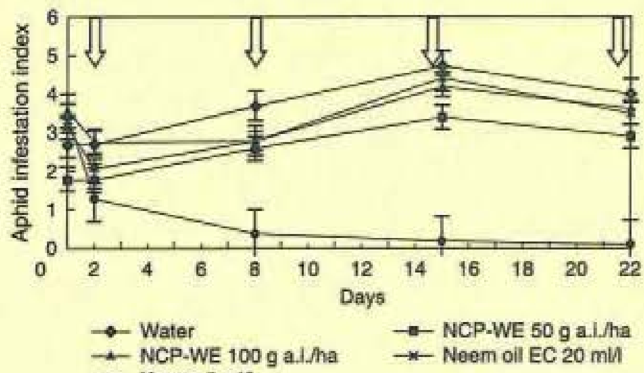

Figure 6.2. Development of infestations of the aphid *B. brassicae* on cabbage plants treated with neem oil, NCP-WEs and Karate. Pretreatment infestations are shown on day 0. Day 1 indicates first treatment

The parasitoid, *Diaterella rapae* (M.) was commonly found in all treated plots. The parasitism rate was much lower on Karate-treated plants (8%) than on the plants treated with neem oil (23%), control plants (18%) and plants treated with neem water extracts (12–15%) (Table 6.6).

Yield comparison was hampered by poor plant establishment. Some plants died after transplanting or had retarded growth.

Table 6.6. Parasitism rates of *Diaterella rapae* on the cabbage aphid *B. brassicae* in plots under different treatments

Treatment	Average number of aphids[1]	Parasitism rate (%)[2]
NCP-WE 50 g aza per ha	595	12
NCP-WE 100 g aza per ha	648	15
Neem oil EC 20 ml/l	228	23
Karate 5 ml/l	39	8
Water	258	18

[1]On 5 leaves per plot collected at harvesting.
[2]Parasitoids emerged out of total number of aphids collected at harvest.

6.2.2 *Effects of neem treatments on* B. brassicae *infestation on kale under field conditions*

This trial was conducted at Tigoni, approximately 25 km northwest from Nairobi. Naturally infested kale plants were treated with NCP water extracts at a rate of 50 g aza/ha, neem oil at 1 and 2%, and water as control.

Neem oil at 2% gave the best protection; most aphids were dead a day after first treatment. NCP water extracts had a low contact effect. However, after two applications aphid populations declined (Table 6.7).

In controlled experiments, neem oil EC at 2% showed the highest efficacy when compared with NCP-WEs and a control. It adversely affected aphid fecundity (Table 6.8). In field trials, neem applications against *B. brassicae* were more effective on kale than on white cabbage. This could be explained by the fact that the aphids on kale are exposed, while on cabbage they are protected in clusters between the leaves. Although the performance of neem products was inferior to Karate, they appeared to be safer to natural enemies as shown by the rates of parasitism (Table 6.6).

6.3 NEEM PRODUCTS FOR MANAGEMENT OF THE BLACK BEAN APHID *APHIS FABAE* SCOP. ON FRENCH BEANS

The effectiveness of seed treatment with neem oil, amendment of soil with neem cake powder, and foliar sprays with formulated neem oil and neem cake powder water extracts (NCP-WE) against the aphid, *Aphis fabae*, were tested in screenhouse experiments. French bean plants were artificially infested with 10–20 aphids per plant. Aphid infestation was evaluated weekly using a visual scale of 0–7 (0= no aphids and 7 over 500 aphids).

6.3.1 *Seed treatment with neem oil*

Seeds of French beans were treated with pure neem oil at a rate of 5, 10 and 15 ml per kg and planted in 2-kg capacity polyethylene bags, and compared to an untreated control. The experiment was laid in a randomised complete block design with three replications and 30 plants per treatment. Seed treatments with neem oil at the tested rates did not affect germination. Similarly, the treatments did not have an effect on the development of aphid populations.

6.3.2 *Soil amendment with NCP*

French beans were sown in soil amended at 7, 14 and 28 g per 2 kg soil in polyethylene bags (two seeds per bag). The experiment was laid in a randomised complete block design with four replicates and 20 plants per treatment. Germination was significantly reduced in soil amended with 14 and 28 g NCP. No significant effect of the treatments on the development of aphid populations was observed.

Table 6.7. Mean reduction of *B. brassicae* on kale after foliar sprays with different neem formulations

Treatment	Mean reduction of aphids+ (%) ± SE		
	1st application	2nd application	3rd application
Control (water)	0 ± 1.6 b	14 ± 5.9 a	3 ± 6.4 a
NCP-WE 50 g a.i. /ha	18 ± 4.1 b 0	51 ± 13.1 a 0	38 ± 17.6 a 0
Neem oil EC %	57 ± 10.6 a	20 ± 11.6 a	13 ± 5.1 a

+Based on aphid infestation before and after each application.
Means followed by the same letters in the same column are not significantly different at $P < 0.05$ according to Tukey's multiple range test.

Table 6.8. Effect of treatment with neem oil (2%) on mortality of immature stages of *B. brassicae* and their fecundity 7 days after treatment

Treatment	Aphid mortality (%) ± SE	Number of offspring /female
Water	22.7 ± 5.7 a	8.3 ± 2.3 a
2% Neem oil EC	69.1 ± 7.3 b	0.9 ± 0.5 b

Means within a column followed by same letters are not significantly different at $P < 0.05$ according to Tukey's multiple range test.

6.3.3 *Foliar sprays with neem oil and NCP-WEs*

The effects of one, two and three applications at weekly intervals of three concentrations of neem oil (1, 2 and 3%) and three concentrations of NCP-WEs (12.5, 25 and 50 g /l water) on aphid infestations, were compared with a control (water) in two individual trials. Thirty plants per treatment were distributed in a randomised complete block design with three replications. Aphid populations on plants treated with neem oil at both concentrations were much lower than on plants treated with NCP-WE. The effect of neem treatments on aphid populations was related to the dose, but not to the frequency of applications. Comparable aphid numbers were observed within the same treatment when applied one, two or three times.

Furthermore, the effect of foliar sprays with NCP water extract (50 g/l water), neem oil EC 3%, on aphid numbers and on yield were compared with the synthetic pesticides Karate and Gaucho, and with water as control. Karate was applied as foliar spray at a rate of 2 ml/l water and Gaucho as seed dressing at 8 ml/kg seed.

The lowest aphid scores were consistently recorded in plants sprayed with neem oil EC and Karate, followed by NCP water extracts and Gaucho, while control plants had the highest aphid scores. Four weeks after the treatments were started, plants treated with neem oil EC, Karate and NCP-WEs had significantly lower aphid scores (1.2–1.6) than Gaucho -treated and control plants (3.6 and 7.0) (Figure 6.3). Plants treated with neem oil and Karate produced the highest harvestable yield measured by the number of pods per plant and fresh pod weight (Table 6.9). Thus, treatments with neem oil EC at 3% were as effective as Karate and superior to NCP-WEs and Gaucho. Plants treated with NCP-WEs had slightly more harvestable yield than plants treated with Gaucho; the difference was not significant. However, the plants treated with Gaucho had a higher percentage of pods contaminated by aphids (42%) than plants treated with NCP-WEs (20%).

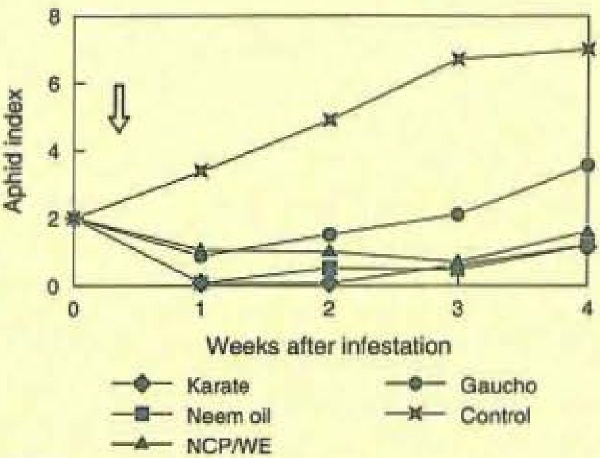

Figure 6.3. Development of aphid infestations on French bean plants infested with 20 aphids/plant on week 0 and treated weekly with neem products, compared to plants treated with two synthetic insecticides and a control

Table 6.9. Yield (number of pods and total fresh pod weight) of French beans following the various treatments

Treatments	Mean number of pods/ plant	Total fresh pod weight (g)
Karate (2 ml/l)	10.3 c	1044 a
Neem oil EC (30 ml/l)	9.3 c	959 a
NCP-WE (50 g/l)	6.2 b	906 b
Gaucho (8 ml/kg)	5.0 b	578 b
Control (water)	3.3 a	60 c

Means within a column followed by same letters are not significantly different at $P = 0.05$, according to Duncan's multiple range test.

6.3.4 *Effect of foliar sprays with neem oil and NCP-WEs on aphid survival*

Aphid nymphs were placed on plants treated with NCP-WEs at 25 and 50 g/l and neem oil at 2 and 3% in two separate experiments. In both instances plants treated with water were used as controls. Six plants per treatment were infested with aphid nymphs (5 aphids/plant), immediately after spraying (day 0), and 4 and 8 days after plants were sprayed.

All nymphs placed on neem-treated plants on the treatment day died, while 60 and 70 % of the nymphs survived in the control plants. Mortality of aphids placed four days after treatment was still significantly higher on neem-treated plants. Mortality was dose-dependent but there was no difference in mortality caused by the two neem oil concentrations. There were no significant differences in mortality of aphids placed on plants 8 days after treatment, which indicates that the effect of the neem treatments was over by then (Table 6.10).

Table 6.10. Mortality of aphids placed on plants treated with neem at different days after treatment

Treatments	Mortality of aphids placed at different days after treatment (%)		
	Day 0	Day 4	Day 8
Control I (water)	40	36 a	28 a
NCP-WE (25 g/l)	100	60 b	32 a
NCP-WE (50 g/l)	100	84 c	44 a
Control II (water)	24	24 a	24 a
Neem oil EC (20 ml/l)	100	68 b	32 a
Neem oil EC (30 ml/l)	100	80 b	32 a

Means within a column followed by same letters are not significantly different at $P = 0.05$ according to Duncan's multiple range test.

6.4 THE USE OF NEEM CAKE POWDER FOR MANAGEMENT OF *FUSARIUM* WILT ON TOMATO

The effects of different concentrations of NCP-WEs on the vegetative growth, sporulation, conidial germination and pathogenicity of *Fusarium oxysporum* fsp *lycopersici* (F.o.l.) were studied in laboratory and screenhouse experiments. Moreover, the effectiveness of soil amendments and drenching with NCP-WEs in management of F.o.l. on the tomato cv Money Maker was investigated.

6.4.1 *Effect of NCP-WE on mycelial growth, sporulation and germination of* F. oxysporum *fsp.* lycopersici

Potato dextrose agar (PDA) amended with NCP-WE at concentrations of 5, 10, 20, 30 and 50 g/l were inoculated with 5 mm plugs of F.o.l. and compared to non-amended PDA in Petri dishes. Similar concentrations were mixed with 5% sugar in microscope cavity slides and about 80 spores of F.o.l. were added to study the effects of NCP-WEs on spore germination.

Mycelial growth, sporulation and germination of F.o.l. were inhibited by the amendments with NCP-WEs. The degree of inhibition depended on the concentration. Thus, concentrations of NCP-WEs of 50 g/l and 5 g/l had the highest and the lowest inhibition on the mycelial radial growth, sporulation and spore germination (Table 6.11).

Table 6.11. Effects of amendments with different concentrations of NCP-WE *in vitro* on development of F.o.l.

NCP g/l	Mean numbers of spores	Percentage of spores germinated after 36 hours+	Mycelial diameter
0	62 a	71 a	56.2 a
5	46 b	74 b	46.3 ab
10	35 bc	66 bc	43.4 bc
20	31 c	59 c	34.2 cd
30	23 cd	39 d	28.5 de
50	15 d	34 d	20.3 e

+Out of 80 spores.
Figures followed by the same letters within a column do not differ significantly ($P = 0.01$) according to Duncan's multiple range test.

6.4.2 *Effect of amendment with NCP on* F. oxysporum *fsp* lycopersici *pathogenicity*

Tomato seedlings were inoculated with F.o.l. from non-amended PDA and PDA amended with 50 g/l NCP-WE. Pathogenicity was measured by the wilt index, based on the length of discolored vascular tissue (LDV) and wilt severity from 0–4 (0=none; 1= 1–25%; 2=26–49; 3=50–74%; 4=75–100%).

F.o.l pathogenicity was significantly affected by amendments with NCP as evidenced by wilt index of 1.19 and 1.60 associated with amended and non amended PDA, respectively (Table 6.12).

Table 6.12. Length of discoloured vascular system (LDV), mean dry shoot weight (DSW), fruit weight (FW), and fruit number/plant (FN) of tomato (cv Money Maker) plants, 56 days after inoculation with F.o.l. from 50 g/l NCP amended PDA and non-amended PDA

Treatments	Mean LDV	Mean wilt index+
PDA	0.4 c	0.001c
PDA+ NCP	0.4 c	0.002 c
PDA + F.o.l.	2.8 a	1.600 a
PDA+ NCP+F.o.l .	1.4 b	1.190 b

+Wilt index based on the LDV and wilt severity from 0–4 (0=none; 1= 1–25%; 2=26–49%; 3=50–74%; 4=75–100%)
Figures followed by the same letters within a column do not differ significantly ($P = 0.01$) according to Duncan's multiple range test.

6.4.3 *Effect of dipping tomato seedlings in NCP-WE on plant development and* Fusarium *wilt severity*

Tomato seedlings (28 days old), were dipped in a solution of NCP-WEs 50 g/l for 3, 6 and 9 hours before transplanting into 18-cm-diameter pots containing sterile soil which had been inoculated with two 14-mm-diameter mycelial plugs per planting hole.

Tomato seedlings dipped in NCP-WE for 9 h had better performance than those dipped for 3 h through the growing period. Disease severity was reduced as the duration of dipping in 50 g/l increased (Table 6.13).

6.4.4 *Effects of soil amendments with NCP on plant development and* Fusarium *wilt severity*

Twenty-eight-days old tomato seedlings were transplanted into 18-cm diameter pots containing sterile soil which had been inoculated with two 14-mm mycelial plugs and amended with 1.75, 3.5 and 7 g of

Table 6.13. Length of discoloured vascular system (LDV), mean dry shoot weight (DSW), fruit weight (FW), and fruit number/plant (FN) of tomato (cv Money Maker) plants 98 days after dipping in 50 g NCP-WE for different periods

Treatment (duration of dipping)	LDV	DSW	FW	FN
NCP 9 h	10.7 d	35.6 a	28.8 a	10.0 b
6 h	13.7 c	29.2 b	25.2 a	16.0 a
3 h	20.1 b	26.3 c	14.5 c	21.0 a
Water 9 h	18.9 b	28.3 b	21.2 b	17 a
6 h	20.0 b	24.1 d	15.6 c	21 a
3 h	24.3 a	21.0 e	7.1 d	14 ab

Figures followed by the same letters within a column do not differ significantly ($P = 0.01$) according to Duncan's multiple range test.

NCP per planting hole. Plant performance was assessed by measuring stem diameter, shoot height, and fruit yield.

Tomato plants from soil amended with NCP performed better than plants from non-amended soil through the growing season. Tomato plants from soil amended with 7 g NCP had significantly better plant performance, compared to plants from soil amended with 1.75 g NCP. Disease severity based on wilt index and length of discoloured vascular tissue was significantly higher for tomato plants in soil amended with 1.75 g and lowest in soil amended with 7 g of NCP (Table 6.14).

These trials showed that NCP treatments improved nutritional status of the plants and had a suppressive

Table 6.14. Length of discoloured vascular system (LDV), mean dry shoot weight (DSW), fruit weight (FW), and fruit number/plant (FN) of tomato cv Money Maker 98 days after transplanting into soil inoculated with F. o.l. and amended with different amount of NCP

Treatments	LDV	DSW	FW	FN
NCP 7 g	7.4 d	38.6 a	50.8 a	16 a
NCP 3.5 g	14.0 c	29.5 b	36.3 b	19 a
NCP 1.75 g	22.8 b	25.4 c	27.0 c	11 b
Control	255.6 a	17.8 d	12.0 d	8 b

Figures followed by the same letters within a column do not differ significantly ($P = 0.01$) according to Duncan's multiple range test.

effect on F.o.l. However, to fully determine their potential for management of *Fusarium*, its effect on microorganisms antagonistic to F.o.l. need to be evaluated.

6.5 EFFECTIVENESS OF NEEM PRODUCTS AGAINST DIPTERAN LEAFMINERS ON TOMATOES

The effects of seedbed treatments with neem cake powder, and foliar sprays with water extracts on leafminers, and their natural enemies are being tested in a screenhouse and the field. The tomato cv Cal-J is being used for these trials.

6.5.1 *Nursery treatments*

The effect of amendments with NCP in the seedbed on germination and plant development and leafminer infestation was studied in a trial in a screenhouse. For that purpose tomato seeds were sown in trays containing soil amended with NCP at a rate of 25, 50 and 100 g per 7 kg of soil.

Amendments with NCP at the highest rates had a detrimental effect on germination. Germination was delayed and the percentage of germination was much lower in soil amended with 100 g (68%) and 50 g (77%) than in untreated soil (86%) or soil treated with NCP 25 g (91%). The effect on leafminers could not be measured due to the high plant mortality in some of the treatments.

6.5.2 *Effect of foliar applications with NCP-WE on leafminers*

Effect of foliar applications with NCP-WEs at two concentrations (25 g/l and 50 g/l) on leafminers was compared to a control. Tomato leaves with mines were collected from a field treated with NCP-WE 25 and 50 g and a control (sprayed with water) in Machakos and kept in the laboratory for leafminer emergence.

The number of larvae from untreated plants was higher (2.4 larvae/leaf) than from plants treated with neem at 25 g/l (1.1 larva/leaf) and 50 g/l (1 larva/leaf). Neem treatments affected larval and pupal survival as indicated by the lower survival to adult from larvae collected from neem treated plants. Larval and pupal mortality increased with the increase in concentration of NCP as shown by the adult emergence which was much lower in plants treated with NCP-WE at 50 g/l (10%) followed by plants treated with 25 g/l NCP-WE (27%) and untreated plants (71%).

In a second field trial the effect of foliar sprays with NCP-WE at 50 g/l on leafminers was compared with the chemical evisect (0.4 kg/ha) and an untreated control (sprayed with water). The trial was set in a randomised complete block design with five replicates. The treatments were applied five times on a weekly basis, and then discontinued due to the onset of heavy rains. The number of leafminers from ten randomly selected plants were recorded. Twenty trifoliate leaves with mines were collected weekly from each plot.

A higher percentage of dead larvae was recorded on plants treated with neem (62%) and evisect (54%), than on plants treated with water (25%). However, there was no difference in larval survival to adult in any of the treatments (Table 6. 15). This disagreement with the results from the previous trial could be due to the heavy rains during the last weeks of the experiment, which could have washed off the applied products.

More parasitoids emerged from water-treated plants, followed by neem- and evisect-treated plants. However this was not statistically significant (Table 6.15).

Table 6.15. Emergence of adult leafminers (*Liriomyza* spp.) and its parasitoids from tomato foliage treated with five weekly applications of NCP-WE and evisect

Treatment	Live larvae	Adult emergence %	% Parasitism
Control (water)	587 a	74 a	8.7 a
NCP-WE (50 g/l)	471 a	73 a	10.4 a
Evisect	314 b	75 a	10.3 a

Means within a column followed by same letters are not significantly different at $P = 0.05$ according to Student-Newman-Keuls test.

6.6 EFFECTIVENESS OF NEEM PRODUCTS AGAINST DIPTERAN LEAFMINERS ON FLOWERS

This trial was conducted in collaboration with Homegrown Kenya in Naivasha. The effectiveness of several concentrations of NCP-WEs for drenching (2, 4 and 8 g/l) and as foliar sprays (12.5, 25 and 50 g/l), to control dipteran leafminers, were tested in microplots of asters in Naivasha. However, due to a general decline of leafminer infestations, it was not possible to measure the effect of the different treatments on leafminer populations.

6.7 NEEM PRODUCTS FOR MANAGEMENT OF LEAFMINERS AND THRIPS ON PASSION FRUITS

A field trial to test the potential of foliar applications with neem oil (1,5 and 3%), NCP-WEs (25 and 50 g/l), for management of thrips and leafminers on passion fruit was started in September 1997 at Kakuzi Ltd, Ruiru. Weekly applications of these neem products were compared with the standard insecticide malathion and water as control. Data were taken on leafminer and thrips infestations on natural enemies and visits by bees. Unfortunately, it was not possible to assess the effect of the treatments on insect populations and damage due to a general decline in thrips and leafminer populations since October 1997, when the unusually heavy rains started.

6.8 EFFECT OF DIFFERENT NEEM PREPARATIONS FOR MANAGEMENT OF ROOT KNOT NEMATODES ON TOMATOES

The effects of dipping in NCP-WEs and amendments with NCP on root-knot nematodes infestation on tomatoes were tested in field trials in Naivasha at Hortitech (K) Ltd.

In the first treatment, bare root seedlings were dipped in NCP water extracts (50 g NCP/ l water for 3 h before transplanting. In the second treatment the soil was amended with 3.5 and 7.0 g of NCP in the planting hole at the time of transplanting. These treatments were compared to an untreated control and to the nematicide Nemacur.

Plant establishment was adversely affected by both bare root dipping treatments. Plant growth was affected by the bare root treatments and by soil amendment with 7.0 g NCP per plant. In a subsequent trial, bare root dipping with NCP-WE at 10 and 20 g /l for 3 hours did not affect plant establishment nor growth. Unfortunately, the effect of the treatments on root-knot nematodes could not be measured because the tomato plants were wiped out by other diseases.

6.8.1 *Amendments with NCP and NSP for root-knot nematode management on tomatoes*

Scientists: *L. Njuguna (KARI), A. M. Varela (ICIPE)*

Amendments with NCP in the seedbed and NCP and neem shell powder at transplanting were conducted in a screenhouse under controlled conditions at KARI. Previous to amendment, the soil was sterilised and infested with root-knot nematodes.

Amendment in the seedbed

Tomato seeds were sown in sterile soil amended with NCP at rates of 25 and 50 g and compared with an untreated control. Seeds were sown in trays (100 per tray) with four replicates per treatment. Soil was inoculated with 500 nematodes per tray 2 weeks after plant emergence. Data on growth and nematode infestation and attack, were recorded from 80 seedlings per treatment before transplanting. One hundred sixty plants per treatment were transplanted into soil infested with nematodes and arranged in a RCBD in four replicates in a screenhouse. Eighty plants per treatment were evaluated 4 weeks after transplanting and 8, 12 weeks after transplanting. Nematode attack was measured by using a rating chart from 0 to 10 (0= no nematodes, 1–4= galling of secondary roots only, 5–10= galling of primary lateral and tap roots, 5= 50% roots galled and 10 for the maximum attack possible).

Germination was not affected by treatments, but seedlings grown in soil amended with 50 g were smaller than the ones grown in soil treated with 25 g and untreated soil. However, after transplanting, this difference vanished as indicated by plant height (Table 6.16). Nematode attack before transplanting was low in all treatments as indicated by low root-knot nematode index (less than 1 for all treatments).

The percentage of wilting plants was higher in the untreated plants 12 weeks after transplanting. However, there was no relationship between the percentage of wilted plants and the root galling,

Table 6.16. Performance of tomato seedlings grown in soil amended with NCP and infested with nematodes before transplanting and 4 weeks after, transplanted into soil infested with root-knot nematodes

Treatment	Plant height (cm) Before transplanting	Four weeks after transplanting
0 g (control)	26.8 ± 0.61 a	34.7 ± 1.17 a
25 g NCP	25.2 ± 0.55 b	33.4 ± 1.40 a
50 g NCP	18.9 ± 0.49 c	32.5 ± 1.38a

Avg ± SE; Data from 20 plants.
Means within a column followed by same letters are not significantly different at $P = 0.05$ according to Student-Newman-Keuls test.

which was severe in plants from all treatments (Table 6.17). Probably the high number of wilting plants in some of the untreated plots was not due to nematodes. Further trials are needed to determine if the differences observed in wilting are related to the neem treatments.

AMENDMENTS WITH NCP AND NEEM SHELL POWDER IN THE PLANTING HOLE

A trial to study the effect of adding NCP and neem shell powder (NSP) in the planting hole at transplanting on root-knot nematode attack on tomato was started in November 1997. Amendments of 3 g NCP and 7 g NSP were compared with furadan (1 g) and an untreated control in potted tomato plants in a screenhouse. Previous to treatment the soil was sterilised and then infested with 500 nematodes per plant.

Other trials on use of neem products for pest management on export vegetables are being reported by the ICIPE-USAID Export Vegetable Project.

(See under the report on Horticultural Crop Pests.)

Output

Conferences attended and papers

Rocco D. 'Production and commercialisation of neem-based insecticides' was presented at the seminar 'Neem for Sustainable Agriculture and Environmental Conservation' held at ICIPE, Duduville on 30 September 1997.

Varela A. M. 'The environmentally friendly pesticides: Neem pesticide products'. Presented at the FPEAK seminar at HORTEC' 97 on 13 March 1997.

Varela A. M. and D. Rocco. 'Potential of commercialising neem-based products as ecofriendly biopesticides: A case study of research-industry linkage'. Presented at the ICIPE-EPZ special seminar 'Business Potential of the ICIPE Technopark' on 24 September, 1997.

Varela A. M. 'Neem for horticultural pest management' was presented at the seminar 'Neem for Sustainable Agriculture and Environmental Conservation' held at ICIPE, Duduville on the 30 September 1997.

Varela A. M. 'The use of botanicals for plant protection: The neem tree' was presented at the 'HCDA-ICIPE-USAID Training Workshop on Pest Management in Vegetable Crops for HCDA Technical Field Officers' on 25 September 1997.

Reports

Report of the activities conducted during the first year of the project was sent to GTZ in June 1997.

Table 6.17. Root-knot nematode infestation and damage on tomato plants, grown during the seedling stage in seedbeds amended with NCP and 12 weeks after, transplanted into soil infested with root-knot nematodes

Treatment	R-K nematode counts[1] Avg ± SE	R-K nematode index[2] Avg ± SE	% Wilted plants[3] Avg ± SE
0 g (control)	31571.1 ± 1236.1	8 ± 0.0 a	51.2 ± 17.84 a
25 g NCP	2563.8 ± 887.5	6.8 ± 0.63 a	18.8 ± 2.39 ab
50 g NCP	1828.4 ± 1060.2	6.8 ± 0.48 a	15.0 ± 3.54 b

[1]Per 200 ml soil.
[2]Index from 0–10.
[3]Out of 20 plants.
Means within a column followed by same letters are not significantly different at $P = 0.05$ according to Student-Newman-Keuls test.

Capacity building

The following postgraduate students conducted their research under the project:

S.O. Okoth. Kenyatta University MSc student.

N. Kuesters. University of Hannover, Germany.

M. Muli. Kenyatta University. MSc student.

K. K. Stanley. Kenyatta University. MSc student

D. Pacho . University of Pretoria. PhD Student.

Varela A. M. Lecture on 'Neem-based pesticides for pest management in vegetables' was given at a field school day at Nguruman, 17 October, 1997

Varela A. M. Lecture on 'Neem for horticultural pest management' was presented at the 6th Training Workshop 'How to Grow and Use Neem', organised by the ICIPE-Finland-UNEP Neem Awareness Project at Mbita Point Field Station, 31 October 1997.

AGRICULTURAL RESEARCH

ANIMAL HEALTH MANAGEMENT

I. TSETSE

African trypanosomosis remains a major constraint to livestock production and continues to impede intensification of crop-livestock production systems across vast areas of the humid and subhumid zones of Africa that hold the greatest potential for increased agricultural production.

ICIPE's research effort has focused on enhancing the management of human and animal trypanosomosis through the development of integrated vector approaches based on tsetse behaviour, population ecology, tsetse-trypanosome and tsetse-host interactions. In fact, ICIPE has been in the forefront of developing, integrating and promoting appropriate technologies for sustainably managing disease vectors.

During the 1995-97 reporting period, research activities fell under four major projects:

- Development and Application of Sustainable Tsetse Management Technologies for Agropastoral Communities in Africa (funded by the European Union)
- A Comparative Assessment of the Impact and Sustainability of Community Participation in the Management of Trypanosomosis in East and Southern Africa (funded by the DFID)
- Integrated Approach to the Assessment of Trypanosomosis Control Technologies and Their Impact on Agricultural Products, Human Welfare and Natural Resources in Tsetse-Affected Areas of Africa (funded by IFAD)
- Sustainable Management of Trypanosomosis and Tsetse Flies through a New Concept: The Lethal Insect Technique (LIT).

The latter is a new project initiated with funds from the Austrian Development Corporation in late 1997. The major objectives of this new project are to explore the possibility of controlling tsetse using entomopathogens and/or insect growth regulators and to develop an improved and cost-effective tsetse mass rearing system.

Much effort was also put in strengthening regional collaboration and ICIPE now has strong linkages with CIRDES and ITC in West Africa, with RTTCP in Zimbabwe, South Africa, Uganda, Ethiopia, Rwanda, Mozambique, ASARECA and with our Kenya national partners, KETRI, KWS and the Department of Veterinary Services. Tsetse research scientists also actively participated in capacity building activities both in Kenya and other institutions in the region. Four PhD students are at an advanced stage in writing their dissertations and more than 50 technicians from several different African countries have been trained in integrated tsetse management. More than 400 farmers have been trained in Kenya and in Ethiopia in tsetse management. In addition, the International Committee of the Red Cross sent 12 technicians from Somalia to ICIPE to be trained in basic tsetse biology and in trap making.

II. LIVESTOCK TICKS

Ticks and tick-borne diseases (T & TBDs) constitute a major constraint to livestock production. Global losses due to T & TBDs in cattle alone have been estimated at US $13.9-18.7 billion annually. In Africa ticks are an important animal problem. The most important are *Rhipicephalus* spp. which transmit theileriosis (*Theileria parva*), *Amblyomma* spp. (for heartwater; also associated with dermatophilosis), *Boophilus* spp. (for babesiosis and anaplasmosis) and *Hyalomma* spp. (for *Theileria annulata*—tropical theileriosis). It is generally accepted that theileriosis, heartwater and dermatophilosis are the major tick-borne/tick-associated diseases of grazing cattle.

Control of ticks has relied heavily on the use of acaricides applied in dips or as sprays. The use of acaricides is fraught with several problems such as prohibitive costs, development of acaricide resistance in ticks and contamination of the environment, meat and milk. The annual costs of acaricide use in several countries have been estimated at US$ 12 million (Zambia), US$ 26 million (Uganda), US$ 13 million (Zimbabwe) and US$ 26 million (Tanzania). There is no major acaricide group to which ticks are not at least partially resistant. The recent spread of resistance to synthetic pyrethroids in *Boophilus* spp. of ticks in many parts of the world has forced veterinary authorities and farmers to seek new alternatives such as amitraz, however the risk of resistance developing in this recently introduced acaricide remains. With the exorbitant cost of developing new drugs currently estimated at US$ 230 million per compound, commercial companies are reluctant to get involved in development of drugs such as acaricides, which are mainly marketed in the developing world and to which resistance develops rapidly.

In view of the above-mentioned problems, alternative tick control methods that are effective, affordable, less toxic to the environment and less likely to allow tick resistance to develop are needed. The goal of the Ticks Megaproject (TMP) is to improve livestock health and productivity through the use of sustainable integrated tick management strategies based on sound understanding of ecology, behaviour, vector–host and vector–parasite relationships of the economically important tick species. The overall objective is to develop integrated strategies for the control of major ticks and tick-borne diseases in collaboration with other institutions working in the same areas of research and on tick-borne diseases. Specifically, ICIPE strives to

- test the effects of individual and integrated cultural/traditional tick control practices on tick populations, tick-borne diseases (TBDs) and cattle productivity, and to study the socioeconomic issues that determine adoption by target communities;
- improve the T3HOST model for *R. appendiculatus*, to develop models for other important tick species and to use the models to optimise individual and integrated tick control strategies;
- develop tick control strategies using entomogenous fungi, nematodes and parasitoids as components of integrated management of T & TBDs;
- develop anti-tick vaccine against *R. appendiculatus* and transmission blocking vaccine against TBDs, especially theileriosis.

The progress made from 1995 to 1997 in developing various components of ICIPE'S integrated tick control strategies and tick models (*ICIPE 5-Year Plan*, pp. 45–61) is presented herein.

Animal Health

TSETSE

X. Development and Application of Sustainable Tsetse Management Technologies for Agropastoral Communities in Africa

Donor: European Union

A. BASIC STRATEGIC RESEARCH ON TSETSE BEHAVIOUR AND BIOLOGY

1. IDENTIFICATION OF KAIROMONE ATTRACTANTS FOR *G. FUSCIPES FUSCIPES* (TST-2)

Background, approach and objectives

Since previous work at ICIPE showed that more than 90% of the blood meals of *Glossina fuscipes fuscipes* in Kenya come from monitor lizards, considerable effort has been put in identifying and evaluating candidate compounds from these preferred reptilian hosts, both in the laboratory and under field conditions.

Participating scientists: *A. Hassanali, R. K. Saini*, M. Girma, P. Njagi (*Project Leader)*

Assistants: *E. Mpanga, J. Andoke, P. Ahuya, J. Mbayi, W. Ouma*

Work in progress

GC-EAD and GC-MS analyses of volatiles collected from monitor lizards, indicate that these volatiles are made up of a series of homologous aldehydes (C_8–C_{15}). Three aldehydes (C_{10}, C_{11} and C_{12}) which elicited strong electrophysiological responses have been identified and characterised. In the wind-tunnel, a mixture of these three compounds elicited activation and upwind flight of *Glossina fuscipes fuscipes* flies.

Field tests in Keto Valley, Ethiopia with blends of these aldehydes, increased *Glossina fuscipes fuscipes* catches by two times; catches of females were increased three times (Table 1.1). However, in Rusinga Island in Kenya, inconsistent results (varying from no increase to twofold increases) were attained. These variable results in Kenya could be attributed to very low densities of flies, present in the experimental sites. In addition, we think that additional attractants may

Table 1.1. Mean catch of *Glossina fuscipes fuscipes* with pyramidal traps baited with different doses of a mixture of C_{10}, C_{11} and C_{12} aldehydes

Release rate (mg/h)	Mean catch					
	Female		Male		Female + Male	
	D. means	Index	D. means	Index	D. means	Index
Control+	1.0	1.0	1.3	1.0	2.3	1.0
0.29	2.0	2.1	1.5	1.18	3.6	1.59
0.71	3.1	3.23*	2.1	1.63	5.3	2.30
1.57	3.4	3.55*	1.7	1.30	5.1	2.23

*Significant at $P < 0.05$.
+Control is unbaited pyramidal trap.

also be involved in host location by the fly. Field observations on fly–host interactions and the results of field tests with monitor lizards and their excretory products, suggest that urine and odours emanating from active hosts after their basking routine, might also be associated with additional attractant components. Hence, the monitor lizard urine is also being analysed for candidate kairomones. So far, GC-EAD and GC-MS analyses of 10 different collections of monitor lizard urine, have been undertaken. Three, EAG active compounds (1-octen-3-ol, phenol and 4-cresol) were identified in two of the urine samples. However, in all others, 1-octen-3-ol was not present. Field tests were therefore conducted with only the two phenols. Field investigations undertaken in Keto, Ethiopia indicate that phenols did not increase catches of *Glossina fuscipes fuscipes* (Table 1.2). A mixture of the identified aldehydes and phenols was also not effective (Table 1.3).

Our field experiments also indicate that *Glossina fuscipes fuscipes* flies are maximally attracted to mobile lizards at optimum metabolic cycles, following periods of basking in the sun. Hence, the metabolic state of the lizards needs to be taken into consideration during trapping of volatiles from these reptiles. In addition, the late-eluting (high-boiling) components in these volatile fractions need to be examined, as possible short range/contact arrestant signals.

Table 1.2. Mean catch of *Glossina fuscipes fuscipes* with pyramidal traps baited with different doses of phenols (4-cresol and phenol)

Release rate (mg/h)	Mean catch: Female D. means	Female Index	Male D. means	Male Index	Female + Male D. means	Female + Male Index
Control+	1.7	1.0	0.5	1.0	2.0	1.0
0.26	2.0	1.21	0.6	1.11	2.7	1.30
0.47	1.7	0.99	0.9	1.69	2.7	1.30
0.82	1.6	0.98	0.7	1.31	2.1	1.02

+Control is unbaited pyramidal trap.

Table 1.3. Mean catch of *Glossina fuscipes fuscipes* with pyramidal traps baited with different doses of mixture of aldehydes and phenols

Release rate (mg/h)	Mean catch: Female D. means	Female Index	Male D. means	Male Index	Female + Male D. mean	Female + Male Index
Control+	4.7	1.0	1.9	1.0	7.4	1.0
a	4.6	0.98	2.1	1.11	7.0	0.95
b	4.4	0.93	2.8	1.47	8.0	1.08
c	4.2	0.91	3.0	1.60	7.0	0.98

a= aldehyde (1.57 mg/h) + phenol (0.82 mg/h)
b=aldehyde (1.57 mg/h) + phenol (0.26 mg/h)
c=aldehyde (0.29 mg/h) + phenol (0.82 mg/h)
+Control is unbaited pyramidal traps.

2. LARVIPOSITION PHEROMONES (TST-5)

Participating scientists: *R. K. Saini, A. Hassanali, P. Njagi*

Assistants: *E. Mpanga, J. Andoke, P. Ahuya, W. Ouma*

Collaborator: • *Regional Tsetse and Trypanosomiasis Control Programme (RTTCP), Zimbabwe*

Work in progress

2.1 LARVIPOSITION PHEROMONES OF *GLOSSINA PALLIDIPES*

Laboratory behavioural experiments indicate that as with *Glossina morsitans morsitans*, female, *Glossina pallidipes* preferred to larviposit over moist sand, conditioned by previously allowing larvae to pupariate in it (Table 2.1).

Work is in progress to identify the GC-EAD active peaks of volatile collections of *Glossina pallidipes* larvae. Identification of three of the major compounds has been confirmed and authenticated by GC-MS as C_{12} to C_{14} hydrocarbons. Identification of other non-hydrocarbon EAD active peaks is in progress, but is hampered by the presence of many inactive peaks. Further identification work has also been frustrated by a lot of variability among samples and the fact that the olfactory system of laboratory-reared *Glossina pallidipes* appears to be insensitive to semiochemicals including larval volatiles.

Table 2.1. Larviposition of *Glossina pallidipes* to sand conditioned with larvae (treatment) *vs* sterilised sand (control)

No. of larvae used for conditioning sand	Flies released	Flies larvipositing	Response % cont.	Response % Trt.
22	18	15	6.7	93.3
30	11	8	25.0	75.0
40	12	9	22.2	77.9
24	23	8	50.0	50.0
20	11	11	27.3	72.7
36	20	7	14.3	85.7

2.2 FIELD EVALUATION OF *GLOSSINA MORSITANS MORSITANS* LARVIPOSITION PHEROMONE

Evaluations of *n*-pentadecane (major component of the larviposition pheromone of *Glossina morsitans morsitans*) continued in Zimbabwe in collaboration with Dr J. Hargrove of RTTCP. Initial field tests undertaken by Dr Hargrove showed no reason to suggest any effect of *n*-pentadecane on the number of tsetse puparia found in any of the artificial larviposition sites (Table 2.2). This could be attributed to the experimental design which placed treated and control burrows within the same cluster close to one another, resulting in diffusion of pentadecane over the whole site. This may have made it difficult for the gravid females to discriminate between control and treated burrows. These experiments were hence repeated using only one dose per cluster of four burrows.

Significantly more *Glossina morsitans morsitans* pupae were deposited in pentadecane-treated (high doses) burrows, compared to untreated burrows (control) in Chuyi. As expected, there was no difference between the control and pentadecane-treated burrows for *Glossina pallidipes*.

At Rekomitijie, however, the results were not significant as one of the sites was characterised by a lot of pupae deposition throughout the experiment, indicating the need for further field experiments in view of the dose and densities of flies present at the sites. Further optimisation of the larviposition sites is also needed. In addition, alternative strategies need to be explored, such as the use of electric nets and strategically placed targets, to simulate visually the entry points of burrows.

Table 2.2. The effect of using pentadecane (diluted to 1 or 10% or undiluted, 100% in artificial warthog burrows, on the number of larvae deposited by tsetse flies, *Glossina morsitans morsitans* (G.m.) and *G. pallidipes* (G.p.) in Rekomitjie, Zimbabwe

I. Total pupae from all burrows after four replicates of the randomised blocks at each of the sites shown

	A		B		C		D		E		M		O	
Treatment	G.m.	G.p.	G.m.	G.p.	G.m.	G.p.	G.m.	G.p.	G.m.	G.p.	G.m.	G.p.	G.m.	G.p.
1%	46	31	11	4	9	6	21	4	26	13	7	1	14	1
10%	45	38	11	9	8	4	12	4	35	19	9	4	12	1
100%	32	34	9	9	11	7	9	5	28	21	9	3	15	0
Control	26	28	10	8	10	1	12	6	33	18	10	2	16	0
Totals	141	131	41	30	38	18	54	19	122	71	35	10	57	2

GT=779

II. Total pupae from all burrows after two replicates at each of the sites shown

	I (1)		J (1)		K(1)		L(1)	
	G.m.	G.p.	G.m.	G.p.	G.m.	G.p.	G.m.	G.p.
1%	1	7	3	8	17	9	4	1
10%	0	3	1	12	17	5	12	1
100%	1	3	3	14	14	12	11	3
Control	0	6	7	15	8	5	12	6
Total	2	19	14	49	56	31	39	11

GT = 221

	K(2)		L(2)	
	G.m.	G.p.	G.m.	G.p.
0.01%	49	6	11	0
0.10%	41	3	8	0
1%	37	4	7	0
Control	40	2	12	0
Totals	167	15	38	0

GT = 220

	I(2)	
	G.m.	G.p.
100%	2	4
Acetone/Sachet	1	1
Acetone/Sachet/100%	1	1
Control	2	2
Totals	6	8

GT = 14

	J(2)	
	G.m.	G.p.
100%	14	1
Warthog urine	6	2
Warthog urine +100%	9	2
Control	10	4
Totals	45	9

GT = 54

3. EVALUATION OF POTENTIAL ALLOMONES (REPELLENTS) (TST-4)

Participating scientists: *R. K. Saini, A. Hassanali, M. Girma*

Assistants: *J. Andoke, E. Mpanga, P. Ahuya, J. Mbayi, W. Ouma*

Collaborators: • *Kenya Wildlife Services* • *ILRI*

Work in progress

Work is in progress to identify and evaluate potential allomones for the *morsitans* group of flies by screening both natural and synthetic compounds. Most progress has been made in synthesising and evaluating responses of major structural analogues of methoxyphenol, a minor component of bovid urine, both in laboratory and field investigations. In wind tunnel bioassays, methoxyphenol showed repellent activity. However, in field trials though a reduction in the number of flies caught occurred, the difference was not significant. Based on a previous structure-activity study of phenolic analogues, we screened four additional analogues in the wind tunnel. Three field trials with one of them confirm that the compound is a potent repellent for *G. pallidipes* as trap catches and even catches using ox odour itself were reduced by nearly 80%. This major finding will assist in synthesising additional analogues and identifying features essential for repellent activity.

Screening of volatiles from unpreferred hosts was initially hampered by the non-availability of the unpreferred animals. Agreement, however, was made with the Kenya Wildlife Services and ILRI, who assisted in the capture and maintenance of some of these animals. Hence, collection of volatiles from water bucks (unpreferred hosts) is in progress on a regular basis to screen for repellent activity.

Output

Publications

Saini R. K., Hassanali A., Andoke J., Ahuya P. and Ouma W. P. (1996) Identification of the major components of the larviposition pheromone from the larvae of tsetse flies *Glossina morsitans morsitans* Westwood and *Glossina morsitans centralis* Machado. *Journal of Chemical Ecology* 22, 1211–1220.

Conference papers and seminars presented

Hassanali A. (1997) Identification of kairomones for riverine tsetse. Paper presented at the internatioanl study workshop on integrated rural development through sustainable management of tsetse and trypanosomiasis/mosquito and malaria, Addis Ababa, Axum, Ethiopia, 3–8 February 1997.

Saini R. K. (1995) Communication in insects. Keynote lecture presented to the 3rd Annual Postgraduate Scientific Conference of the Zoology Department of Kenyatta University Nairobi, Kenya, 5 July, 1995.

Saini R. K. (1996) The potential of semiochemicals to manipulate tsetse behaviour. Keynote paper presented at the request of FAO at the first, research coordination meeting of the coordinated research programme on improved attractants for enhancing the efficiency of tsetse fly suppression operations and barrier systems used in tsetse control/eradication campaigns, KETRI, Kenya, 23 September, 1996.

Saini R. K. (1996) Larviposition behaviour of tsetse mediated by pheromones emanating from larvae. Paper presented at the International Behavioural Ecology Conference, Canberra, Australia, 29 September–4 October, 1996.

Saini R. K. (1997) Role and importance of semiochemicals in tsetse control. Paper presented at the international study workshop on integrated rural development through sustainable management of tsetse and trypanosomiasis/mosquito and malaria. Addis Ababa, Axum, Ethiopia, 3–8 February, 1997.

Saini R. K. (1997) New semiochemicals to manage tsetse flies. Symposium paper presented at the 14th Annual Meeting of the International Society of Chemical Ecology, Vancouver, Canada 12–16 July 1997.

Saini R. K. and Hassanali A. (1997) Larviposition of tsetse mediated by pheromones emanating from larvae. Paper presented at the 24th OAU/ISCTRC, Maputo, Mozambique, 29 Sepetember–3 October 1997.

Capacity building

PhD students supervised

J. B. Muhigwa. Visual and olfactory cues of *Glossina fuscipes fuscipes* (R. K. Saini and M. O. Bashir, Advisors)

C. Akinyi. Factors affecting the reproductive performance and the effects of certain insect growth regulators on the reproduction of *Glossina fuscipes fuscipes* (R. K. Saini and N. O. Oguge, Advisors)

N. Gikonyo. Semiochemical basis of non-preference of water buck (*K. defassa*) by *G. morsitans* group of tsetse (A. Hassanali, P. Njagi and R. K. Saini, Advisors)

International training courses

At the request of the International Red Cross, Dr Saini organised and coordinated two International Group Training Courses on Basic Tsetse Biology and Trapping Technologies for Mid-level Professionals from Somalia. (14 –26 July 1996 and 20 April–5 May 1997).

Lectures

Larviposition behaviour and use of repellents: 4 lectures presented at the Regional Training Course on Principles of Integrated Area-Wide Tsetse/Trypanosomiasis control (Eradication with Emphasis on SIT), Tanga, Tanzania 1–4 Dec. 1997.

4. DEVELOPMENT OF ODOUR ATTRACTANTS FOR *GLOSSINA F. FUSCIPES* AND OTHER RIVERINE TSETSE FLIES (TST-2)

Participating scientist: *M. M. Mohamed-Ahmed (Activity Leader)*

Assistants: *J. Muchiri, S. Mokaya, P. Ongele*

Background

Riverine tsetse are the main vectors of animal and human trypanosomosis in Central and West Africa. In the past, vector control was done largely by spraying with insecticides, but lately insects are trapped using unbaited cloth traps. An odour bait dispensed near traps or simple insecticide-coated cloth screens would improve monitoring and control of these flies. Since 1992, ICIPE has been identifying effective odour attractant(s) for *G. f. fuscipes*.

Three contrasting tsetse habitats were selected near Mbita Point Field Station and Ungoye Research Site along the Kenya shore of Lake Victoria. The studies started with investigations into feeding preferences and periodicity of flies for optimum trap placement and efficiency. By late 1994 studies commenced on the responses of tsetse to live animals, their models and odour. Some achievements during the latter work are highlighted below.

Work in progress

4.1 LANDING RESPONSES OF *GLOSSINA FUSCIPES FUSCIPES* NEWSTEAD (DIPTERA: GLOSSINIDAE) TO ANIMAL MODELS

Landing responses of *Glossina fuscipes fuscipes* Newstead were studied in three vegetation types near Lake Victoria, Kenya using electrified pipe models mimicking Nile monitor lizards, *Varanus niloticus niloticus* Laurenti, (preferred hosts) and box and drum models mimicking cattle and goats (rejected hosts). Effect of odour, carbon dioxide (2.5 l/min) and fresh lizard urine (1000 mg/h) on landing, was studied. Catches of males and females increased significantly with increase in size of the model, regardless of shape or location. The percentages of females and well-nourished males also increased significantly with model size. Both carbon dioxide and lizard urine improved the landing of males on model, but only carbon dioxide did so for females.

4.2 RESPONSES OF *GLOSSINA FUSCIPES FUSCIPES* (DIPTERA: GLOSSINIDAE) AND OTHER DIPTERA TO CARBON DIOXIDE IN LINEAR AND DENSE FORESTS

Near Lake Victoria, Kenya, the responses of *Glossina fuscipes fuscipes* Newstead and other blood-sucking Diptera to carbon dioxide in linear and dense forests were studied together with concurrent wind direction and speed. Flies were caught by using biconical traps and electric nets. Carbon dioxide dispensed at 5 l/min at the linear forest failed to increase significantly the attraction or catches of *G. f. fuscipes* in traps. In contrast, catches of non-biting Muscidae, Stomoxyinae and Tabanidae were improved by up to 13 times. Inside the dense forest, carbon dioxide released at 2.5 l/min increased significantly the attraction and catches of tsetse by 1.7 and 2.6 times, respectively; catches of other Diptera increased by over 90 times. The unbaited trap efficiency was greater at the linear than in the dense forest and greater for males than females in both habitats.

4.3 OLFACTORY RESPONSES OF *GLOSSINA FUSCIPES FUSCIPES* TO THE MONITOR LIZARD, *VARANUS NILOTICUS NILOTICUS*

Visual and olfactory responses of *Glossina fuscipes fuscipes* Newstead to the monitor lizard, *Varanus niloticus niloticus* Laurenti were studied using various catching devices near Lake Victoria, Kenya. Electric nets baited with visible lizards, caught more males (2.1x) and significantly more females (2.0x) than unbaited nets. Lizards concealed in electrified black PVC pipe models, simulating the shape and size of a monitor lizard, increased significantly the catches of tsetse by 2.1 times. Fresh lizard urine dispensed at an evaporation rate of 500 to 1000 mg/h also increased significantly the catches of flies at biconical traps, electrified models and electric nets. Identification of chemical constituents of the odour could improve monitoring and control strategies for *G. f. fuscipes*, and possibly for other *palpalis* tsetse species.

4.4 FIELD RESPONSES OF *GLOSSINA FUSCIPES FUSCIPES* NEWSTEAD TO HUMANS, CATTLE, GOATS AND CARBON DIOXIDE

Field responses of *Glossina fuscipes fuscipes* to humans, cattle, goats and carbon dioxide were studied using various techniques, including ventilated pits and incomplete rings of electric nets. An empty unshaded ring of nets, attracted more tsetse than any enclosed live bait. A calf enclosed in a shaded ring attracted more tsetse than the empty ring or the unshaded calf. Odour of two or four cattle concealed in pits or carbon dioxide alone released at 5 or 8 l/min, increased significantly the catches of males by 2–4 times and females by 2–5 times. Odour of two cows was 80% more attractive for males and 135% more attractive for females than carbon dioxide released at 5 l/min. Both odours were more effective for females than males, and more effective for both sexes near electrified model alone, model plus electric net, net alone and least near a biconical trap. Biased catches on the downwind face of nets suggested that flies found the odour source by upwind anemotactic flight. Less comprehensive data indicated that the smell of humans or goats was either ineffective or slightly repellent.

Output

Publications

Mohamed-Ahmed M. M. Olfactory responses of *Glossina fuscipes fuscipe* (Diptera: Glossinidae) to the monitor lizard *Varanus niloticus niloticus*. *Bulletin of Entomological Research.* (In press).

Mohamed-Ahmed M. M. and Odulaja A. (1997) Diel activity pattern and host preferences of *Glossina fuscipes fuscipes* along the shores of Lake Victoria, Kenya. *Bulletin of Entomological Research* 87, 179–186.

Mohamed-Ahmed M. M. and Wynholds Y. (1997) Effects of vegetation and weather on trap catches of *Glossina fuscipes fuscipes* near Lake Victoria, Kenya. *Entomologia Experimentalis et Applicata* 14, 511–527.

Odulaja A. and Mohamed-Ahmed M. M. (1997) Estimation of the efficiency of the biconical trap for *Glossina fuscipes fuscipes* along the Lake Victoria shore, Kenya. *Entomologia Experimentalis et Applicata* 82, 19–24.

5. DEVELOPMENT OF AN ELISA SYSTEM TO IDENTIFY BLOOD MEALS FROM TSETSE

Participating scientists: *S. Mihok*, E. Osir (*Activity leader)*

Assistants: *J. Kabii, E. Munyoki, O. Maramba*

Collaborator: *University of Nairobi*

Background

Epidemiological studies often require a detailed understanding of the interactions between hosts, parasites and vectors. The insights gained can help guide the cost-effective application of many intervention techniques, for example the use of live-baits (insecticide-treated cattle) as opposed to trap/target technology. For some disease vectors, little or no information is available on host preferences, precluding the formulation of appropriate control strategies.

Work in progress

From 1995 through 1997, ICIPE consolidated past efforts to develop an ELISA system for the identification of blood meal residues in the guts of tsetse flies. This system is now undergoing the final stages of validation and is expected to be fully operational in 1998. The system can identify about 30 host species of interest to tsetse biologists and has been calibrated relative to about 50 species of wildlife and domestic animals in Africa.

The system is based on the following hosts:

Suidae	Bushpig *Potamochoerus porcus*, warthog *Phacochoerus aethiopicus*, domestic pig
Primates/Livestock	Human, common baboon *Papio cynocephalus*, dromedary camel, donkey, sheep, goat, cattle
Miscellaneous wildlife	Nile crocodile *Crocodylus niloticus*, monitor lizard *Varanus niloticus*, ostrich *Struthio camelus*, black rhinoceros *Diceros bicornis*, hippopotamus *Hippopotamus amphibius*, Burchell's zebra *Equus burchelli*, elephant *Loxodonta africana*, giraffe *Giraffa camelopardalis*, lion *Panthera leo*
Wild Bovidae	
Madoquinae	Kirk's dik dik *Madoqua kirkii*
Tragelaphinae	Bushbuck *Tragelaphus scriptus*, greater kudu *Tragelaphus strepciceros*, common eland *Tragelaphus oryx*
Hippotraginae	Oryx *Oryx gazella*
Reduncinae	Defassa waterbuck *Kobus ellipsyprimnus*
Alcelaphinae	Kongoni *Alcelaphus buselaphus*, blue wildebeest *Connochaetes taurinus*
Aepycerotinae	Impala *Aepyceros melampus*
Gazellinae	Grant's gazelle *Gazella granti*, Thomson's gazelle *Gazella thomsonii*
Bovinae	Buffalo *Syncerus caffer*

(See also the report under the Molecular Biology and Biotechnology Department.)

6. STUDIES OF FACTORS INFLUENCING VECTORIAL CAPACITY IN TSETSE FLIES

Background, objectives and approach

Differentiation of bloodstream trypanosomes into procyclic (midgut) forms is an important step in the establishment of infection in the tsetse vector. Consequently, most studies on the tsetse-trypanosome infections have concentrated on elucidation of fly midgut factors that mediate the formation of procyclic-form trypanosomes. Of the factors that have been implicated in the process, lectins, trypsin-like molecules and lysins appear to be the most important. Apart from these factors, the type of host blood at the time of an ineffective feed also plays an important role in determining the infection prevalence in tsetse. Buffalo and eland blood have been reported to support low infection prevalence compared to goat blood which enhances infection. In order to gain insight into the roles played by factors in tsetse and in host blood in the establishment of trypanosome infection, we are continuing the work that was reported in 1994.

The objective was to identify, isolate and characterise tsetse midgut factors involved in differentiation and lysis of trypanosomes. An additional objective was to examine factors in the blood of domestic and wildlife that modulate trypanosome infections in tsetse.

Scientist: *E. O. Osir*

Technician: *J. Kabii*

Donors: *EU, WHO (TDR) and Core*

Collaborators: *• Yale University (USA) • University of Nairobi (Kenya) • University of Bern (Switzerland) • IAEA/FAO Joint Division (Vienna)*

Work in progress

Crude midgut homogenate was prepared by feeding the tsetse flies, *Glossina morsitans* on blood meal, 24 h after emergence and then starving for 72 h prior to dissection of the midguts. The midgut factors involved in differentiation and lysis of trypanosomes were isolated from the crude midgut homogenate by a combination of ion-exchange and affinity column chromatography. The role of the isolated midgut lectin in differentiation of the trypanosomes was assessed *in vitro* by mixing it with freshly isolated parasites (5 x 10^6 trypanosomes/ml). Differentiation of the parasites was assessed microscopically on the basis of their morphological characteristics at different time intervals. The ability of various host blood to modulate differentiation of trypanosomes was assessed by allowing the flies to feed on blood samples from eland, buffalo, goat and rat, and differentiation assessed as described above.

The role of the isolated trypanolysin in lysis of trypanosomes was assessed by mixing double serial dilutions of the trypanolysin with equal volumes of freshly isolated trypanosomes (5 x 10^6 trypanosomes/ml). The plates were incubated (2 h at 27° C) and lysis assessed microscopically.

A midgut lectin with trypsin activity was successfully purified using a two-step ion-exchange and affinity chromatography. The molecule (M_r ~ 65,700) was comprised of two subunits (M_r ~ 28,800 and M_r ~ 35,700). The subunits are synthesised in the fat body and midgut tissues as precursors of M_r ~42,000 and M_r ~62,000, respectively. The lectin-trypsin complex was immunologically detected in the fat body, haemolymph and midgut tissues in an inactive form and the active form was present in the peritrophic membrane. The trypsin moiety was found to be synthesised by the midgut tissues. There was no cross-reactivity between the antibodies raised against the lectin-trypsin complex and midgut extracts from other haematophagous insects. The purified lectin-trypsin complex was found to be capable of inducing transformation of bloodstream trypanosomes to procyclic (midgut) forms. The transformation rate increased with concentration of the lectin-trypsin complex. Another midgut factor, trypanolysin, capable of lysing bloodstream trypanosomes, was isolated by a combination of ion-exchange and affinity chromatography. It was a high molecular weight molecule (M_r ~ 700,000). Unlike the lectin-trypsin complex, it had no trypsin activity. The activity of the molecule was not inhibited by the sugars tested. However, the activity was inhibited by diethyl pyrocarbonate. The different host blood meals showed different abilities to support transformation of bloodstream trypanosomes into procyclic forms. Compared to rat and goat blood, eland blood had the least capacity to support trypanosome transformation, while buffalo blood showed intermediate capacity. The low transformation rates observed in the eland blood was attributed to an inhibitory factor in the plasma fraction.

The ability of bloodstream trypanosomes to transform to procyclic forms is an important requirement for successful establishment of midgut infections in the tsetse. Midgut infections are, therefore, correlated to the ability of the midgut factors to either lyse the parasites or induce their transformation. In this study, a lectin-trypsin complex capable of inducing differentiation of bloodstream trypanosomes to procyclic (midgut) forms was isolated from *G. morsitans*. However, a similar molecule was not detected in midgut extracts of other haematophagous insects studied (*S. calcitrans, P. duboscqi, A. aegypti*). The presence of this molecule only in tsetse might explain why they are the only vectors of trypanosomes. The lectin-trypsin complex was found to be associated with several tissues such as the fat body, haemolymph, posterior midgut (inactive form) and the peritrophic membrane (the active form). The proximal association between the peritrophic membrane and the gut lumen where the lectin is supposedly secreted after stimulation by blood meal, emphasises the possible involvement of this molecule in interaction between tsetse tissues and trypanosomes, prior to or during parasite tropism.

The trypanolysin, which is also secreted in response to a blood meal, may be responsible for lysing the trypanosomes in refractory tsetse flies. Thus, susceptible flies simply do not secrete enough trypanolysin to remove the invading trypanosomes. Since these midgut factors are blood meal-induced, the infection prevalence would be expected to be influenced by the type of host blood at the time of an ineffective meal. Indeed, the results of these studies showed that rat and goat blood supported trypanosome transformation, whereas buffalo and eland blood gave intermediate and low transformation rates, respectively. The mechanisms by which host blood modulate midgut infections in tsetse are still not clearly understood.

Further characterisation of trypanolysin molecule need to be carried out in order to elucidate the mode of action and site of synthesis. Using a new assay for procyclin, the role of lectin-trypsin complex in trypanosome differentiation will be assessed further. The mechanism of lectin-trypsin mediated differentiation and trypanolysin-mediated lysis of the trypanosome also need to be elucidated.

The genes encoding for the trypsin-lectin complex and trypanolysin, need to be identified and sequenced. This will be achieved through collaboration with the Yale University (USA). The activation and expression of the genes for the above key molecules will be studied and finally a correlation established between the expressions of these genes and refractoriness or susceptibility of tsetse flies under field conditions.

Capacity building

Three ARPPIS PhD students are working in this area: G. Zimba; H. Abakar, L. Abubakar.

B. TRAPPING TECHNOLOGY

7. HOW EFFICIENT IS THE LATIN SQUARE DESIGN FOR TSETSE TRAPPING EXPERIMENTS?

Participating scientists: *A. Odulaja, I. M. Abu-Zinid*

Background, approach and objectives

The superiority of the latin square design (LSD) over the simpler and more flexible to execute alternative—the randomised complete block design (RCBD)—is usually taken for granted. Whereas the LSD is able to eliminate two sources of variation—compared to one eliminated by the RCBD—in addition to treatment effect, the design is less efficient than the RCBD when the day x site interaction effect is appreciable or when one of the two sources of variation (site and day) is statistically unimportant. It is therefore useful to investigate the relative importance of these sources of variation as well as the efficiency of the LSD, quantify the power of the design and the conditions under which it is most advantageous. This information is essential for the design and interpretation of results from tsetse trapping field experiments.

Work in progress

Five different latin square sizes (3x3, 4x4, 5x5, 6x6, 7x7) were composed from a 2200 trap-days data set collected at Nguruman, using all possible combinations of sites and consecutive days within each month. Data for each combination were analysed as LSD and as randomised complete block design (RCBD) using either the days or sites as the blocking factor. The efficiency of the LSD relative to the corresponding RCBD, termed RE, was obtained by comparing the observed information from the two designs. This is computed as

$$RE = \{(n_a + 1)/[(n_a + 3)s_a^2]\} \;/\; \{(n_b + 1)/[(n_b + 3)s_b^2]\},$$

where n_a and n_b are the ANOVA error degrees of freedom, and s_a^2 and s_b^2 are the error mean squares for the LSD and RCBD, respectively. The relative proportion of variation due to sites and days were also compared using their mean squares. This is presented as the importance of sites relative to days (RI), as sources of variation.

To explore the possibility that LSD efficiency depends on the relative magnitude of site and day effects, the median RE values were plotted against the median RI values and an appropriate regression model was fitted to the plot for each of the two blocking factors.

LSD was found to be more efficient than RCBD when block=days, but less efficient when blocks=sites, especially when experiments involve only three or four treatments. Effects due to site differences were found to be more important than day to day variability. By relating LSD relative efficiency to the relative importance of sites, it was found that LSD efficiency depended on the relative magnitude of effects of sites and days.

A plot of the median RE against the median RI showed some relationship between the two variables. The model

$$\mathrm{Log}_e Y = a + bX$$

where a and b are constants, was found to fit best to the plot with $R^2 = 81.97\%$ when blocks=days, and $R^2 = 36.69\%$ when blocks=sites. This suggests that LSD efficiency depends on the relative magnitude of site and day effects. The implication of this fit is that, on average, RCBD will be equally as efficient as LSD (RE = 1) when RI = -a/b. This gives an RI value of about 0.5 when blocks=days and about 25 when blocks=sites. For RI less than these values for the respective blocking factors, LSD will be less efficient (RE < 1), while it will be more efficient (RE > 1) for higher RI values. Since the range of the median RI obtained in this study is 3.2–28.8, with a mean of 17.2 ± 1.4, LSD is always likely to be more efficient than RCBD when blocks=days, but may not always be more efficient when blocks=sites.

8. ESTIMATION OF THE ABSOLUTE EFFICIENCY OF TSETSE TRAPS

Participating scientists: *A. Odulaja, M. M. Mohamed-Ahmed*

Assistants: *J. Muchiri, S. E. Mokaya, P. Ongelle*

Background, approach and objectives

The usually employed technique for determining the absolute efficiency of tsetse traps involves placing an incomplete ring of electrified nets around a test trap, thereby enabling the estimation of the total number of flies which approached and the proportion actually caught by the trap. The method assumes, among other things, that the flies neither avoid nor fly over the ring of nets while approaching, or departing from the trap. The violation of these assumptions will lead to wrong estimates of the efficiency. There is need therefore to develop hypotheses and analytical approaches to test and correct for the assumptions in the estimation of absolute efficiency for tsetse trap.

Work in progress

Prior to estimation of the absolute efficiency of the unbaited biconical trap for *G. f. fuscipes*, the proportions of the flies travelling naturally at various heights were estimated with 1 m^2 electrified nets placed between 0 and 4 m above the ground level. About 48 and 35% of male and female flies were respectively captured travelling above one metre.

The degree of avoidance of these nets by the flies was determined by comparing catches in traps surrounded and those not surrounded by the nets. Up to 13 and 35% of male and female files appeared to have avoided the nets. Fewer tsetse were caught in traps surrounded by an incomplete ring of nets of up to 2 m radius than in traps not surrounded. Significantly higher ($P < 0.05$) proportion of males (48.6%) were flying over the 1 m net than the females (35.4%).

By subtracting the observed outside net catches from the expected, and expressing the difference as a percentage of the expected catch, about 42–55% (46.7 ± 4.1%) of the total flies approaching the trap seemed to have avoided the nets, with the percentage ranging between 45–78 (61.4 ± 9.6%) for males and 27–51 (40.0 ± 7.1%) for females.

Since 42–55% of the flies were shown to 'see' and avoid the nets, the figures of the overflyers may well be taken to apply to the 45–58% which did not 'see' the nets. Provided that the flies did not fly over a net in an attempt to avoid it, it can be shown that 72–93% of all approaching flies will escape being caught by the 1 m net as against the mean of *ca* 42% obtained when assuming that the flies do not 'see' the nets. The proportions of flies which naturally fly over the ring of nets together with those which 'see' and avoid the nets must therefore be accounted for when estimating trap efficiency.

Higher estimates of trap efficiency were obtained for males than females and higher values for the 2 m radius than the 1 m radius ring. Higher efficiency estimates would probably be obtained if larger radii of the ring of nets were used. There is therefore a need to determine the optimum radius of the incomplete ring of nets in such experiments.

9. QUANTIFICATION OF THE SAMPLING BIAS OF TSETSE TRAPS

Participating scientists: A. Odulaja, L. C. Madubunyi

Background, approach and objectives

It has been noted that the susceptibility of tsetse to traps may be age-dependent. Many studies have suggested that all tsetse traps are biased in one way or another. A detailed knowledge of these sampling biases is needed to enable the translation of sample data into field population data. This knowledge could also lead to better evaluation of traps for tsetse control and better planning of tsetse control using traps. The sampling bias, in addition to the efficiency, of tsetse traps, determines how effective they can be in controlling the fly population.

Work in progress

Eight progressive stages of midgut evacuation (MES), which reflect increasing degrees of hunger, were used to define the hunger cycle in tsetse. In a thriving tsetse population, flies would normally not exceed MES 5 before re-feeding. Also, most flies should be in the early stages of the MES, and the probability of finding a fly in the MES should decrease as MES increases, if the population is to thrive. We denote such a probability density function (*pdf*) by $f(x)$, where x is the transformed MES. Our model is hence based on a mathematical representation of the proportion of tsetse at the various MES. The function $f(x)$ should hence be skewed to the right and have the largest values when x is small. The probability of finding tsetse in advanced stages of the MES should be higher for the disturbed than the undisturbed ecosystems scenario. The general class of the exponential distribution readily satisfies the required properties stated above.

Since odour-baited traps, primarily target hungry tsetse foraging for a bloodmeal, the MES distribution of the catches should ideally be similar to the hunger cycle described above. That is, the *pdf* should be two-tailed, with the direction and degree of skewness being trap-dependent. To cater for various possible performances of odour-baited traps, the *pdf* should be flexible enough to skew either to the left or to the right in various degrees as suggested by the field data. The two-parameter beta *pdf* was employed to represent this situation.

Let the beta probability density function $g(x)$ intersect the exponential probability density function $f(x)$ at points $x = k$. This intersect enables calculation of the areas below the intersection of each pair of curves (p). This parameter represents the proportion of the tsetse population that actually succumbs daily to a sampling device. Thus:

$$p = \int_{0,k} g(x)\, dx + \int_{k} f(x)\, dx.$$

The higher the p value of a sample, the less skewed to the left will be the curve of its beta *pdf*, and the greater its content of the population elements succumbing to a sampling device.

In our simulations, we varied the mean of $f(x)$ between 0.2 and 0.5 to fit the majority of the fly population within the hunger cycle, within MES 1 and 5. These mean values may never be as high as 0.5 or below 0.2 in a thriving tsetse population, going by the feeding behaviour of tsetse. Hence, we varied the values of between 1 and 8, and those of between 1 and 5. The parameters of beta *pdf*, $g(x)$, obtained from field data, varied between 3.59 ± 1.22 and 5.76 ± 2.7 for α, and between 1.05 ± 0.54 and 3.58 ± 0.99 for β. The value of α was always higher than that of β in each fit by between 1.5 and 2.2. Our simulations covered these ranges of α and β ensuring that α is larger than β by not less than 1.5, but not more than 2.2.

After 9300 runs of the simulation based on the above parameter values, the mean and median of *k*, respectively, were reasonably close, ranging between 0.31 and 0.37, while their first and third quartiles ranged between 0.27 and 0.43. The mean and median of *p* ranged between 0.39 and 0.64. The first and third quartiles ranged between 0.30 and 0.67, indicating that p may be < 0.30 for up to 25% of the time and not higher than 0.67 at least 75% of the time. Thus, with the current provisional trapping mortality rate of 6% day^{-1} at a density of two traps km^{-1}, and population growth rate of 1.7% day^{-1}, cow urine-baited NGU traps may, on the average, reduce a *G. pallidipes* population by about 97% in one year. Using this trapping system for tsetse suppression could cause up to 98% population reduction within one year in 75% of control campaigns. In about 25% of these, it may not effect an appreciable reduction in the fly population.

10. INTERACTION BETWEEN SITE AND TIME IN TSETSE TRAP CATCHES

Participating scientists: *A. Odulaja, S. Mihok, I.M. Abu-Zinid*

Background, approach and objectives

Trap catches of tsetse flies are known to be highly variable in space and time. These large fluctuations have been ascribed to various factors including climate, vegetation, host and unknown site effects.

While much has been done to understand the nature of spatial and temporal distribution of tsetse, little or nothing has been done about the interaction of the two factors. This interaction effect is just as critical, if not more, as the main effects of the two factors for the design and analysis of experiments to compare different sampling devices. The significance of this interaction effect would imply that the spatial differences in trap catches is not consistent over time, and vice-versa. In this event, differences between sites should be considered for individual times. Neglecting the interaction effect may lead to a confounding of the spatial and temporal effects. No work has been carried out to determine the negligibility, or otherwise, of this interaction effect. The determination of the conditions under which the interaction effect may be negligible is of equal importance. We therefore investigate the interaction effect of site and time in tsetse trapping experiments.

Work in progress

One hundred and twenty-one combinations of different numbers of sites and months ranging from 2 to 12, were composed from a 2200 trap-days data set collected at Nguruman. Given a combination of s sites and m months, the total number of possible choices from the data set is ${}^{20}C_s \times {}^{20}C_m$ (${}^{a}C_b = a!/(b!(a-b)!)$). Samples (20,000) for each combination, were randomly selected from the possible choices and analysed. The days within any selected month served as replication points to allow for the estimation of the site x month interaction effect. We employed the following model for the analysis of variance (ANOVA) of each of the 20,000 samples in each of the 121 combinations:

$$y_{(i)jk} = \mu + m_i + d_{j(i)} + s_k + ms_{ik} + {}_{(i)jk}$$

where μ is the general mean, m_i is the effect of month, $d_{j(i)}$ is the effect of days within month, s_k is the effect of site, ms_{ik} is the month x site interaction effect, $y_{(i)jk}$ is the corresponding catch/trap/day, and ${}_{(i)jk}$ the residual.

A random model was assumed regarding the selected months, days within month and sites as representative sample from their respective populations.

The percentage variance component (%VC) for each ANOVA, attributed to each of the model's effects was estimated using the theoretical expected mean squares (EMS). The mean %VC over all the 20,000 samples was obtained for each combination of months and sites.

To measure the importance of the interaction, relative to each of the main effects, the mean interaction %VC was divided by the %VC due to each of the main effects. These are denoted as RI/S and RI/M for the importance of the interaction effect relative to site and month effects, respectively. A value greater than unity implies that the interaction effect is more important than the main effect.

The percentage number of times for each combination of months and sites, out of the 20,000 samples in which the ANOVA effect was significant at $P < 0.05$ level was calculated.

Generally, the percentage of significant interaction effects increased as the number of sites and months increased. The percentage for *G. pallidipes* varied between 59 and 100% for the different combinations of sites and months. The corresponding range for *G. longipennis* was 46–100%. Hence, interaction effects were significant at least half of the time, regardless of number of sites and months chosen. The percentage number of significant interaction effects increased more rapidly with an increase in months rather than sites. With a combination of more than six sites and 3 months, nearly 100% of the interaction effects were significant for both species.

The mean %VC due to the interaction, ranged between 4 and 28% for *G. pallidipes* and between 12 and 36% for *G. longipennis*. A combination of more than five or seven months and any number of sites, limited the interaction effect for *G. pallidipes* to at least 10 or 20% of the total variation, respectively. With only two or three sites, the interaction %VC was always above 17% for *G. pallidipes*. The interaction effect was more pronounced for *G. longipennis* with the %VC as high as 28 or 36% for a combination six or eight months with any number of sites, respectively. Also, with only two or three sites, the interaction %VC was at least 20% for *G. longipennis*.

The importance of the interaction effect relative to site effect (RI/S) ranged between 0.04 and 0.88 for *G. pallidipes*, and between 0.26 and 2.0 for *G. longipennis*. It generally decreased with an increase in the number of sites, while increasing with an increase in the number of months. The importance of the interaction effect relative to month effect (RI/M) was in most cases greater than unity or very close to unity for all combinations of sites and months as well as for both species. It ranged between 0.84 and 7.8 for *G. pallidipes*, and between 11 and 26 for *G. longipennis*, generally increasing with an increase in number of sites, but decreasing with an increase in the number of months. These trends indicate clearly that the interaction effect is more important than the time effect and as important as the site effect as a source of variation.

Output

Publications

Kitron U., Otieno L. H., Hungerford L. L., Odulaja A., Brigham W. U., Okello O. O., Joselyn M., Mohamed-Ahmed M. M., and Cook E. (1996) Spatial analysis of the distribution of tsetse flies in the Lambwe Valley, Kenya, using TM satellite imagery and GIS. *Journal of Animal Ecology* 65, 371–380.

11. DEVELOPMENT OF TRAPPING TECHNOLOGIES FOR TSETSE AND BITING FLIES IN KENYA, TANZANIA AND ETHIOPIA (TST-6)

Participating scientists: *S. Mihok*, P. Ndegwa (*Activity Leader)*

Assistants: *E. N. Munyoki, S. O. Maramba, D. K. Mungai*

Collaborators: • *Tropical Pesticides Research Institute, Arusha (TPRI)* • *Ethiopian Science and Technology Commission*

Work in progress

There are perhaps 50 varieties of traps for tsetse and biting flies in use by scientists. They vary in efficiency for different species in different environments, countries, seasons, etc. The reasons for differences in trap performance have never been addressed in a systematic fashion, and hence the choice of trap for any application is based largely on tradition, mixed with some science. In new situations, researchers are often forced to repeat experiments in order to choose optimal trap designs. To promote a more rational use of trapping technology (e.g. by removing the need for expert technical advice on trap choices), ICIPE embarked on a major trap development exercise in 1993. The overall goal was to develop a practical cloth trap with balanced efficiency for as many vectors as possible. This objective was met in 1994, with the development of the Nzi trap based on many trap trials conducted in Kenya (*nzi* is the Swahili word for fly). From 1995 to 1997, the Nzi trap has been tested relative to other popular insect traps in coordinated trials around the world using standard materials and standard protocols. Results of these trials are nearly complete and have shown that the trap is a substantial improvement on existing traps for many kinds of biting flies and for *fusca* group tsetse. The trap also performs as well as standard traps for savanna tsetse in nearly all situations. The only deficiency appears to be poor performance for riverine tsetse, for which there is already an efficient trap (the biconical) in use.

Traps such as the Nzi and biconical now provide us with tools to both study and control many species of flies, but major problem remains. Certain species within the savanna group of tsetse are only poorly attracted to stationary objects, and hence, even the best traps are inefficient. Targets of various kinds, impregnated with insecticide, are therefore used in many countries for the control of the savanna species. To address this deficiency, we began trap development studies in 1996 for *Glossina swynnertoni*, a savanna species restricted to northern Tanzania and the Mara region of Kenya. The goal was to develop a trap which would be as efficient as an S-type black target (1 m^2 piece of black cloth).

Through a series of latin square experiments, fly behaviour was investigated around traps using sticky panels and electric nets in order to develop practical designs. The final result was the S3 trap, a new multiple-entrance design that catches about the same number of tsetse flies as a Black Target (Table 11.1). Preliminary estimates of trap efficiency indicate that this trap catches about one out of every three approaching *G. swynnertoni*. These results are similar to those obtained for the successful NG2G trap for *G. pallidipes*. Altogether, it appears as if a trap-based control technology for this species may be feasible.

Table 11.1. Detransformed mean catches and capture indices for *Glossina swynnertoni* comparing S3 trap with other traps at Naitolya in Tanzania

Trap type	Males	Index	Females	Index
Black Target	20.9^a (1.32 ± 0.10)	2.9	30.8^a (1.49 ± 0.11)	2.4
S3	17.7^a (1.25 ± 0.12)	2.4	41.5^a (1.62 ± 0.10)	3.2
S2	10.5^b (1.02 ± 0.11)	1.5	25.1^b (1.40 ± 0.09)	2.0
Biconical	7.2^c (0.86 ± 0.12)	1.0	12.8^c (1.11 ± 0.10)	1.0
	F-ratio=16.4***		F-ratio=8.3***	

Means in the same column followed by different letters are significantly different.

***significant at $P < 0.001$. Numbers in parentheses show transformed means ± standard error.

Trap development work for savanna tsetse was shifted in 1997 to the Ketto Settlement Scheme in Western Wollega, Ethiopia after the government requested ICIPE to address the problem of trapping technology for *G. morsitans submorsitans*. Ketto is a productive farming area at a height about 1200–1400 m, with good rainfall and abundant water from permanent rivers. Settlers live mostly on the fringes of wild river valleys (which contain three species of tsetse: *G. morsitans submorsitans*, *G. pallidipes* and *G. fuscipes*). Hence, agricultural production is severely constrained by trypanosomosis:, villagers at Ketto lost half of their oxen early in 1997 when trypanosome infection rates rose to about 50%. Most habitats also contain extremely high densities of stable flies (*Stomoxys*) that clearly harass livestock (e.g. catches of 10–20,000 *Stomoxys* on a blue/black sticky trap with a surface area of 2–3 m^2).

The performance of standard traps representing different design principles was tested initially (7x7 latin square, 3 replicates), as a basis for selection of a trap format for novel development work. The candidate traps were epsilon, S3, biconical, canopy, pyramidal, Nzi and NG2G. The highest catches were obtained with the NG2G for both *G. m. submorsitans* and *G. pallidipes*. Three other traps representing variations on a triangular format (Epsilon, S3 and Nzi) were also good alternatives for both species (Table 11.2).

Odour-baited Nzi and NG2G traps were further compared in well-replicated latin square designs in three habitats. In the first experiment in riverine forest with a partial understorey of coffee (typical of areas near villages), the Nzi trap in cotton drill caught significantly more *G. pallidipes* (1.7x) than the version of the NG2G being used by farmers in a pilot control programme started recently. This difference appears to be related to the use of a non-Phthalogen Blue cotton/polyester cloth in the local version of the NG2G. Results from two final trials in grazed and ungrazed woodland habitats, indicated no significant difference in catch between the two traps when they were made from the same materials (Nzi catch 7% greater than NG2G for *G. pallidipes*, Nzi catch 7% less than NG2G for *G. m. submorsitans*).

Odour bait performance was assessed in a final experiment with Nzi traps. Acetone, cow urine and octenol in various combinations were compared in 8 x 8 latin squares replicated three times. Results were unusual, overall based on past experiences, indicating that it may be unwise to extrapolate results from other countries to the high-altitude populations of flies in Ethiopia (Table 11.3).

Table 11.2. Detransformed mean catches of *G. m. submorsitans*, *G. pallidipes* and *Stomoxys*, in traps baited with acetone, cow urine and octenol during the rainy season in woodland near villages 11/12

	G. m. submorsitans			*G. pallidipes*			*Stomoxys*
Trap	Males	Females	Total	Males	Females	Total	Total
NG2G	3.3^{a}	3.9^{a}	6.4^{a}	2.9^{a}	8.9^{a}	11.1^{a}	43^{bcd}
S3	2.3^{ab}	3.4^{ab}	5.0^{ab}	2.4^{a}	6.7^{a}	8.8^{a}	36^{cd}
Epsilon	3.1^{a}	3.0^{ab}	5.0^{ab}	2.8^{a}	6.4^{a}	7.6^{ab}	95^{ab}
Biconical	2.4^{ab}	2.1^{bcd}	3.4^{bc}	2.7^{a}	2.1^{c}	2.8^{d}	25^{d}
Nzi	1.7^{bc}	2.4^{abc}	3.1^{bc}	1.9^{a}	3.8^{b}	5.3^{bc}	169^{a}
Pyramidal	1.3^{c}	1.7^{cd}	1.9^{cd}	1.5^{a}	3.5^{b}	4.5^{c}	69^{bc}
Canopy	1.3^{c}	1.3^{d}	1.6^{d}	1.6^{a}	1.7^{c}	2.3^{d}	9^{e}

Means in the same column followed by the same letter are not significantly different (SNK test, $P < 0.05$).

Table 11.3. Detransformed mean catches in Nzi traps baited with various odour baits during the dry season in woodland near villages 11/12

	Mean catches of			
Odour bait	*G. pallidipes*	*G. morsitans submorsitans*	*Stomoxys*	Non-biting muscids
Acetone	4.1^{b}	3.1^{a}	55.5^{a}	86.4^{a}
Octenol	3.3^{b}	3.5^{a}	23.8^{b}	56.5^{b}
Cow urine	9.0^{a}	3.0^{a}	39.6^{b}	70.0^{a}
Acetone + Octenol	3.3^{b}	2.5^{a}	31.0^{b}	74.6^{a}
Acetone + Cow urine	3.7^{b}	2.8^{a}	33.5^{b}	69.8^{a}
Acetone + Octenol + Cow urine	3.0^{b}	3.3^{a}	45.2^{ab}	59.4^{b}
Octenol + Cow urine	7.3^{a}	2.6^{a}	39.9^{ab}	88.7^{a}
No odour bait	2.0^{b}	1.6^{b}	27.2^{b}	49.9^{b}

Means in the same column followed by the same letter are not significantly different ($P < 0.05$; SNK test).

As initial experiments confirmed that triangular trap formats were appropriate for catching *G. pallidipes* and *G.m. submorsitans* at Ketto, we started further trap development work by conducting a detailed multiple choice experiment using simple odour-baited triangular objects resembling traps. The experiment was based on a latin square design at four sites run over 16 days. Two matching control sites were used for interpretation of fly behaviour and for statistical calibration of daily variations (an epsilon trap in the wet season, Nzi trap in the dry season, and a triangular object of 1 x 1 m panels of blue, black and white cloth). At each site, white (high UV reflectance), blue and black cotton drill (low UV reflectance) or transparent white netting, was used as a background to which we attached six randomised fabric panels (32 x 75 cm), in either blue or black, arranged vertically on the edges of each side of the triangle (to resemble the entrance of a tsetse trap).

Fly landing behaviour was enumerated with a sticky panel strip at two heights (0–30 cm and 30–60 cm), rotating among days, so that less than half of the test panels would be covered with material each day. The fabrics were carefully chosen from about 50 fabrics, to provide contrasts in texture, opacity, shininess, and also to provide clear contrasts in the relative proportions and peaks of reflectance, in the ultraviolet, blue and infrared spectral regions, for representative materials (cotton, polyester, and blends). Raw data for *G.m. submorsitans* are shown below for the test panels by background during the wet season, with a constant comparison to landing behaviour on the central panel, and the catch in an epsilon trap.

These results indicate that an odour-baited epsilon trap is inefficient for *G. m. submorsitans*, with a maximum capture rate relative to similar triangular sticky objects of only 5–18% (calculated from the actual numbers of flies enumerated). Repetition of this experiment in the dry season produced quite different results. Nzi traps caught from 33 to 161% as many *G. m. submorsitans* as did the sticky imitations of traps. These results are puzzling, as similar data for *Stomoxys* species showed very little variation between seasons (range of all estimates between 1 and 6%). Further cross-validation experiments combining electric nets with sticky materials need to be done, to guide a rational process of trap/target development for *G. m. submorsitans*. It seems likely that fly behaviour and hence trap efficiency, vary greatly for some species with many unknown factors. The use of trapping technology in new situations may therefore lead to quite unpredictable results.

Output

Publications

Majiwa P. A. O., Maina M., Waitumbi J. N., Mihok S. and Zweygarth E. (1995) *Trypanosoma (Nannomonas) congolense*: Molecular characterization of a new genotype from Tsavo, Kenya. *Parasitology* 106, 151–162.

Mihok S. (1997) Tsetse and trypanosomiasis and wildlife/livestock interactions, pp.165–172. In *Proceedings of the East Africa Livestock Assessment Workshop*, University of California, Small Ruminant CRSP, Davis, California.

Mihok S. and Clausen P. H. (1996) Feeding habits of *Stomoxys* spp. stable flies in a Kenyan forest. *Medical and Veterinary Entomology* 10, 392–394.

Mihok S., Kang'ethe E. K. and Kamau G. K. (1995) Trials of traps and attractants for *Stomoxys* spp. (Diptera: Muscidae). *Journal of Medical Entomology* 32(3), 283–289.

Mihok S., Kock R. and Masake R. (1996) Health implications of translocations of endangered species in Africa: Trypanosomiasis in rhinoceros, pp. 423–424. In *Proceedings of the Joint Conference of AAZV/WDA/AAWV*. Michigan, USA.

Mihok S., Machika C., Darji N., Kang'ethe E. K. and Otieno L. H. (1995) Relationships between host blood factors and proteases in *Glossina morsitans morsitans* subspecies infected with *Trypanosoma congolense*. *Medical and Veterinary Entomology* 9, 155–160.

Mihok S., Maramba O., Munyoki E. and Kagoiya J. (1995) Mechanical transmission of *Trypanosoma* spp. by African Stomoxyinae (Diptera: Muscidae). *Tropical Medicine and Parasitology* 46(2), 103–105.

Mihok S., Maramba O., Munyoki E. and Saleh K. (1996) Phenology of Stomoxyinae in a Kenyan forest. *Medical and Veterinary Entomology* 10, 305–316.

Mihok S., Moloo S. K., Oden'y J. O., Brett R. A., Rakwar J. G., Munyoki E., Kiilu J. and Kyorku C. A. (1996) Attractiveness of black rhinoceros (*Diceros bicornis*) to tsetse flies (*Glossina* spp.) (Diptera: Glossinidae) and other biting flies. *Bulletin of Entomological Research* 86, 33–41.

Zweygarth E., Mihok S., Majiwa P. A. O. and Kaminsky R. (1995) A new *Nannomonas*-type trypanosome; isolation, *in vitro* cultivation and partial characterisation, pp. 188–190. In *First International Congress of Parasitology and Tropical Medicine* (Edited by B. Sinnah). Malaysian Society of Parasitology and Tropical Medicine, Kuala Lumpur.

Conferences attended

S. Mihok (1995). Joint Conference of AAZV/WDA/AAWV and presented a paper on 'Health implications of translocations of endangered species in Africa: Trypanosomiasis in rhinoceros', Michigan, USA, 12 – 16 August.

S. Mihok (1995). OAU/IBAR (ISCTRC) meeting. Presented a paper on 'Towards a universal trap for tsetse and biting flies', Banjul, The Gambia, 4–9 September.

S. Mihok (1996). East Africa Livestock Assessment Workshop organised by the Small Ruminant Collaborative Research Support Programme of the University of California, Davis and presented a paper on 'Tsetse and trypanosomosis and wildlife/livestock interactions', Entebbe, Uganda, 28 January–3 February.

S. Mihok (1996). Programme Coordination Committee Meeting and the Steering Committee Meeting of the EU-funded 'Collaborative Research Programme on Trypanosomosis and Trypanotolerant Livestock for West Africa' organised by CIRDES, International Trypanotolerant Centre (ITC) and ILRI, Bobo-Dioulasso, Burkina Faso and Banjul, The Gambia, 24 February–9 March.

S. Mihok (1996).Workshop on revision of the tsetse distribution map of Kenya organised by KETRI/ODA, Kikuyu, Kenya, 17–18 April.

S. Mihok (1996). Biting Fly Workshop organised by Louisiana State University held at various locations in Louisiana and presented a paper on 'Tabanid Research in Africa', Louisiana, USA, 13–17 May.

S. Mihok (1996). World Congress of Engineering Educators and Industry Leaders to present a proposal 'The Nzi trap: Environmentally-friendly technology for tsetse and trypanosomosis control' for funding by UNESCO at the UNISPAR session, Paris, France, 30 June–6 July.

S. Mihok (1996). OAU/IBAR executive committee meeting of the International Scientific Council for Trypanosomosis Research and Control, Mombasa, Kenya, 14–18 July.

S. Mihok (1996). IAEA research coordination meeting of the Coordinated Research Programme on 'Improved attractants for enhancing the efficiency of tsetse fly suppression operations and barrier systems used in tsetse control/eradication campaigns', and presented a paper on 'Towards improved fabrics for tsetse control', Kikuyu, Kenya, 23–27 September.

R. Saini (1996). Meeting of the coordinators to Advisory Groups of the FAO, IAEA, OAU/IBAR, WHO Programme Against African Trypanosomiasis, representing Dr Mihok. Nairobi, Kenya, 15–17 October.

S. Mihok (1997). CIRAD-EMVT Workshop to formulate the logical framework for the Programme Against African Trypanosomosis (PAAT), Montpellier, France, 5–12 April.

S. Mihok and P. Ndegwa (1997). OAU/IBAR ISCTRC meeting to present papers on 'Appropriate fabrics for tsetse traps' and 'Development and field-testing of new trap designs for *Glossina swynnertoni*', respectively. A flyer and a technical brochure on the Nzi trap were prepared for distribution at the meeting along with many sample traps. Dr Mihok also attended the meeting of the co-ordinators to Advisory Groups of the FAO, IAEA, OAU/IBAR, WHO Programme Against African Trypanosomiasis, as well as the executive council meetings of the ISCTRC, 29 September–3 October Maputo, Mozambique.

A team of ICIPE scientists (1997). Visited region VI in Ethiopia to formulate an expanded project proposal on the control of *Glossina tachinoides* in the Beles River Valley area near Lake Tana, as an adjunct to an ongoing rural development initiative funded by Italian Cooperation and executed by an Italian NGO: Comitato Internazionale per lo Sviluppo dei Popoli (CISP), 13–19 December, Pawe, Ethiopia.

S. Mihok (1997). Joint workshop on scientific collaboration with the government of Sudan in Khartoum from 4 to 9 December.

Workshops organised

R. Olubayo and S. Mihok organised a workshop on 'Stakeholder-based strategies for sustainable management of tsetse-transmitted trypanosomosis in wildlife conservation areas and allied ecosystems of East Africa. It was held at ICIPE for about 30 participants. (Sponsored by the International Development Research Centre of Canada), Nairobi, Kenya, 29–30 April, 1996.

Proposals written

The 'Nzi' trap: Environmentally-friendly technology for tsetse and trypanosomiasis control—submitted to UNESCO's UNISPAR-Africa Initiative 1996 (not funded).

Sustainable Technologies for the Control of Camel Trypanosomosis (Surra) and its Vectors—submitted to IFAD and other donors (under consideration).

Capacity building

A group training course on integrated tsetse management was held throughout November 1995 with a Nairobi lecture/laboratory component followed by field exercises at Shimba Hills National Reserve. There was extensive participation in teaching the course on the part of International Livestock Research Institute (ILRI) and Kenya Trypanosomiasis Research Institute (KETRI), with additional participation by Organisation of African Unity (OAU)/Inter-African Bureau for Animal Resources

(IBAR), Ministry of Agriculture, Livestock Development and Marketing (MOALDM) and the University of Nairobi. A young scientist from Centre internationale de recherche développement sur l'elevage en zone sub-humide (CIRDES) was also sponsored to participate in the field exercises. There were 15 external trainees (Kenya—4, Tanzania—3, Uganda—3, Ethiopia—3, Zimbabwe—1, South Africa—1), as well as three internal ICIPE trainees.

Four senior veterinary staff from Ethiopia received intensive training in trap technology for the control of tsetse flies at the Nguruman field station in April–May 1996. The training focused on practical field activities and the scientific principles underlying tsetse trapping technology. A follow-up training session was later held in Ethiopia through the visit of ICIPE technicians and scientists to various sites for 6 weeks in August. Three of the four trainees are now supervising rural communities in the deployment of thousands of tsetse traps in the vicinity of Soddo-Bedessa, Welkite (Gurage) and Arba Minch.

With the assistance of the Oromia Agricultural Bureau and the Ethiopian Science and Technology Commission, a formal introductory training course on tsetse management was held at the Faculty of Veterinary Science, University of Addis Ababa in Debre Zeit and at the town of Welkite from 21–26 August 1996. Four ICIPE scientists lectured on tsetse control with the assistance of university and government lecturers. About 45 professional staff, mainly from the Oromia region, participated. The group also worked for a few days with 100 farmers at Welkite, teaching the construction and use of tsetse traps. The Ministry of Information filmed course activities and prepared a video on tsetse trapping technology.

With the assistance of ICIPE–Ethiopia and logistical and financial support from the Ethiopian Science and Technology Commission, the workshop on tsetse / trypanosomosis and mosquito / malaria control strategies 'The Way Forward' was held in Addis Ababa and Axum in early February 1997. There were about 100 participants, with excellent participation by Ethiopian researchers, policy makers and senior government officials.

A group training course was held in Kenya between 5 November and 5 December 1997 for tsetse and trypanosomosis professionals nominated by their respective governments from Farming in Tsetse Controlled Area (FITCA) project countries: 3 participants from each country, Kenya, Uganda, Tanzania and Ethiopia. The course was held in Nairobi (lectures/laboratories) and at the coast in Shimba Hills National Reserve (field exercises) following a format similar to the course held in 1995. Forty-one resource staff participated from eight organisations. A young scientist from CIRDES-EMVT also participated in the field exercises.

Postgraduate training

E. Misiani. (ARPPIS PhD, Kenyatta University, June 1996–ongoing). The role of insect vectors in the maintenance and transmission of lumpy skin disease.

P. N. Ndegwa. (Postdoctoral Fellow, June 1996–May 1998 completed). Development of attractive bait technologies for *Glossina* spp.

Z. W. Njagu. (ARPPIS PhD, Kenyatta University, ongoing). Role of the monitor lizard (*Varanus niloticus*) Laurenti in the epidemiology of trypanosomiasis along the shores of Lake Victoria, Kenya.

A. L. Sumba. (MSc, University of Nairobi 1997 completed). Mechanical transmission of *Trypanosoma evansi* and *Trypanosoma congolense* by African *Stomoxys* species.

P. N. Ndegwa. (PhD, University of Nairobi 1997 completed) Ecological and epidemiological studies of *Glossina swynnertoni* in the Aitong region of the Maasai Mara, Kenya.

F. Masaninga. (ARPPIS PhD, University of Zambia 1997) Adaptation of *Trypanosoma (Nannomonas) congolense* Borden 1904 types to different hosts and transmission by *Glossina* spp.

Impact

The Nzi trap is now being used in Senegal, Chad, Kenya, Tanzania and USA for the practical control of biting flies in situations where these flies are a nuisance (e.g. with dairy cattle) or where biting flies mechanically transmit trypanosomes to domestic animals such as horses and camels. The trap is also being used by scientists in South Africa, Zambia, Kenya, The Gambia and elsewhere, as a practical tool for the sampling of many species of tsetse and biting flies.

Research on fly visual ecology has resulted in the development and refinement of synthetic fabrics specifically for tsetse traps. A Danish company (KVF Disease Control Textiles) is now producing appropriate fabrics for this purpose.

NG2G traps, and to a lesser extent Nzi traps, are now in use in Ethiopia with many thousands of traps deployed by farmers and government organisations for disease control.

12. DEVELOPMENT OF A DURABLE AND AFFORDABLE TRAP

Participating scientist: *R. Copeland (Activity Leader)*

Assistants: *J. Kiilu, S. Pukare, J. Tanchu, J. Kobaai*

Work in progress

Twelve latin square experiments were conducted at Nguruman to evaluate various modifications of the NG2G trap with the purpose of lowering material and operational costs, thereby making tsetse control programmes more attractive to rural communities. When cotton trap components were replaced with material of tightly woven sisal, the new trap significantly outperformed the standard NG2G; blue colour components of the sisal trap were poorly matched to those of the standard. Evaluating and standardising dyeing procedures should further improve performance of the sisal trap, which has other features that may make it an attractive replacement for the NG2G trap in suppression programmes.

Currently, theft of cotton trap components is a continuing problem, particularly in areas where school uniform colour resembles that of the blue trap components. Sisal may prove less attractive to thieves. Sisal material may be more durable than cotton. This is currently being tested and, if so, overall cost will fall as a result of reduction in material costs. More importantly, an increase in the servicing interval will reduce operational expenses. A marked reduction in the attention required of community members for upkeep of traps will, hopefully, increase the chances of sustaining such a programme.

13. DEVELOPMENT OF A SUSTAINABLE BARRIER SYSTEM FOR CLEARED AREAS

Participating scientist: *R. Copeland (Activity Leader)*

Assistants: *J. Kiilu, S. Pukare, J. Tanchu, J. Kobaai*

Work in progress

A major experiment was conducted in order to test components of a barrier system to prevent immigration of tsetse flies. Several interesting results were obtained. A barrier composed solely of odour baits significantly reduced immigration. During the one month when complete odour-baited traps were presented at barrier stations, 278,680 *Glossina pallidipes* were captured. The minimum estimated probability of penetration of the barrier by an individual tsetse was 0.0038. Males were less likely to penetrate the barrier than females. When a repellent component was added, tsetse appeared to fly away from the repellent odour and into specific areas where their capture in traps was made more likely.

In September 1996 ICIPE's trap-based tsetse suppression programme was handed over to the local Maasai community. Thereafter, tsetse populations were monitored in the suppression area and a nearby check area. Tsetse numbers were reduced by approximately 90% for the following 5 months. However, beginning with the rains in April 1997, this level of control was not seen again and coincided with a steady decline in the number of upright and working suppression traps.

C. COMMUNITY-BASED TSETSE CONTROL AND SOCIOECONOMIC ASPECTS

14. ADOPTION OF CONTROL METHODOLOGIES BY LOCAL COMMUNITIES IN KENYA AND ASSESSMENT OF TAKE-UP AND SUSTAINABILITY OF TRAPPING TECHNOLOGY BY PASTORALIST AND AGRICULTURALIST COMMUNITIES

Participating scientist: *G. Tombe Lako (Activity Leader)*

Assistants: *R.Emongor, D. K. Kahuria, P. Muasa*

Collaborators: • *Ministry of Agriculture, Livestock Development and Marketing* • *Kajiado District Development Committee* • *KETRI*

Work in progress

14.1 COMMUNITY MOBILISATION

Since March 1996, the community in Nguruman has held meetings to mobilise people and resources for the purpose of tsetse control in the area. The community has held over 16 meetings with the purpose of mobilisation for tsetse control. Since January this year a few meetings have also been held in the continued effort of mobilisation. Many meetings could not be held in the area from September 1996 to June 1997 because of the unfavourable weather condition which prevailed.

14.2 COMMUNITY ORGANISATION AND MANAGEMENT OF TSETSE CONTROL ACTIVITIES

Olkiramatian location has four sub-locations, all involved in tsetse trapping. Different sub-locations are at different levels of community organisation. So far each sub-location has been divided into blocks (a block comprises several villages combined for management purposes).

The community is organising itself and executing new ways of raising resources as can be seen from Table 14.1.

These groups have an elected functional committee composed of a chairman, secretary, treasurer, trap materials secretary, trap making secretary, trap deployment secretary and trap servicing secretary. The community is also to organise itself for the purpose of financial accountability and open a bank account to keep the money for trapping purposes.

Table 14.1. Groups formed for tsetse control in Nguruman sub-location

Name of the group	Official membership	Resources collected (Money)
Olare group	22	Kshs 2200
Sairo group	15	Kshs 1500
Ebollyio group	30	Kshs 3000
Naromoru	20	Kshs 2250
Olkereyian	25	Kshs 2500
Lebitiro	34	Kshs 10,000
Total	146	Kshs 21,450

When the community was handed over traps they had not mobilised any resources of their own. Since then, the community has sought ways to mobilise resources and these range from contributing money, goats and receiving gifts from other organisations as shown in Table 14.2. This can be viewed as a step forward and therefore the take-up of the technology by the community is proceeding on well. The need for patience on the part of every stakeholder in this adoption process cannot be over-emphasised. Also the nature of the economy has to be understood to guard against comparison with other production systems which are sedentary and hence face different constraints as compared to the pastoralists economy.

14.2.1 *Handing over of ICIPE control traps to the community*

The ICIPE control traps were handed over to the community on 6 September 1996 by the Vice President of the Republic of Kenya, Prof. George Saitoti. Before this, all the 232 traps were under the management of ICIPE and its staff.

14.3 TRAPPING ACTIVITIES

14.3.1 *Trap status in the control zone*

Trap status in the control area has been monitored by the staff of the ICIPE Social Sciences Department since the handing over to the community in September 1996 and the performance of the traps is shown in Table 14.3. The take-up of the trap by the community has been fair and we expect better performance as the mobilisation of community and resources improve. The community has maintained and serviced traps in the control zone.

Trap status has been on the decline as shown in Table 14.3 and this can be attributed to the following factors:

(i) The community was not fully trained and organised by the time of the handing-over of the ICIPE traps. In fact the day before the handing-over ceremony, community leaders expressed that they were not prepared to take over control

Table 14.2. Status of resource mobilisation for community-based tsetse control at Nguruman

Name of the group	Resources collected (Money) Kshs	Other resources—livestock	Official membership
Linkobei tsetse control group	22,400+	10 goats	40
Nguruman tsetse control group	21,450	A number of households pledged a goat a year	146
Olkiramatian tsetse control group	25,000	-	25
Loorgoswa / Musenge	-	-	-
Entasopia	-	-	-

+Contributions from other sources: The Kajiado Veterinary Department has pledged to contribute Kshs 10,000 to the Linkobei tsetse control group when they have registered with the Ministry of Social Services.

Table 14.3. Status of the traps in the control zone since the handing over

	Traps (%)			
Date	Total number of traps	In good working condition	In good working condition, but lacking baits	% Not in working condition (need replacement)
October 1996	232	40.5	35.4	24.1+
November, 1996	232	80	12	8
March 1997	183	75.5	6.5	18.0
September 1997	170	59.0	-	41.0

+The above record indicates that not all traps had been fully operational at the time of handing over.

during a meeting at the DO's office on 5 September 1996.

(ii) Seasonality: The control programme was also hampered by the adverse weather conditions (September 1996 to May 1997), which forced people to move to distant places. It meant that during that time there were no people, and hence it was difficult for the community to hold meetings to manage the control activities. When they returned, there was flooding of the control zone and traps were not accessible to the community.

(iii) Nature of production systems / economy: This is a semi-arid area with semi-pastoral production system. This system is different from a sedentary system such as that of Lambwe Valley. Adoption of the trap in this production system needs further study and understanding of the specific nature of this system.

14.3.2 *Status of traps outside the control zone*

Other sub-locations outside Olkiramatian have also formed groups for tsetse control. Lenkobei tsetse control group have made and deployed 30 traps in their area. Individuals have also acquired and deployed traps in and around their manyattas. Individuals (18) have acquired 53 traps in total and have deployed them in and around their compounds. This shows that the trap technology is being adopted by the community who understand the usefulness of the trap technology.

The objective of the adoption study at Nguruman was not to show success or failure, but to observe, advise and monitor the adoption process of the trap and this was done and has been reported in the status tables. This report shows a balanced report of what has happened since the traps were handed over to the community. The report has documented how the condition of the traps has been and also the emerging new groups (Lenkobei in Shompole and Loorgoswa / Musenge in Odorko). There has also been a move towards privatisation where individuals have acquired and maintained traps on their own.

14.4 ASSESSMENT OF ECONOMIC COSTS / BENEFITS OF COMMUNITY-BASED TSETSE CONTROL SCHEMES AMONGST PASTORALISTS AND AGRICULTURALISTS

To attain this objective two approaches were used:

- ICIPE collaborated with KETRI to write-up livestock production / productivity status at Nguruman. The joint report was finalised and is available.
- Community's assessment of impact of tsetse control.

Highlights of the KETRI / ICIPE report are as follows:

14.4.1 *Livestock production/productivity*

Rainfall in Olkiramatian group ranch has been decreasing significantly between 1989 to 1995; almost every year there has been no rain for 3–4 months.

The mean monthly minimum temperature is slightly below 23°C and the maximum temperature is slightly below 35°C. This reflects (among other things) that the available water sources are susceptible to evaporation, thus exacerbating the problem of water availability.

Livestock populations and breeds (1991–1995) are shown in Table 14.4.

Table 14.4. Livestock population on Olkiramatian group ranch

Type of livestock	Livestock population	% of the divisional population	% of the district total
Cattle	6705	18	1
Sheep	18153	23	3.5
Goats	19325	30.5	4

14.4.2 *Community's assessment of impact of tsetse control*

Impact assessment from the community's point of view was done using a questionnaire survey. A sample of 104 household heads (representing 30 % of the total population) was taken in Olkiramatian Location where the control activities have been going on. The location is administratively divided into three sub-locations: Olkiramatian, Nguruman and Entasopia. Simple random sampling with probabilities proportional to size was used to select a sample of 104 households. The sample was selected from all the three sub-locations. The household heads who were pastoralists, agriculturalists or both were interviewed using a structured questionnaire. Due to non-availability of some of the sampled people (because during the interview some people had already moved to far places and could not be reached), the final sample was reduced to 99 household heads. The data has been analysed and a report of the study is soon to be finalised. The results of the entire sample is shown below. The results show that the tsetse problem has been highly reduced by trapping of tsetse (Tables 14.5 and 14.6).

14.4.3 *Household's assessment of the effect of tsetse problem in farming*

The effect of the tsetse problem on farming was negative in the pre-suppression period as shown in Tables 14.7 and 14.8. Respondents (44%) said that the negative effect of tsetse on farming was high, 44.4 % that it was moderate and 11.1 % that it was low in the pre-suppression period. In the post suppression period the problem was highly reduced as shown in Table 14.7 and 14.8.

Table 14.5. Households' assessment of the tsetse problem

	Pre-suppression period			Post-suppression period		
Parameter	High (%)	Moderate (%)	Low (%)	Highly reduced (%)	Somewhat reduced%	Hardly any change (%)
Biting menace to humans	47.5	46.5	6.1	61.6	36.4	2.0
Biting menace to animals	46.5	46.5	7.1	51.5	44.4	4.0
Number of flies in the area	54.5	38.4	10.1	50.5	40.4	9.1
Infection of livestock with disease (nagana)	51.5	38.4	16.2	50.5	40.4	9.1
Fear of grazing in the forest because of tsetse flies	48.5	35.4	16.2	55.5	26.3	18.2

Table 14.6. Mean household assessment (%) of the tsetse problem in pre-suppression period (1990) and post-suppression period (1995–1996)

	Tsetse problem		
Parameter	High ± SE	Moderate ± SE	Low ± SE
Biting menace to humans	54.6 ± 7.05 NS	41.5 ± 0.05 NS	4.1 ± 2.05 NS
Biting menace to animals	49.0 ± 2.50*	45.5 ± 1.05*	5.6 ± 1.55 NS
Number of flies in the area	56.1 ± 1.55*	36.4 ± 1.00*	7.6 ± 2.50 NS
Infection of livestock with disease	52.0 ± 0.50**	39.4 ± 1.00*	9.6 ± 0.30*
Fear of grazing in the forest, because of tsetse flies	52.0 ± 3.50*	30.9 ± 4.55NS	1.74 ± 0.85*

NS—Not significantly different (t 0.025, 200).
* Significantly different (t 0.025, 200).
** Significantly different (t 0.005, 200).

Table 14.7. Extent to which the tsetse problem negatively affects farming

	Pre-suppression period			Post-suppression period		
Parameter	High (%)	Moderate (%)	Low (%)	Highly improved (%)	Somewhat improved (%)	Hardly any change (%)
Access to forest resources (firewood, herbs, etc.)	44.4	44.4	11.1	75.0	25.0	-
Use of land for cultivation	22.2	55.6	22.2	87.5	-	12.5
Use of land for grazing animals	55.6	44.4	-	62.5	37.5	-
Use of land for human settlement	33.3	55.6	11.1	75.0	25.0	-

Table 14.8. Mean household assessment (%) of the extent to which the tsetse problem negatively affected farming in pre-suppression period (1990–1994) and post-suppression period (1995–1996)

	Tsetse effect on farming		
Parameter	High ± SE	Moderate ± SE	Low ± SE
Access to forest resources (firewood, herbs)	43.5.6 ± 14.2 NS	36.9 ± 11.6 NS	19.7 ± 2.5 NS
Use of land for cultivation	46.0 ± 24.80 NS	28.3 ± 9.0 NS	25.8 ± 15.7 NS
Use of land for grazing	51.5 ± 13.10 NS	36.4 ± 12.20 NS	12.10 ± 1.00*
Use of land for human settlement	49.5 ± 20.20 NS	33.4 ± 13.15 NS	17.2 ± 7.05 NS

NS—Not significantly different (t 0.025, 200).
* Significantly different (t 0.025, 200).
** Significantly different (t 0.005, 200).

14.5 HOUSEHOLDS' ASSESSMENT OF THE EFFECT OF TSETSE PROBLEM ON LIVESTOCK PRODUCTION

In general in the pre-suppression period, the effect of tsetse on livestock production was negative. The effect of tsetse control on livestock production has been positive. Milk production has increased, livestock mortality has been highly reduced and the number of livestock have changed significantly as shown in Tables 14.9 and 14.10.

14.5.2 *Herd size changes*

Herd sizes have been declining as shown in Table 14.12. The average number of cattle per household has been declining over the years. The major reasons for this apparent decline in cattle numbers since 1990 to date are the frequent droughts, which have hit the area over the period and pasture has been in short supply. The number of cattle dying have reduced and this can be attributed to reduced trypanosomosis incidence. In 1993 when there was a breakdown of the control programme there was a higher number of cattle that died in 1994 as shown in Table 14.13.

Table 14.9. Households' assessment of the effect of tsetse on livestock production

	Pre-suppression period			Post-suppression period				
Parameter	High (%)	Moderate (%)	Low (%)	Highly improved	Highly reduced (%)	Somewhat improved	Somewhat reduced	Hardly any change (%)
Milk yields	50.5	42.4	7.1	43.3	-	50.5	-	6.1
Mortality of livestock	44.4	50.5	5.1	-	42.3	-	51.5	6.1
New births	41.4	51.5	7.1	52.4	-	44.4	-	3.0
Number of livestock	51.5	37.4	11.1	56.4	-	41.4	-	2.0

Table 14.10. Mean household assessment (%) of the effect of tsetse on livestock production in the pre-suppression period (1990–1994) and post-suppression period (1995–1996)

	Effect of tsetse on livestock production		
Parameter	High ± SE	Moderate ± SE	Low ± SE
Milk yields	46.9 ± 3.6*	46.5 ± 4.05*	6.6 ± 0.5*
Mortality of livestock	43.4 ± 1.05*	51.0 ± 0.5**	25.8 ± 15.7 NS
New births	46.9 ± 5.5 NS	47.90 ± 3.55*	5.1± 2.46 NS
Number of livestock	54.0 ± 2.5*	39.4 ± 2.0*	6.55 ± 4.60 NS

NS—Not significantly different (t 0.025, 200).
* Significantly different (t 0.025, 200).
** Significantly different (t 0.005, 200).

Table 14.11. Average milk yield per household (l/day)

	Year						
	1990	1991	1992	1993	1994	1995	1996
Cow milk l/day	53.90	51.27	54.92	54.93	50.1	57.45	46.54
Goat milk l/day	13.31	11.29	14.36	12.93	13.64	19.28	16.11

14.5.1 *Households assessment of milk production*

Milk production has shown a variable trend increasing and declining in some years, but generally it has shown an increasing trend as shown in Table 14.11. The results suggest that the decline in milk production in some years has been due to persistent droughts and lack of pastures. Nevertheless, the reduction of tsetse, besides other factors, seems to have impacted positively on milk production of goats. In general goats are less adversely affected by drought as they feed on shrubs, acacia tree seed pods (which are plenty in the study area) etc., as opposed to cattle which rely almost entirely on grass.

14.6 USE AND COST OF TRYPANOCIDES

In the pre-suppression period (1990–1994) the use of trypanocides was high as compared to the post-suppression period. The use of these drugs is assumed to be inversely related to the disease incidence. In that period the tsetse menace was significant and hence the use of these drugs by households to treat infected cattle was high and so was the cost. The tsetse control programme executed by ICIPE and at one stage the Olkiramatian and Shompole Community Development Project (OSCDP), brought the tsetse numbers in the area to low levels between 1991–1993,

Table 14.12. Herd size/household/year

	Year						
	1990	1991	1992	1993	1994	1995	1996
Average number of cattle per household	20.0	20.5	16.9	16.5	16.6	12.7	12.8
Total number of cattle by sample households	1979	2037	1678	1637	1640	1261	1265
Total number bought by sample households	54	38	121	42	60	54	45
Total number sold by sample households	112	66	85	67	89	90	77
Total number that died by sample households+	139	118	106	61	92	107	30

+It is worth noting that cattle mortality has dropped since 1990.

Table 14.13. Cost of chemotherapy and trypanocidal drugs /household/year

Year	Total number of cattle treated	Cost (Kshs) Samorin	Novidium	Berenil	Teramycin	Total cost
1990	4566	720	43,875	29,486	43,020	134,246
1991	4861	720	22,621	28,239	50,420	129,090
1992	3319	-	16,435	25,087	176,260	234,702
1993	2268	-	29,610	28,455	110,235	183,930
1994	2540	-	26,860	29,200	64,625	133,775
1995	2129	-	25,440	38,575	57,825	167,000
1996	1848	-	18,250	24,335	22,770	105,125

leading to lower cost for drugs for each household. In 1993 and 1994 there was a breakdown of the control programme and the effects of this can be seen in the increased use of trypanocides in 1995, even though the tsetse numbers had been brought down to very low levels by ICIPE (Table 14.13). Significantly this cost has gone down by half in 1996. However, in 1995 some members of the community adopted the use of pour-ons (spot-on) to protect their cattle against trypanosomosis infection by tsetse flies. The results nonetheless show that in 1995/1996, the use of spot-on by the community was not so widespread. Only about 20 % of the sampled people were using spot-on or had paid to acquire it. The major constraint faced by the community in the use of spot-on was the high cost of the drug. When the drug was introduced in 1995 a single dose was at Kshs 50 which was high, so KETRI and the company concerned subsidised it at Kshs 20 per animal for a single dose. Despite this subsidy the respondents still complained of the high prices.

In order to understand more about the use of spot-on in the community, a study was carried out in Entasopia Sub-Location where spot-on was first introduced. About 135 pastoralists/farmers were sampled and a structured questionnaire administered to them. The study is still going on.

14.7 SUCCESS OF TRAPPING

The respondents were asked to give their opinion on the success of trapping tsetse in the area. Respondents (100%) said that tsetse trapping was highly successful. This response further supports the perceptions of the people on the tsetse problem and its effect on farming and livestock production as discussed before in this report. Most of the negative effects of the tsetse problem on agricultural production, livestock production and access to natural resources, has been highly reduced and or improved, and the impact is noticeable to the community.

14.8 DEVELOPMENT AND ASSESSMENT OF COMMUNITY-BASED TRAINING COURSES

A training programme on community-based management of the tsetse technology for the Olkiramatian and Shompole Group Ranch communities of Kajiado District, was executed at the MPFS during the period 8 to 14 June 1995. The communities within the two group ranches selected 25 (20 men and 5 women) from amongst them to participate in the training.

The Catalytic Group (CG) of 25 Maasai men and women trained at the MPFS in June 1995, were taught the basics of the biology, ecology and history of tsetse in Nguruman. They learned about the problems and diseases both to humans and animals caused by tsetse. In addition to the epidemiology of diseases caused by tsetse, they learned about the impact on livestock productivity. Perhaps most importantly, as far as sustainability of the tsetse trapping technology is concerned, they were taught the importance of being self-reliant at all times, as far as possible. In order that they could achieve this, they were also taught methods of community organisation and mobilisation for the control of tsetse, using traps.

During this training period, the pastoralists and farmers from Olkiramatian and Shompole group ranches interacted with the Lambwe Valley farmers, who had already successfully adopted the tsetse trapping technology. Both groups held a one-day farmer to farmer (or farmer to pastoralist) discussions on the transfer of the tsetse trapping technology to their communities.

There was also a field demonstration day on trap site selection and trap setting-up in the Ruma National Park, followed by a visit to the Lambwe Valley community's traps in Nyaboro thicket.

The formal training of the community was mainly done in 1995/96. The CG which was trained by ICIPE continued with the training of the other members of the community. Just before the onset of the rains, we advised the CG to organise a 3 days training session during which they should form a dry-season servicing team (DSST). As a result a team of 6 former ICIPE technical assistants was formed and are continuing with the task. The DSST is being supported by 19 community members who were nominated by the community. After these developments the trap status improved considerably.

The dry season servicing team is continuing with the maintenance and servicing of traps. There is need for this team to be sustained and paid a small fee by the community to do this work, especially when the people have moved far away.

14.8.1 *Future training recommendations*

- The CG members should continue training the community. ICIPE could continue to give technical advice and help as necessary.
- Training of extension staff in Kajiado District should be initiated to ensure sustainability of the adoption process. It is worth noting that Kajiado ASAL organised a week's training on TC, in which we participated. This resulted in Lenkobei group being formed.

14.9 MAIN CONCLUSIONS

The adoption process has been slow and has been affected by the nature of the semi-pastoralist economy. However given time it is likely to take-up. In fact new groups have been formed and registered, e.g. Lenkobei in Shompole. Some 18 individuals have made 53 traps and placed them in and around their homesteads.

In general, it seems to us that the impact of trapping has so far been more positive than negative. It is too early to make conclusions on sustainability. There is need therefore for some 'seed' external financial support either from the government, NGOs or the private sector in the short term.

Ultimately, privatisation of the control activities using community organisations seems to be more appropriate and likely to be sustained. The on-going training of the community by the CG needs support if control is to be diffused throughout the wider community.

Output

Publications

Lako G.T. Cost of tsetse trapping using the NG2G tsetse trap: A case study in Kenya. *Insect Science and Its Application*. (In press)

Lako G.T. Maintaining the community-based approach to tsetse control in Nguruman, Kenya. *Social Sciences Department, Research Paper No. 16, 1995.*

Project reports

Study of the potentialities of the local community to sustain the tsetse trapping technology in Kajiado District, Kenya. 1996.

Assessment of households' incomes, expenditures and affordability of the tsetse trapping technology to sedentary and pastoralist populations in Kajiado District, Kenya. 1996.

Conference/workshop papers

G. T. Lako. Training as a tool in promoting community participation in tsetse control in Nguruman, Kenya. Under publication by *Insect Science and its Application* as part of the Proceedings of the 11th Meeting and Scientific Conference, 6–11 August, 1995, Yamoussoukro, Côte d'Ivoire, African Association of Insect Scientists (AAIS) and Entomological Society of Côte d'Ivoire.

G. T. Lako. Economic impact assessment (EIA) of community-based tsetse programmes. Presentation made at the Workshop on 'Integrated Rural Development through Sustainable Management of Tsetse and Trypanosomiasis—The Way Forward'. Axum, Ethiopia, 3 to 8 February, 1997.

G. T. Lako. Privatization of tsetse and trypanosomiasis control in the tropics. A paper presented at the Joint OAU / FAO / IAEA / WHO Programme against African Trypanosomiasis. Third Committee Meeting, WHO, Geneva, 19–21 November 1997.

G. T. Lako. Community Participation in Tsetse and Trypanosomiasis Control in Transmara District, Kenya. A Preliminary study. Paper presented at the International Scientific Council for Trypanosomiasis Research and Control, Maputo, Mozambique, 29 Sept.–4 Oct., 1997.

Capacity building

Training activities

Executed a training programme on community-based management of the tsetse trapping technology for pastoralists from Nguruman at Mbita Point Field Station, 8–14 June 1995.

The International Group Training Course on Tsetse Management, Monitoring and Evaluation, The ICIPE, 1–30 November, 1995.

Executed a refresher course for the catalytic group of Maasai pastoralists already trained on community-based management of the tsetse trapping technology at Mbita Point Field Station, on 3–4 May 1996.

Training course for Veterinary Officers and farmers on management and control of tsetse at Debre Zet and Welkite, Ethiopia, 19–25 August 1996.

National Group Training Course on Integrated Management of Crop Pests —Tanzania, ICIPE, 13 October–26 November, 1996.

The Integrated Group Training Course on Basic Biology and Trapping Technologies for Mid-level Professionals from Somalia—Sponsored by the International Red Cross (20 April–May 1997).

15. COMMUNITY-BASED *GLOSSINA PALLIDIPES* SUPPRESSION: A MODEL PROJECT IN SOUTHERN NATIONS, NATIONALITIES, AND PEOPLES REGIONAL STATE OF ETHIOPIA

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Technicians: *T. Mekonen, K. Gebre-Medhem, B. Wolde-Mariam*

Additional funding received from: *Ethiopian Science and Technology Commission (ESTC), Southern Nations, Nationalities, and Peoples Regional State of Ethiopia (SNNPRS), Local businesses in Gurage communities*

Collaborators: • *Ethiopian Science and Technology Commission* • *The Southern Nations, Nationalities, and Peoples Regional State of Ethiopia* • *Ethiopian Ministry of Agriculture* • *The Permaculture and Parasitology Institute (PPI)* • *Howard University* • *Peasant Associations of Damot Weyde Woreda, North Omo Zone* • *Peasant Associations of Cheha, Enemor and Goro Woredas, Gurage Zone*

Background, approach and objectives

Ethiopia, like many countries in Africa, faces many development challenges. Some of the major development challenges are in the sphere of sustainable food production and security, human and livestock health, and the conservation of agricultural resources, especially soil and water. Arthropods contribute significantly to these challenges at various stages of food production. Disease-carrying arthropods, tsetse flies and mosquitoes have dictated the pace and pattern of economic development in the western and southern parts of Ethiopia. The settlement patterns in many parts of present Ethiopia reflect, to a large extent, the problems caused by these arthropods. Many communities in rural areas have been forced to retreat from tsetse- and mosquito-infested fertile lowlands. Population displacement to the highlands because of high human and animal morbidity and mortality inevitably led to overgrazing, erosion, and associated social and ecological problems, including destruction of woodlands and water catchment areas.

Problems directly attributed to trypanosomosis in Ethiopia are, in many cases, difficult to clearly separate from other problems of a developing country. However, the following are some of the major and well recognised menaces brought about by African bovine trypanosomosis in this country:

- Some 10–14 million heads of cattle and an equivalent number of equines and small ruminants (goats and sheep) are exposed to the risk of trypanosomosis at any time. Morbidity and mortality losses from ruminant livestock alone are estimated at some US$ 200 million. (According to FAO, 1991, estimates of morbidity and mortality losses run to US$ 10–20/animal/yr).
- Livestock, and particularly cattle, are prevented from introduction and use for agricultural production in about 150,000 km² of fertile valleys in the west and southwest parts of Ethiopia.
- Human and livestock populations are concentrated in tsetse- and trypanosomosis-free, but ecologically fragile highlands, with the resultant effect of overgrazing, overploughing, soil erosion, land degradation, loss of resources and poverty. Food security attempts have been stifled due to unbalanced land use and access exclusion from otherwise available land resources.
- The government is obliged to spend a substantial amount of scarce resources annually in order to curb the effects of trypanosomosis and related problems. About US$ 1 million is spent for

trypanocidal drugs every year and the problem is still serious.

- Unofficial estimates from the Ethiopian Ministry of Agriculture put the overall trypanosomosis-related losses at between US$ 1408 and US$ 1540 million per annum, excluding animal traction power and manure values.

In view of the above, the Ethiopian Government signed charter and country agreements with ICIPE on 8 January 1992, and 9 January 1993, respectively. Subsequently, ICIPE signed memoranda of understanding with the Ethiopian Science and Technology Commission (ESTC), Ministry of Agriculture, Ministry of Health, Addis Ababa University, and Amhara, Oromia, Southern Region and Tigrai Regional Governments. In addition, ICIPE has pending project agreements with several non-governmental organisations in Ethiopia.

As a result of this, the Ethiopian Government, through the Ministry of Agriculture and Ministry of Foreign Economic Development, endorsed in 1995 the regional EU project for tsetse and trypanosomosis control proposed by ICIPE.

Until recently, the Ethiopian Government's approach to trypanosomosis control has been through chemotherapy and chemoprophylaxis. At the moment the Government spends precious hard currency to import needed drugs. Chemotherapy cannot solve the problem of trypanosomosis, because of the recurrent cost involved and the potential for an endless cycle of drug resistance, requiring new drugs.

In Ethiopia, very limited work has been done on the ecology, population dynamics, behaviours and trapping of tsetse flies in order to more cost-effectively control the pest with limited government funds. Therefore, it has not been possible to develop a sustainable tsetse control package to date. The tsetse and trypanosomosis team of the Ministry of Agriculture has reconfirmed the wide distribution of *G. pallidipes* in Ethiopia. It is also known as one of the most important vectors of trypanosomosis in this country.

A great deal of money and effort has been devoted to insecticidal spray campaigns against tsetse flies, which have not succeeded. Recent attention has focused more on the use of traps and targets that are cheap and that can be made and maintained by people living in the affected areas, offering sustainable control.

ICIPE collaborates with the federal and regional governments of Ethiopia, communities, and non-governmental organisations to transfer the technology on odour-baited traps and promote capacity building at all levels. In this effort, the ESTC has played a major role by coordinating the operation and providing local grants to the regional agriculture bureau. Furthermore, the regional, zonal, and woreda agricultural bureaus have coordinated the actual operation and have also provided traps and other essential material for the pilot programme. The communities have been involved from the initial project planning and programming to the final project implementation and evaluation.

Four committees were formed within the peasant associations intending to suppress tsetse populations. Farmer workshops and training were carried out by technical staff of regional laboratories and by ICIPE. The community had participated in all the activities, including deploying/redeploying traps, cow urine collection, etc.

This approach has resulted in a joint technology transfer, validation, and adoption by both the community and the extension services. This interaction has led us to further examine and develop effective methods for technology up-take and sustainability.

The objectives of the project are to:

(i) develop cost-effective odour-baited tsetse traps, validate and transfer the technology and control system with full community participation;
(ii) evaluate technology up-take and sustainability of the tsetse control operation;
(iii) improve animal health and productivity to enhance food production;
(iv) develop capacity building at all levels in the region.

Work in progress

15.1 SOCIOECOMONIC SURVEY METHODOLOGY AND ACTIVITIES

The SNNPRS is located in the southwestern part of the country bordering Kenya in the south, the Sudan Republic in the southwest, Gambela Region in the northwest, and Oromia Region in the north and east. The region lies between 4°27′ and 8°30′ N and 34°21′ and 39°11′ E. The grid reference indicates that the region is located within the Tropic of Cancer close to the Equator. It has an area of about 118,000 km² and accounts for 10% of the total area of the country (Figure 15.1).

According to a recent population estimate (1994), the total population of the region is about 11.31 million. The agricultural population, which consists of 1.54 million family heads, is now organised into 4023 peasant associations. There are about 7.36 million cattle, 1.25 million equines, 2.16 million sheep and 830 camels in the region. Maize, teff, enset, coffee, tea, cotton, banana, pineapple, spices, potato, wheat, fruits and vegetables are major crops in the region. Hides and skins are the major foreign currency earners after coffee. Eucalyptus tree farming is also a major income generating activity in the region.

The amount and distribution of rainfall varies from place to place within the region. The mean annual rainfall in the region ranges from 500 to 2200 mm and the mean annual temperature ranges from 15 to 30° C.

The major constraints to development are to a

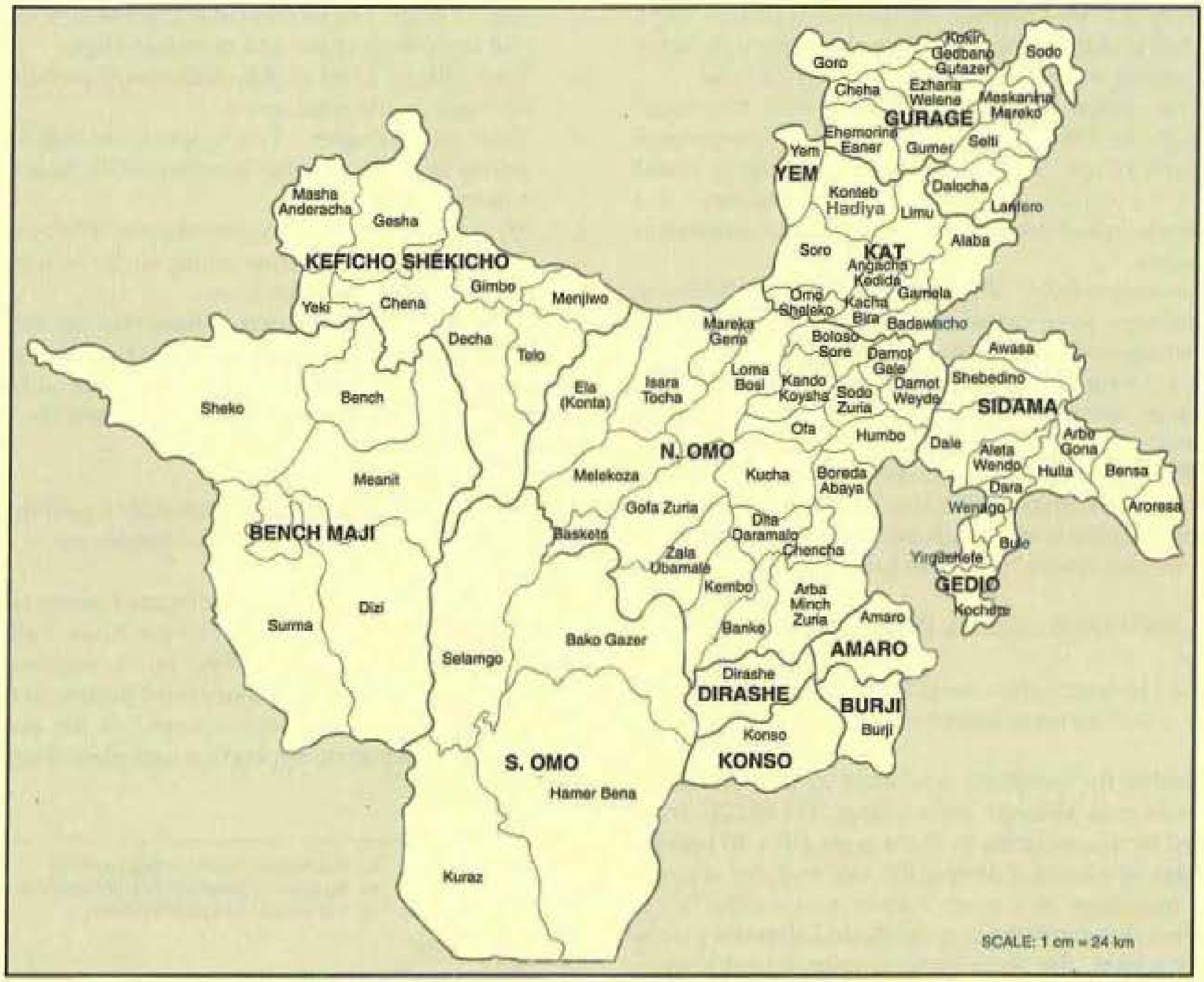


Figure 15.1. Administrative zones and woredas of the Southern Nations, Nationalists and Peoples' Regional State of Ethiopia

large extent associated with malaria and trypanosomosis. In 1995, with the request of the regional government, the ESTC and ICIPE initiated a community-based tsetse control project using odour-baited traps in Damot Weyde Woreda, covering an area of 300 km^2.

Following the successful suppression programme in Damot Weyde Woreda, the Gurage Zone administration requested ESTC and ICIPE to extend the pilot tsetse control project to Goro, Cheha and Enemor woredas. On the basis of the request from the zonal agricultural bureau and the farming community in the tsetse-infested area, a pilot project was initiated at the end of 1996.

The pilot control project covers about 350 km^2 of fertile arable land along the Wabe, Walga, Luke, Jatu and Ghibe River systems.

15.1.1 *The survey methodology*

The survey was planned, designed, and executed by socioeconomic specialists of ICIPE in collaboration with various regional and community-level organisations. The survey covered four woredas of the SNNPRS of Ethiopia where the tsetse control activities are in operation.

The survey was designed to represent typical rural households in infested areas of each woreda (district). A total of 241 households, comprising of 158 from Damot Weyde and Goro, 29 from Ener, and 54 from Cheha woredas, were selected. Samples were randomly taken from a list of households in the infested areas. The survey field work was done from November 1995 to November 1997. A total of 12 personnel, including ICIPE experts and supporting staff, carried out the field work.

After the data were collected, the questionnaires were coded to facilitate computer data entry. The data were fed into the computer using an Integrated Micro-Computer Processing System (IMCPS) statistical package that allowed consistency and accuracy checks. Finally, the edited data were converted into a format readable by SAS and statistical analyses were done using the IMCPS.

15.1.2 *Organisation and community mobilisation*

Before the launch of the Pilot Tsetse Suppression Programme, a series of discussions were held with the ESTC, the SNNPRS Agriculture Bureau, and representatives of woreda communities (Figure 15.1). The ESTC allocated a grant for technology validation and testing in the southern region of Ethiopia.

Two group-training workshops were organised for high- and mid-level professionals to demonstrate the technology for the envisaged community-based tsetse control and the methodology for epidemiological data collection and impact assessment activities.

Subsequently, three major farmer-training workshops were organised in both Damot Weyde woreda and Gurage Zone with special emphasis on trap making with locally available materials. In addition, farmers were trained how to set and service the traps.

Through collaboration between the staff of Sodo Regional Veterinary Laboratory and the tsetse survey team, the collection of epidemiological, entomological and socioeconomic data was initiated in April 1995.

15.2 ENTOMOLOGICAL DATA COLLECTION

15.2.1 *Pre-intervention sampling of* G. pallidipes *and other haematophagous insects*

Extensive fly sampling was done in Damot Weyde Woreda and Gurage Zone using 300 NG2G traps baited with cow urine in eight grids (10 x 10 km) for 10 days in each site during the wet and dry seasons. The operation in Damot Weyde was conducted in collaboration with the regional Sodo Laboratory tsetse survey team, the Sodo Bedessa animal health team, extension workers and the community at large. The preliminary data collection in Gurage Zone (i.e. Cheha, Enemor and Goro Woredas) was done with the zonal and woreda animal health teams and the farming communities. The extensive fly survey operation covered different eco-types, fly breeding, and animal watering, resting, and grazing sites in order to establish the overall distribution and abundance of *G. pallidipes* in the study areas.

Concurrently, intensive monthly *G. pallidipes* samplings were instituted using 40 NG2G traps baited with acetone and cow urine in order to collect detailed information on the tsetse population (e.g. age, sex ratio, infection rate). A series of experiments were also conducted to evaluate the response of the fly to durable but affordable trap materials.

15.2.2 Glossina pallidipes *suppression*

A total of 1500 NG2G traps were made with the support of ESTC, SNNPRS and ICIPE. The communities in the study areas of Damot Weyde and Gurage Zone woredas were mobilised and trained to make, set and maintain traps. In addition, they were trained to collect fly catches from traps and also to grease the poles of monitoring traps to protect them from predators such as ants.

The farmers organised four groups to run the operation:

1. Trap makers. The farmers identified skilled men and women to make and maintain traps.
2. Trap setters. Most of the community members set traps as the need arose.
3. Trap maintenance. Traps were maintained primarily by the younger members of the farming community.
4. Fly collection and bait replenishment. Flies were collected and cow urine replaced by younger members and cattle owners.

A total of 646 NG2G traps in Damot Weyde, 500 in Arba Minch (control site) and 500 in the three Gurage Zone woredas were deployed with the active participation of the community to suppress the *G. pallidipes* population.

15.2.3 *Seasonal fluctuations and reduction of* G. pallidipes *populations and trypanosomosis prevalence*

Glossina pallidipes populations fluctuated seasonally in the control site in the Wabe/Ghibe River Valley from January to December 1996, but a decline in tsetse fly populations and a concurrent decline in the incidence of trypanosomosis occurred in the areas where the fly intervention operation took place (Figure 15.2).

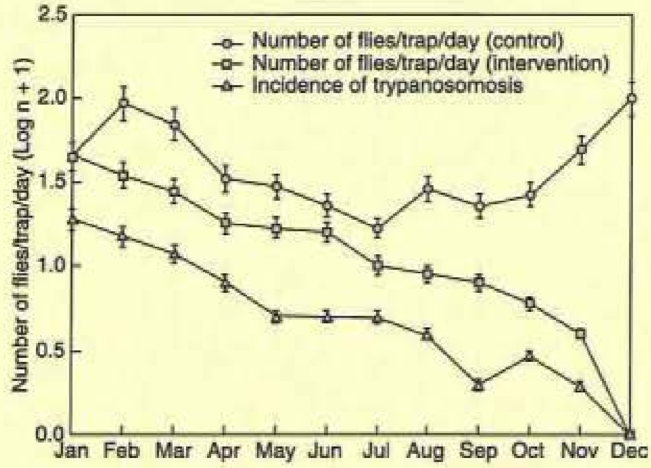


Figure 15.2. Tsetse control and trypanosomosis incidence in Wabe/Ghibe River Valley (Jan.–Dec. 1996)

In Damot Weyde Woreda, most of the *G. pallidipes* (96%) and a relatively high proportion of biting flies were caught between April and June 1995 (Figure 15.3). The highest *G. pallidipes* catches were recorded in April 1995 in Ankadamote and in May 1995 in Ellorasho Peasant Associations, and the lowest in Chericho Peasant Association, where no tsetse were caught throughout the trapping period. To-date, *G. pallidipes* is the only species recorded in Damot Weyde Woreda and 60% of the tsetse caught were females. Tabanids account for 85% of the biting flies caught, while the remaining 10 and 5% were *Stomoxys* and *Haematopota*, respectively (Figure 15.4).

In Damot Weyde Woreda (Sodo) from April 1995 to March 1996, two main trypanosome species were recorded during the study period, *T. congolense* accounted for 69.62%, *T. vivax* for 27%, and mixed infection for 3.38% of the cases. Disease incidence declined from 15.5 to 2.7%, which constitutes an 82.6% reduction. A high trypanosome prevalence (29%) for Ankadamote was recorded in April 1995, which corresponded with a high tsetse catch in that village at that time. Overall prevalence of the disease declined to zero in January and February.

Percentage of mean packed cell volume (PCV) of cattle in the area was lowest in June and March, while the highest PCV was recorded in October and November (Figure 15.5). In April 1995, 56.6% of animals had PCV<25. Afterwards, the proportion of animals with PCV>25 increased, indicating that the prevalence of the disease was declining. A greater number of animals with PCV<25 was found than was expected from numbers of infected animals (Figure 15.6). However, both infected and uninfected animals showed lower PCV results than expected, and the PCV value of trypanosome-infected cattle was generally lower than in uninfected cattle (Table 15.1).

The average age of female animals to fertility for cattle (cows) before suppression was 5.06 years while after suppression it was reduced to 3.32 years (Figure 15.7). The average age for goats, sheep, donkeys, and horses was also reduced, though less dramatically. In general, the mean age to reach reproductive capability had been reduced tremendously for the livestock after suppression. Mortality rates of cattle, goats, sheep, donkeys and horses in the surveyed woreda (Damot Weyde) had been reduced dramatically after tsetse suppression (Figure 15.8). The most significant

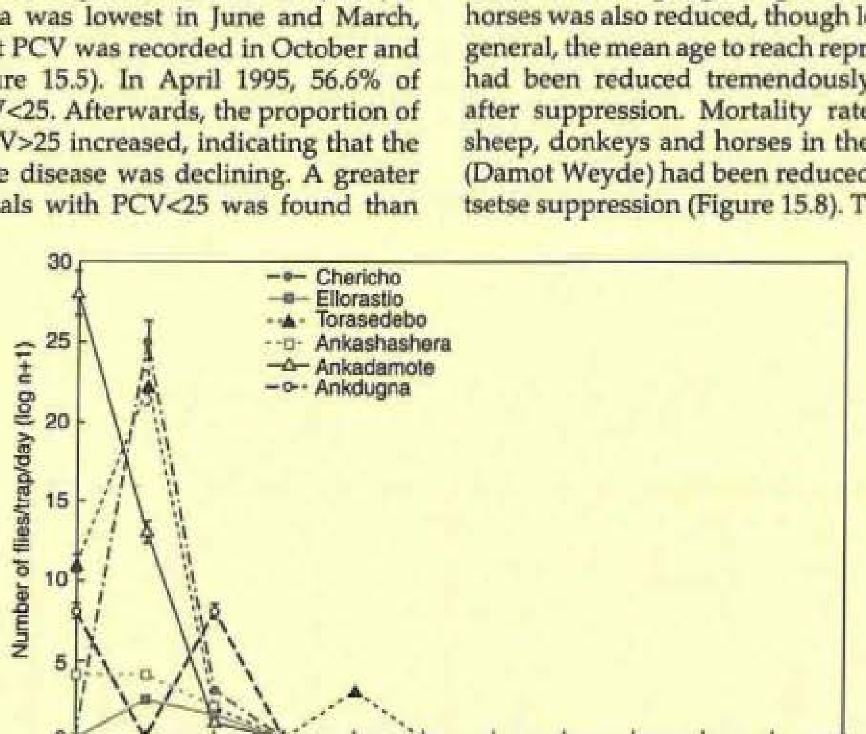


Figure 15.3. Monthly *Glossina pallidipes* catch in six peasant associations of Damot Weyde (April 1995–March 1996)

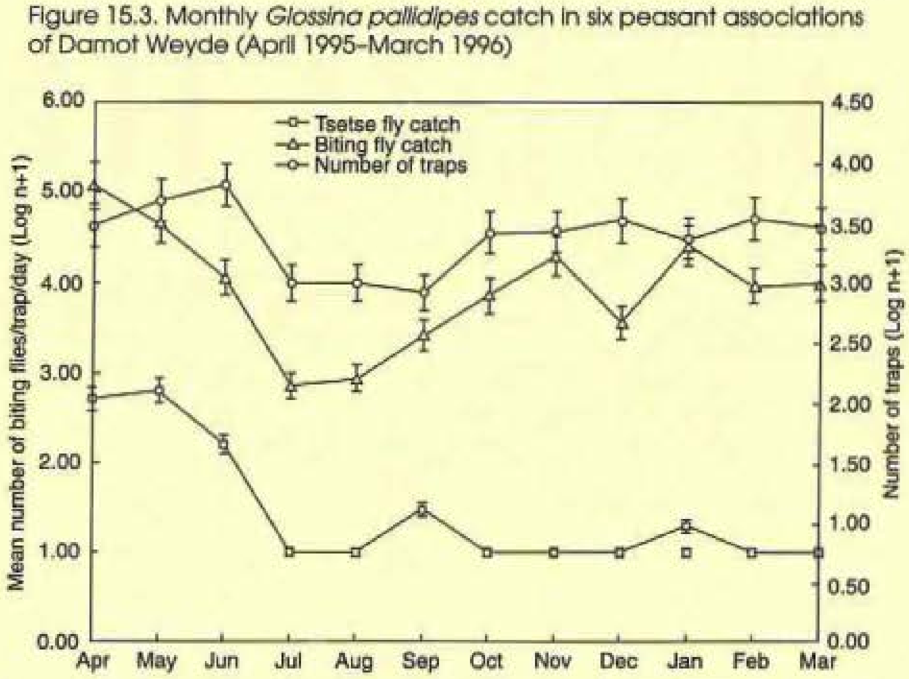


Figure 15.4. *Glossina pallidipes* catches/trap/day in Damot Weyde (April 1995–March 1996)

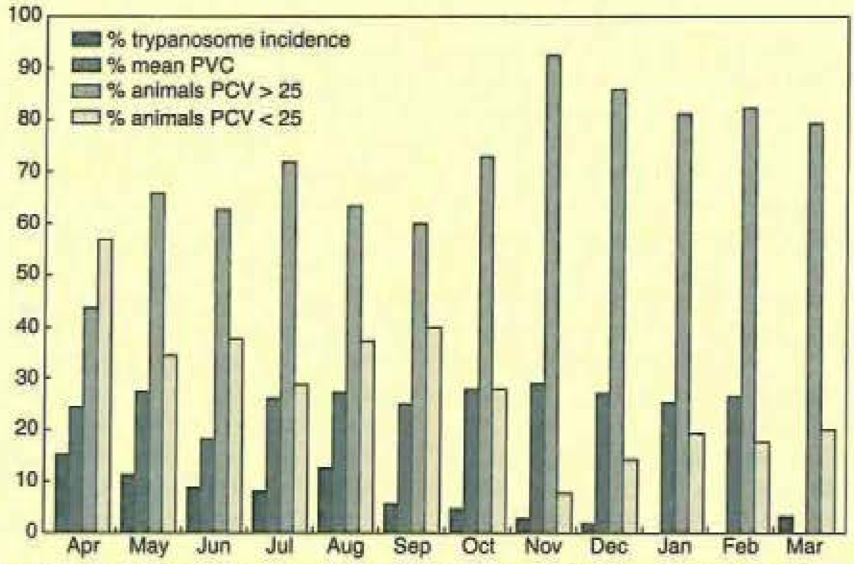


Figure 15.5. Monthly trypanosomosis incidence and mean packed cell volume (PCV), in Sodo (April 1995–March 1996)

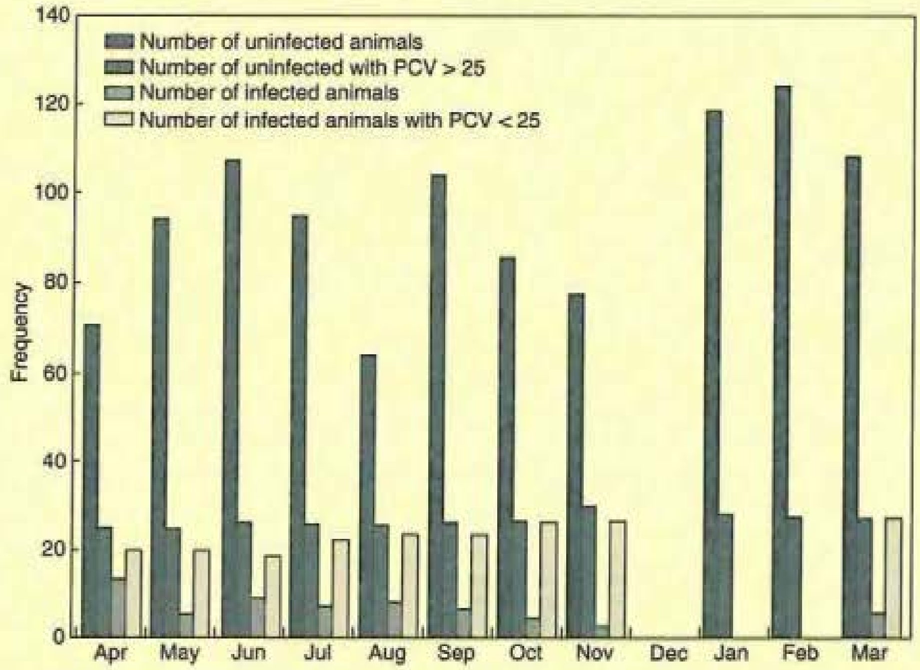


Figure 15.6. Mean PCV of uninfected and infected animals

reduction occurred in the mean cattle mortality rate, from 10.7 before suppression to 0.05 after suppression.

The overall mean weekly yield per cow before suppression was 4.10 litres (± 0.260 SE) for all villages in Damot Weyde Woreda, and that this figure was significantly boosted to 8.71 litres (± 0.526 SE) per cow after suppression activities were carried out (Figure 15.9). A consistently high increase occurred in all villages.

REASONS GIVEN FOR LOW CALVING RATES BEFORE TSETSE CONTROL MEASURES WERE TAKEN

Out of six peasant associations questioned in Damot Weyde Woreda, two reported that lack of bulls and trypanosomosis were the major constraints to calving before tsetse suppression (Figure 15.10). Three other associations cited that poor nutrition, combined with

Table 15.1. Mean PCV values of livestock animals infected and uninfected by trypanosomes in Damot Weyde Woreda

	Uninfected animals		Infected animals	
Date	No. of animals	PCV< 25	No. of animals	PCV< 25
1995				
April	70	24.55	13	20.34
May	94	24.65	5	20.36
June	107	26.34	10	18.90
July	-	-	-	-
August	64	25.59	9	22.69
September	103	25.91	6	23.33
October	86	26.38	4	26.00
November	77	29.07	2	27.50
1996				
January	118	26.80	-	-
February	123	27.00	-	-
March	108	26.67	6	27.50

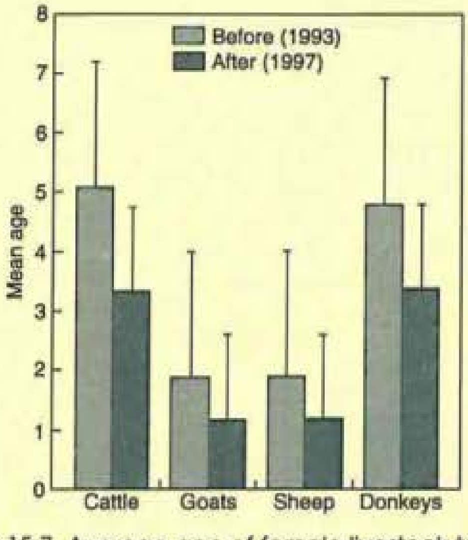


Figure 15.7. Average age of female livestock to reach fertility before and after suppression (Damot Weyde Woreda)

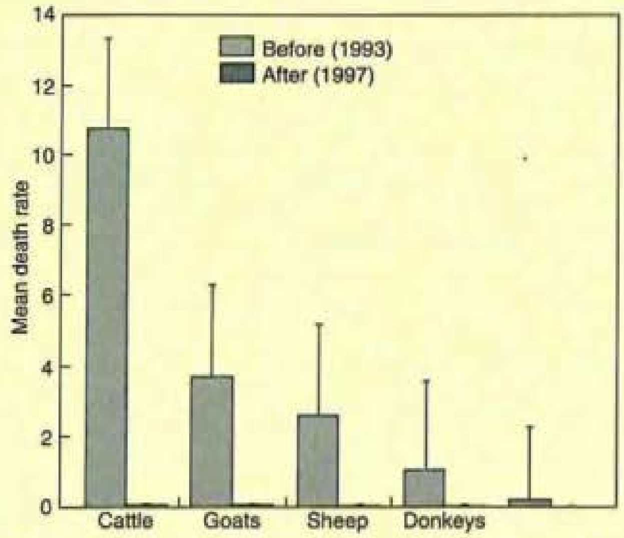


Figure 15.8. Livestock mortality rate before and after suppression (Damot Weyde Woreda)

lack of bulls and trypanosomosis, were the major constraints causing low calving rates. In five of the six villages, therefore, trypanosomosis was cited as a main concern.

15.2.4 *Comparison of the catches of NG2G traps made by substituting components with cheaper and locally available materials*

The standard NG2G trap used in the tsetse suppression study was made with nylon mosquito netting and Awassan blue and black fabrics, at an estimated cost of US$ 11.50 each (ETB 82.50). An attempt was made to study the feasibility of using cheaper traps made with materials more easily available at the tsetse suppression site. The test was made during the dry season of 1997 in Nechsar National Park, Arba Minch, an isolated site with a high population of only a single tsetse species, *G. pallidipes*.

The traps were incorporated into a randomised 4x4 latin square arrangement and the experiment was run in triplicates. Acetone and aged cow urine were used as odour attractants. The daily catches per trap for each sex were recorded and transformed into logarithmic scale ($\log x+1$) and a two-way analysis of variance was performed. An index of increase was also calculated from the detransformed mean.

A description of the trap materials tested and estimated costs is provided in Table 15.2. Colours of substituted materials could not be exactly matched with the standard, but the Kenyan blue cloth and blue woven plastic can be characterised as lighter than the standard Awassan blue cloth, while the blue side of the polsheet is as dark. The black materials were all as dark as the Awassan black.

Trap type significantly affected daily catches for both sexes. Substitution of plastic material for fibre cloth was more economical, but clearly had a negative effect on trap catch for both sexes. Type 1 traps improved catches by about 2.5 and 3.3 times the

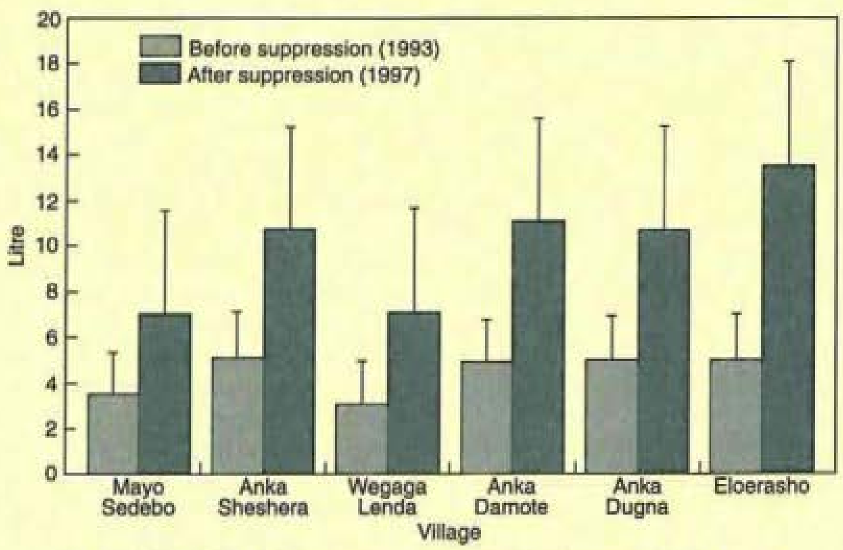


Figure 15.9. Milk yield per cow per week before and after suppression (Damot Weyde Woreda)

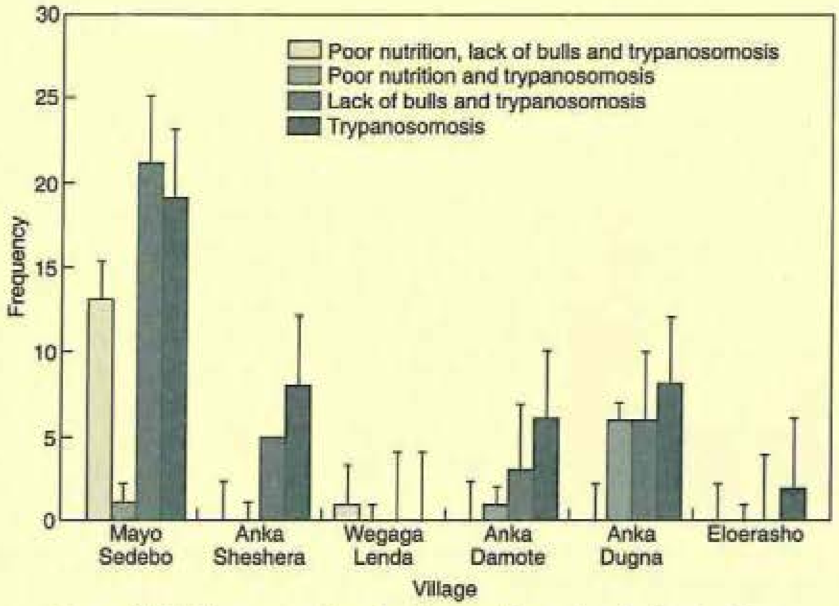


Figure 15.10. Reasons given for low calving rates before tsetse control measures were taken (Damot Weyde Woreda)

Table 15.2. Substituted trap materials and costs relative to the standard NG2G trap

Trap code	Trap component substituted: Nylon mosquito net	Awassan blue (local)	Awassan black (local)	Type	Estimated unit price per trap	Percentage cost reduction relative to the standard
1	Nylon mosquito net	Awassan blue (local)	Awassan black (local)	Standard	82.50 ETB	-
2	Locally woven cotton (*Debella/Pelekina*)	Kenyan blue	Black sac (Sisal)	Type 1	39.90 ETB	-51.64%
3	White woven plastic (Madaberia)	Blue woven plastic (Madaberia)	Black woven plastic (Madaberia)	Type 2	10.30 ETB	-87.52 %
4	White woven plastic (Madaberia)	Blue woven plastic polshee+	Black woven plastic (Madaberia)	Type 3	18.45 ETB	-77.64 %

+One side is white.

standard catch for females and males, respectively, at about half the cost of the standard. Such promising results are prompting further modification and testing of the Type 1 trap, using Awassan blue cloth in place of the Kenyan blue.

15.2.5 *Parasitological and haematological data collection*

Blood samples were collected for haematological examination from 50 randomly selected East African zebu (*Bos indicus*) throughout 20 peasant associations in the two study sites. Anaemia was estimated by measuring the packed cell volume (PCV) of the blood. Thick and thin smears were prepared from centrifugal haematocrit tube samples and the buffy-coat procedure was used for parasite species identification and parasitaemia determination.

15.3 SOCIOECONOMIC PROFILE OF THE STUDY POPULATION

The human and livestock populations in tsetse-infested and tsetse-free areas in Gurage Zone woredas that took part in the programme are shown in Table 15.3. Agriculture, crop production and animal husbandry, is the most important economic activity in the project area. In addition, some farmers grow coffee, quat, and enset for day-to-day income generation. The major human diseases include malaria, pneumonia, trachoma, diarrhoea and internal parasites (Table 15.4). According to the 1995 Gurage Zone Agricultural Bureau reports, trypanosomosis is the major constraint for livestock production in the area. The incidence of trypanosomosis is given in Table 15.5. The zonal veterinary team has compiled a list of the major preventive and curative veterinary intervention strategies used in the study area (Table 15.6).

Table 15.3. Basic statistics on human and animal populations in tsetse-infested and unifested areas in Cheha, Enemor and Goro woredas

	Cheha	Enemor	Goro	Total
Total area (km^2)	444	1 152	576	217,312
Total tsetse-infested area (km^2)	148	385	192	72,524
Total human population	161,423	229,190	103,912	494,525
Human population in tsetse-infested area	40,356	76,397	34,638	151,391
No. of animals in tsetse-free area	149,439	190,675	67,658	407,772
No. of animals in tsetse-infested area	23,141	43,915	32,991	100,047

Table 15.4. Major public health problems in Cheha, Enemor and Goro woredas over a number of years

Disease	Cheha				Enemor				Goro	
(cases/year)	1993	1994	1995	1996	1993	1994	1995	1996	1995	1996
Malaria	9402	11,756	17,721	16,426	26,800	9000	36,000	53,200	13,814	18,935
Pneumonia	2941	4042	5535	6646	600	1,500	1300	2800	2646	4129
Trachoma	5490	7896	13,710	5344	16,400	6120	18160	17,020	5346	6254
Diarrhoea	9524	6,672	6,939	6762	1,760	2950	3420	6360	2478	3694
Internal parasites	9216	10,626	10539	10,626	3,430	4870	4120	3100	4354	4564

The respondents indicated that tsetse flies were a problem in their villages and farming areas (Figure 15.11).

Constraints of livestock production encountered included trypanosomosis, lack of feed and water and attacks from wildlife (Figure 15.12). The results also show that trypanosomosis plays a significant role in reducing and limiting livestock production in all the woredas.

Damot Weyde Woreda has the highest fly density among the surveyed sites and Gurage Zone, Cheha Woreda has more tsetse flies than Enemor Woreda, which agrees with the disease prevalence in those sites (Figure 15.13).

Lack of draught power in Damot Weyde and Enemor woredas, and lack of draught power and

Table 15.5. Livestock populations and incidence of trypanosomosis (tryps.) in Cheha, Enemor, and Goro Woredas

Animal type	Cheha: Number infected with tryps.	Cheha: Total number of animals	Enemor: Number infected withtryps.	Enemor: Total number of animals	Goro: Number infected with tryps.	Goro: Total number of animals
Oxen	71	575	353	6101	250	8762
Cattle	9693	57,539	12,013	39,985	7352	21,955
Calves	3920	27,922	13,258	28,382	7093	17,852
Donkeys	205	1173	1811	5239	1785	3885
Horses	-	352	69	4876	-	189
Sheep	293	4150	1623	18,495	356	1106
Goats	2574	58,670	6092	15,329	3695	12,177
Heifer	4554	15,556	4661	15,795	5572	15,384
Bull	1764	5569	2943	8495	4356	11,506
Mule	67	1160	1092	3049	2532	7783
Total	23,141	75,608	43,915	234,590	32,991	100,649

Table 15.6. Records of preventive and curative measures carried out by the Gurage Zonal Veterinary Team in Cheha, Enemor and Goro woredas over a number of years

	Cheha			Enemor				Goro	
Cases/year E.C.	1993–94	1994–95	1995–96	1993	1994	1995	1996	1995	1996
Vaccinations	7200	6700	4510	2650	8400	1900	4800	4657	16,220
Trypanosomosis	6700	7120	12,200	5500	1400	4000	8900	1990	5485
Internalparasites	3600	3800	4212	6500	2000	4000	4900	1410	1354
Externalparasites	1612	2510	2515	800	1900	900	950	4303	1198
Variousdiseases	950	1150	1150	850	900	1300	850	2303	519

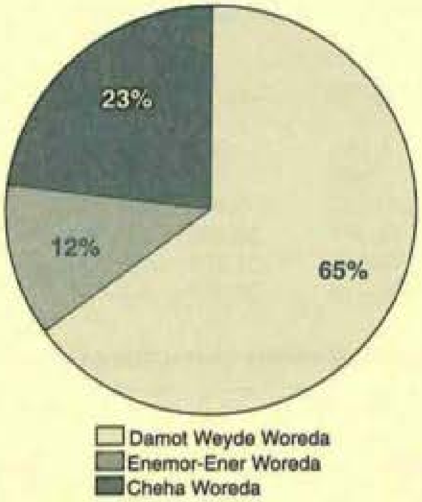


Figure 15.11. Households who responded 'yes' on whether tsetse is a problem

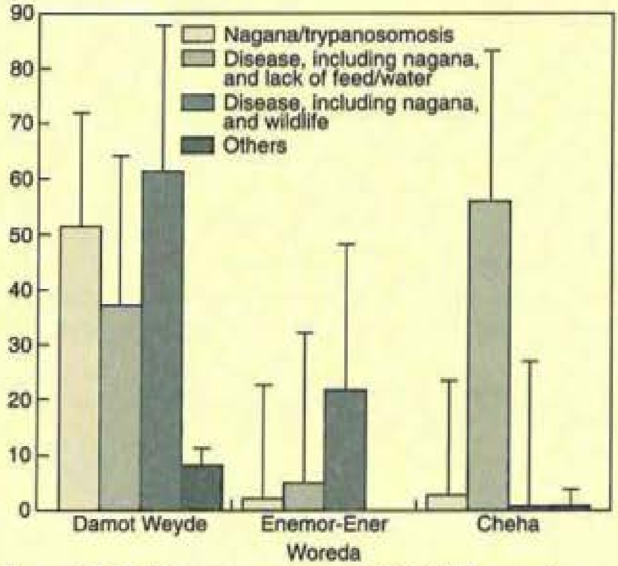


Figure 15.12. Response on constraints to livestock production

seed in Cheha Woreda were the major constraints for crop production (Figure 15.14). Lack of fertiliser, fertile soil and improved seed and crop destruction by wildlife were also noted as additional limiting factors in Damot Weyde and Cheha woredas.

The majority of households in Damot Weyde and Cheha woredas expressed their willingness to fight the tsetse menace to free their villages and farm lands of the flies. However, in the Enemor-Ener Woreda, only those people who are faced with high tsetse challenge and associated problems responded positively, while the remaining 50% who were living in lower tsetse challenge areas were not willing to do so. This clearly shows that the participation of the community is strongly related to the magnitude of its problem. In other words, any operation that requires the participation of the community should rely on the demand and the need of the end-users, i.e. it must be driven by demand.

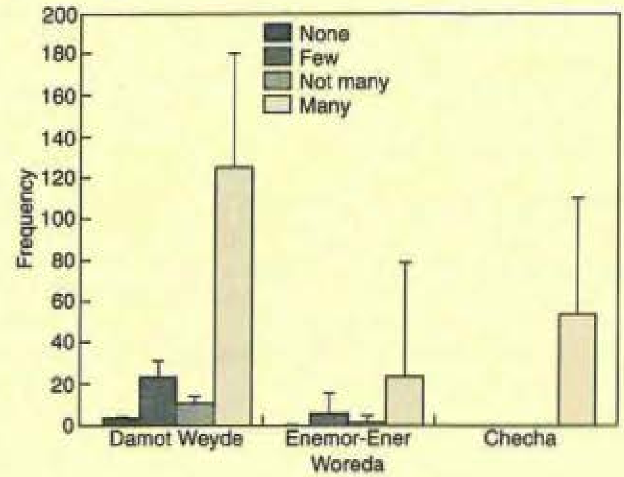


Figure 15.13. Perceived abundance of tsetse flies

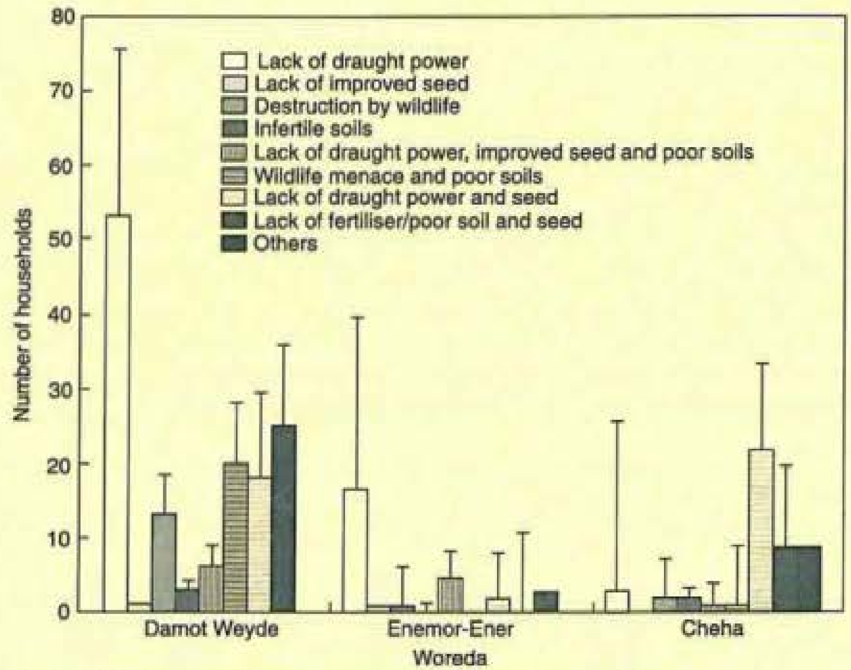


Figure 15.14. Response on constraints to crop production

The means used by households to combat tsetse and disease are shown in Figure 15.15.

The majority of households (about 120) indicated their preparedness to set traps and to participate in trap pole preparation, clearing of trapping site and provision of odour baits (cow urine) (Figure 15.16). On the other hand, the proportion of people who were interested in trap making and management were fairly low. This indicates that it is necessary to identify the best candidates to make traps and to simplify the trap itself.

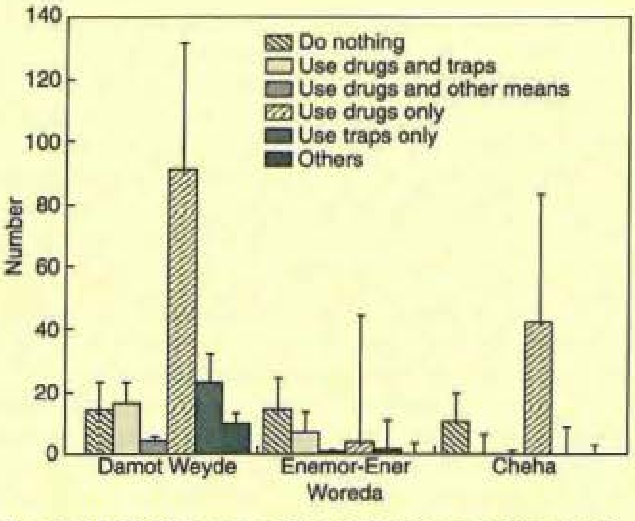


Figure 15.15. Response of households on methods of combating tsetse problems

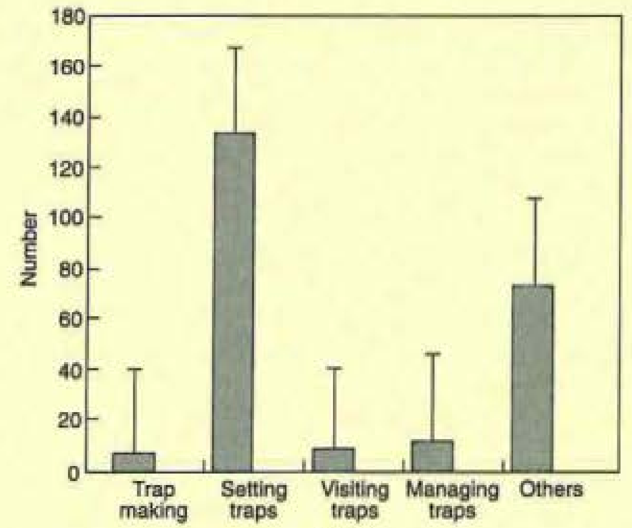


Figure 15.16. Response on how the community intends to participate in tsetse control activities (in all woredas)

15.4 SUMMARY

The control operation undertaken jointly by the SNNPRS Agricultural Bureau, the ESTC and ICIPE has demonstrated the effectiveness of NG2G traps baited with cow urine for control of *G. pallidipes* under Ethiopian conditions.

The current tsetse control operation in Damot Weyde Woreda is part of an area-wide *G. pallidipes* eradication programme. Thus, the activities will be sustained and the knowledge and experience gained will be used effectively. The chances for reinvasion are minimal. With regard to the Gurage Zone operation, the Agriculture Bureau is making 1000 traps to extend the operation. Farmers have also cultivated 40 hectares of teff as an income generating package to sustain the tsetse control operation.

A socioeconomic survey showed that average weekly milk production per cow before tsetse fly suppression was 4.10 ($\pm$ 0.260 SE) litres. After suppression of tsetse flies there was a significant improvement to 8.71 ($\pm$ 0.526 SE) litres/cow/week during the survey time. As a result of tsetse suppression, milk production increased more than 100%. The overall mean percent in livestock mortality before and after suppression was also reduced significantly.

The mean age of female livestock to fertility after tsetse fly suppression was reduced by 23%. Furthermore, the survey showed that the fly control operation decreased livestock abortion and increased calving rate.

In the survey areas, the vast majority of the households willingly responded regarding the presence of tsetse flies and were aware of the problems associated with them. About 65% of the households in Damote Weyde, 23% in Cheha, and 12% in Enemor knew that there is a relationship between their livestock problems and the tsetse flies in their respective villages. This awareness was one of the fundamental bases for the success of the study and the field trials.

In both Damot Weyde Woreda and Gurage Zone, successful technology uptake and sustainable vector management have been demonstrated in a very short period of time. As a consequence of this success, the project has the following important developments:

- *Glossina pallidipes* control projects are being initiated in four regions with about 7000 traps.
- The developmental phase of a holistic vector management and integrated rural development project, called the 'BioVillage Initiative' is being finalised (see below).
- Integration and validation of vector control using different attractants and techniques such as contaminating devices (CDs) and lethal insect technique (LIT) have been initiated.
- Integrated human and animal health management projects in the Beles Valley are being consolidated and a comprehensive project proposal has been developed.

The *G. pallidipes* suppression pilot project of the SNNPR Agriculture Bureau programme in Damot Weyde, Cheha, Goro, and Enemor-Ener woredas is the largest community-based operation using odour-baited NG2G traps in Ethiopia. The results achieved so far are very encouraging and the operation must continue in order to improve the quality of life of the people in the control area and beyond.

The following recommendations are for future implementation:

1. Integration of the tsetse control operation with other rural development programmes to make it more rewarding and beneficial.
2. Participation by end users not only with provision of labour and material for the control programme, but also in every stage of project design, planning, execution, and evaluation in order to sustain the proposed tsetse control project.
3. Education of the community on the various aspects of trapping technology and disease epidemiology. This will ensure the successful adoption, uptake, and sustainability of the control technology, because success requires control of adequate information on every aspect of the technology in use.
4. Integration of trapping technology with other tsetse and trypanosomosis control techniques to optimise benefit depending upon the situation.
5. Inclusion of environmental and socioeconomic impact analyses as essential components of community-based tsetse control programmes.

16. OTHER TSETSE AND TRYPANOSOMOSIS CONTROL EFFORTS

16.1 THE BIOVILLAGE INITIATIVE

The BioVillage Initiative is a response to community-level requests to address economic development problems of rural communities in Ethiopia. It is a comprehensive community-driven approach combining several strategies, including tsetse and trypanosomosis control, aimed at improving human, animal, and plant health, and integrates initiatives and projects intended to catalyse and exploit income-generating potential. It also aims to develop the capacity for sustainable implementation of development initiatives through efficient resource utilisation and conservation. The specific long-term objectives of the initiative are:

(1) improvement of human, animal, and plant health through preventive pest and vector control methods;

(2) initiation of sustainable development through better resource management techniques; and (3) alleviation of poverty through the broadening of the income base of the community. The project is initially being implemented over a period of three years.

16.1.1 *The lethal insect technique*

The lethal insect technique (LIT) is being tested and validated in Kenya. However, this programme is being extended to Ethiopia through a collaborative project with Addis Ababa University and the ESTC. Two colonies of *Glossina* spp. are being maintained under suboptimal conditions to test the feasibility of rearing flies for LIT under rural conditions with minimal environmental control. Under a collaborative agreement with the Microbiology Department of Addis Ababa University, strains of tsetse pathogens are being located, isolated, and characterised as candidates for LIT.

(See also the Overview of the Animal Health Section.)

Output

Conferences, workshops

A month-long theoretical and practical workshop on community-based vector control was organised by ICIPE, Addis Ababa University and the Oromia Agriculture Bureau. Over 250 peasants and 45 professionals attended. August, 1996, Debre Zeit and Gurage, Ethiopia.

'The Way Forward': International Study Workshop on Integrated Rural Development through Sustainable Management of Tsetse and Trypanosomosis, and Mosquito and Malaria. Organised by the Ethiopian Science and Technology Commission and ICIPE, 3–8 February, 1997, Addis Ababa and Axum, Ethiopia.

Project proposals

Integrated Human and Animal Health Management in the Beles River Valley is a three-year project proposal jointly prepared by the International Committee for Peoples Development (CISP), ESTC, Benishangul and Gumuz Regional Government Agriculture Bureau, ICIPE, and relevant national and international partners.

The proposed project has a concurrent, interrelated, three-stage programme, as follows:

1. Continuation of the present tsetse trapping and monitoring programme through the dry season and into the 1998 wet season, with ancillary studies collating data on human and animal health in the project area (from clinics and project records), with the aims of immediate reduction of the trypanosomosis challenge and an increase in the awareness in local people, of malaria risk.
2. Investigation of alternative approaches to disease management through alternative (i.e., cheaper) trap/bait technologies, environmentally sensitive use of insecticides, reducing cattle–fly contact by changing grazing patterns and investigation of the use of bed-nets, insect-proof tukuls (traditional houses) and environmental sanitation/management for malaria control, all with the aim of improvement of risk reduction methodologies.
3. Study of the potential of biological pathogens as control agents of tsetse populations and of the distribution and abundance of mosquitoes and

tsetse in the Beles River system, their seasonal infection status, mosquito–human and tsetse–cattle contact rates and the local incidence and prevalence of malaria and animal trypanosomosis, with the aim of understanding disease transmission in order to provide the most cost-effective, sustainable solution to the disease management problem in the Beles area.

Capacity building

Over 350 farmers and 90 mid- and high-level government staff have been trained in workshops, and over 100 farmers trained individually by ICIPE field staff to successfully implement community-based integrated vector control.

XI. A Comparative Assessment of the Impact and Sustainability of Community Participation in the Management of Trypanosomosis in East and Southern Africa

1. GENDER ANALYSIS OF PARTICIPATION IN COMMUNITY-MANAGED TRYPANOSOMOSIS IN LAMBWE VALLEY, WESTERN KENYA

Background, approach and objectives

There is a recognised lack of methodology for monitoring and evaluating community participation in agricultural research and development and there is little basis for comparative evaluation. Apropos of this, the Overseas Development Group at the University of East Anglia (ODG/UEA), UK, designed a project to carry out a comparative assessment of the impact and sustainability of community participation in the management of trypanosomosis in Kenya (Lambwe Valley), Uganda and Zambia. A second objective was to carry out a gender analysis of participation in community management of tsetse (GAP/CMT). The specific objectives of GAP/CMT were to document and explain the participation of men and women in respect of: (a) tsetse control activities, (b) control of resources including management, and (c) share in the benefits of control. ODG implemented the larger component in the three countries and contracted ICIPE to investigate in Kenya the gender analysis aspects.

Participating scientist: J. W. Ssennyonga (Project Leader, GAP/CMT component)

Technicians: S. Ojwang', J.N. Kariuki and S. Akinyi

Donor: DFID

Collaborators: • ODG/UEA • NARES: Kenya, Uganda and Zambia

Work in progress

Three sources of information were used: (a) existing Lambwe Valley project databases, (b) a questionnaire to generate new data, and (c) in-depth probing to gain insight into qualitative processes. Gender was investigated as one of the nine factors influencing participation (independent variables). Participation activities (dependent variables) were categorised under five major clusters: capacity building, management of organisation, performance of technical tasks such as trap construction, mobilisation of and control of resources, and (d) impact assessment. Cluster, interpretive and regression analysis was used to determine the importance of gender, relative to other factors, in influencing participation.

The results show significant gender differences in participation. For example, Pearson's correlation

Table 1.1. Pearson's correlation coefficients of the relationships between gender, labour spent on trap work, training and knowledge of tsetse and trypanosomosis

	Labour		Training		Knowledge of tsetse and trypanosomosis	
	Men	Women	Men	Women	Men	Women
Labour	1.00000 0.0	1.00000 0.0023	0.12527 0.3361	0.45742 0.0023	0.15459 0.2342	0.32612 0.0351
Training	0.12527 0.03361	0.45742 0.0023	1.00000 0.0	1.00000 0.0	0.56490 0.0001	0.47018 0.0017
Knowledge of tsetse and trypanosomosis	0.15459 0.2342	0.32612 0.0351	0.56490 0.0001	0.47018 0.0017	1.00000 0.0	1.00000 0.0

coefficients show that the relationship between training and labour expended on trap work is significant for women (0.45742) but not for men (0.12527). Similarly, the relationship between knowledge (of tsetse and trypanosomosis) and hours worked, is significant for women (0.32612) but not for men (0.15459) (Table 1.1).

Output

Terminal Technical Report, 'Gender Analysis of Participation in Community-Managed Trypanosomosis in Lambwe Valley, Western Kenya' was submitted to DFID through ODG/UEA, UK.

Impact

The methodology developed for this project has been applied to the IFAD-funded Lambwe Valley project.

(See report XII)

XII. An Integrated Approach to the Assessment of Trypanosomosis Control Technologies and Their Impact on Agricultural Production, Human Welfare and Natural Resources in Tsetse-Affected Areas of Africa (TST-3)

Background, approach and objectives

African trypanosomosis is the single most important vector-borne disease affecting people, livestock and crop production in sub-Saharan Africa. The population at risk to trypanosomosis is estimated at 55 million, while the number of infected or new cases per year is 250,000 to 300,000 in 37 countries with a total endemic area of 10 million km^2 holding the continent's greatest agricultural potential. Estimated direct economic losses range from US$ 1.5 to 4.7 billion per annum. Considerable resources have therefore been put to the research and development (R&D) of trypanosomosis control technologies, chief of which are vector suppression strategies, chemotherapy, and use of trypanotolerant breeds of cattle and sheep.

The R&D of control technologies reached a turning point towards the close of the 1980s when consensus was reached that focus should shift away from developing new control technologies to finding solutions to three problems. First, models should be developed for putting the technologies in the hands of end users. Reports of efforts to involve communities in managing trypanosomosis using traps had indicated that after the initial success, enthusiasm tended to wane in the course of time, highlighting the need for focusing on issues of sustainability. Second, the impact of control technologies on livestock productivity and incomes needed to be demonstrated. Third, there was strong concern that tsetse control would lead to environmental degradation and eventual extermination of wildlife.

Against this background, ICIPE, with funding from DFID through the Natural Resources Institute (NRI), UK and in collaboration with Kenya Ministries, carried out a study, 1992–1996, in Lambwe Valley, western Kenya, focusing on:

(i) empowering the communities to rely on their own financial and management resources to control trypanosomosis using odour-baited traps, and
(ii) assessing the impact of control on livestock productivity, incomes and natural resources.

At the close of the project, trypanosomosis had been reduced to a level which no longer posed a threat to human and livestock health. But the impact on livestock and the environment had not been fully assessed due to the short project cycle. Financial support from IFAD enabled ILRI (implementing institution) and ICIPE (participating institution) to research on essentially the same issues (1995–1997) in five countries representing four ecological zones, namely, the central corridor of the sub-humid zone of west Africa (northern Côte d'Ivoire and southern Burkina Faso); Ghibe Valley (Ethiopia) in the Horn of Africa; the Lambwe Valley (Kenya) in the Lake Victoria Basin of eastern Africa and the Zambezi Valley (Zimbabwe) in southern Africa).

The overall objective was to assess the sustainability of alternative trypanosomosis control technologies; livestock and crop production; human welfare; and the natural resource base. Specific objectives were to assess:

(a) alternative control technologies in terms of adoption, delivery, organisation and management,
(b) impact of control on the numbers, types and uses of livestock and on land-use,
(c) impact of changes in land-use on ecosystem structure and function,
(d) economic performance (costs, benefits and impact).

A three-pronged approach was adopted. First, an IPM focus entailing the use of two or more compatible control strategies was adopted. Second, an interdisciplinary approach was taken and to this end, an anthropologist, 3 economists, 3 ecologists and 2 entomologists were posted to the various sites. Third, two workshops were held to integrate the conceptual and methodological frameworks as well as streamline activities across sites to make optimal use of expertise and to minimise duplication.

This report covers the work carried out in the Lambwe Valley on the assessment of community management of trypanosomosis, monitoring the tsetse population and trypanosomosis, and environmental impact assessment.

Participating scientists: *J. W. Ssennyonga*, M.M. Mohamed-Ahmed, J. M. Maitima (*Project Leader)*

Technicians: *M. Were, J. Obinga, M. Ayugi, S. Akinyi, R. O. Tumba*

Donor: *International Fund for Agricultural Development (IFAD)*

Collaborators: • *International Livestock Research Institute (ILRI)* • *Ministry of Agriculture, Livestock Development and Marketing (MOALDM), Kenya*

Work in progress

1. ASSESSMENT OF THE SUSTAINABILITY AND EFFECTIVENESS OF COMMUNITY MANAGEMENT OF TRYPANOSOMOSIS IN THE LAMBWE VALLEY

1.1 APPROACH AND METHODOLOGY

Effective and sustainable community-managed trypanosomosis using NGU traps translates into the performance of three major tasks: (i) management of the organisation, (ii) mobilisation and control of resources, and (iii) trap deployment. The performance of these tasks is expected to bring about the reduction of tsetse and trypanosomosis to levels which pose no threat to human and livestock health. Information on the performance of these tasks formed the basis for assessing the sustainability of community management.

1.2 MONITORING AND EVALUATION OF COMMUNITY MANAGEMENT OF TRYPANOSOMOSIS

1.2.1 *Organisation*

With respect to organisation, two complementary methods were used. First, direct observations were regularly made during the organisation meetings. Second, information was also recorded from the organisation's records. Specifically, data were collected on the performance of key functions such as planning, coordination, control, etc. Data were also recorded on the mechanisms by which the organisation manages conflicts, tackles equity issues such as free-riders, and gender, builds the capacity to sustain itself, and how it adopts to change.

A reliable indicator of management effectiveness is the record of meetings, because most of the planning, coordination, control and information management activities are performed and reported in these meetings. Altogether 245 meetings were planned of which 197 (80%) were held, 41% by the overarching committee (KISABE) and 59% by lower level constituent units (Blocks). KISABE had an average of 2.3 meetings per month, compared to only 3 meetings a year for Blocks. The difference is partly due to the fact that most of resource mobilisation and trap deployment were organised at the KISABE level, and partly due to weaknesses in Block organisation. Although there are weaknesses in planning and quality control, KISABE showed considerable improvement in 1997. For example, an annual work plan showing all the major activities such as trapping, fundraising, training members and farmers' field day was prepared and was almost fully implemented. One of the signs for the capacity for self-renewal was the successful elections carried out at the 15 Blocks and KISABE at the end of 1996, in which virtually new teams were elected. Major weakness is the inability to integrate effective organisation, resources management and trap deployment.

1.2.2 *Mobilisation and management of resources*

Regarding resource mobilisation and control, the objective was to assess: (i) the capability for raising the required resources on a timely and sustainable basis, and (ii) the technical efficiency in planning and controlling resources. The following data were compiled: (i) kinds of resources (money, labour, materials and premises for meetings and storage); (ii) quantities mobilised; (iii) sources; and (iv) level (individual and group).

Farmers have experimented with four major ways of raising funds to meet the cost of trapping. Funds raised increased by 104% from Kshs 23,070 in 1995 to 47,080 in 1997, but declined by 47% in 1996 due to poor fundraising skills. Fundraising at public meetings *"Harambee"*, introduced since 1996, has gained pivotal importance, accounting for 70% of funds in 1997 (Figure 1.1). Arrangements are underway to acquire two hand-operated oil seed presses to extract edible oil from sunflower and use the by-product as animal feed. This enterprise is expected to provide a

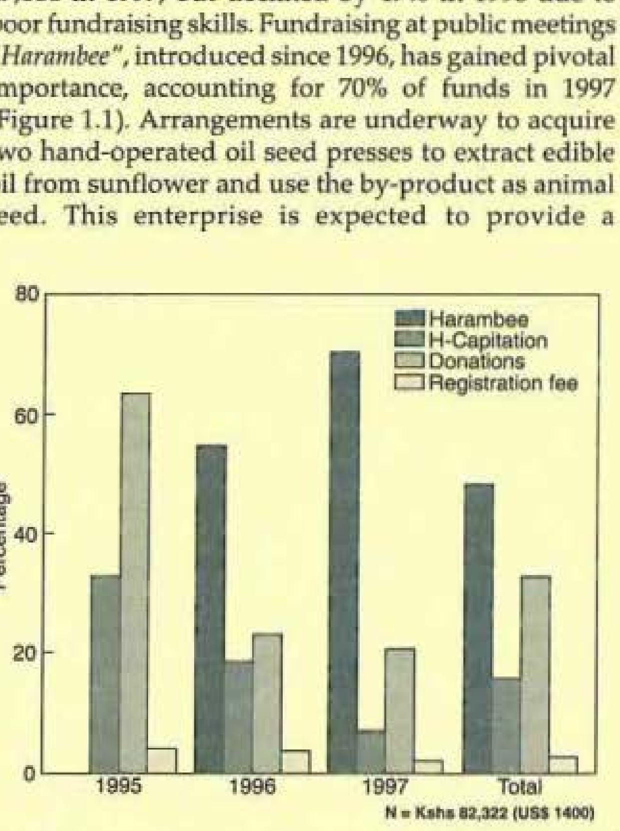


Figure 1.1. Sources of funding by percentage share and year

sustainable source of income for financing trapping and household needs.

1.2.3 *Trap deployment*

Four types of data were collected on trap deployment: (i) organisation of trap work; (ii) number of traps constructed, placed and serviced; (iii) physical condition of traps; and, (iv) labour budgets.

Organisation of trap work revolves around two sets of issues, namely (i) centralised versus decentralised control, and (ii) technical efficiency versus self-determination and equity. The original model developed by the community espoused decentralised control, whereby each Block would finance and manage traps in its territory. This would make Block leaders directly accountable to the immediate beneficiaries and promote self autonomy. But it entailed training a large number of people, and more significantly, the selection of suitable trap sites; distribution was very skewed. For example, 64 traps would be placed in an area of 8 km^2 (Nyaboro thicket) and 120 barrier traps along Ruma National Game Park (RNGP). As a result , the mid-term review team had little difficulty convincing the farmers to regard Nyaboro and the boundary with (RNGP) as "common threats" in which tsetse would be controlled centrally. Accordingly, KISABE took the responsibility for financing and managing trap deployment.

The strategy of focusing on Nyaboro thicket and the barrier with RNGP drastically reduced tsetse and trypanosomosis throughout the control zone, however, communities at the foothills complained of having to walk long distances to service traps. At the start of 1997, the responsibility for trap deployment devolved upon the Blocks again but KISABE still plays an important role in raising funds especially through Harambee. These organisational changes have greatly improved the pace of trap deployment. Traps (eighty-six) were deployed in 1997 compared to 65 in 1995 and 55 in 1996.

1.2.4 *Labour budgets*

Total number of person-days worked amount to about 14 per week or 10.4 person-days per trap in 3 years. Servicing takes 84.4% of this time, followed by placement 13.3% and construction, 2.3% (Figure 1.2). Labour does not vary linearly with the number of traps deployed. Thus, mean person-days per trap dropped from 13 in 1995 and 1996 to only 6.7 in 1997

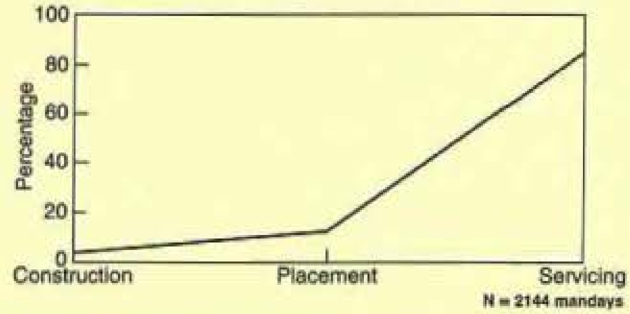


Figure 1.2. Percentage share of mandays allocated to the construction, placement and servicing traps, 1995–1997

due to trap removal (46%) for several months, because of flooding and the larger number of traps placed initially (less time budget). The shift to decentralised control in 1997 may also have forced farmers to economise on time.

1.2.5 *Factors influencing participation*

The foregoing analysis has focused on the group (KISABE/Block) as the unit of analysis. In order to determine the factors influencing participation, we adopted the individual as the unit of analysis. This entailed the performance of three closely related operations as follows. First, we operationalised participation into 17 activities (dependent variables), grouped into five clusters. Second, we identified 9 factors influencing participation (independent variables). Third, we established relationships between the dependent and the independent variables. One of the results obtained is summarised in Table 1.1. The search for the best variables that contribute to

Table 1.1. Factors contributing significantly ($P = 0.05$) to community participation and their percentage share

Participation	Training	Knowledge of tsetse and trypanosomosis	Gender	Residence in low/high zone
Labour	-	9.5	-	-
Financial contribution	8.9	25.2	-	-
Participation in meetings	7.3	3.4	3.4	-
Registration as a member	-	4.4	-	-
Training others	20.9	2.9	9.3	-
Leadership tasks	10.8	-	1.8	16.1
Presentation to visitors	36.9	1.5	-	-
Attending workshops	19.2	-	-	2.5
Performance of ad hoc tasks	4.0	-	9.4	-
Total	108.0	46.9	23.9	18.6

community participation was carried out by help of multiple regression using stepwise selection (SAS Institute, 1995). Variables with the strongest relationships (partial correlation coefficients, R^2 at ($P \leq 0.05$) significance) were selected. R^2 were converted into percentages.

Overall, training contributes most significantly (108.0), followed by knowledge of tsetse, trypanosomosis (46.9) and gender (23.9). Binary relationships are strongest between training and presentation of farmers' work to the visitors (36.9), followed by knowledge of tsetse and trypanosomosis and making financial contributions.

1.2.6 *Perceived benefits of tsetse control*

A total number of 103 interviewees (42 women and 61 men) were asked to state the benefits of tsetse control in their area. Total number of responses was 416. Overall, increased livestock productivity has the largest share of responses, 26.7%. Interestingly, 61% of women cite the rise in milk yield, compared to 54% for men. The most important benefit (26.8%) for men is the availability of more land for cultivation. (Acquiring land is a man's responsibility.) The most important benefit for women is the decrease in trypanosomosis, with a ratio of 28.7% of female responses; 73% of women cited the decrease in sleeping sickness. The desire to save life is cited as one of the forces driving women to participate in tsetse control. Human welfare mostly, increased cash income and human settlement benefits have a share of 18.3%. These results will be compared to those obtained from the observations recorded by researchers.

1.2.7 *Conclusions*

(a) The trap is an easy-to-construct device, but, its management is complex. Information on trap tear and wear and vandalism is essential for planning labour and financial budgets. Other skills (bookkeeping, managing meetings and motivating members, etc.) are also essential and have to be strengthened periodically as new leaders are elected. External agencies such as NGOs and Government ministries have to make an input into this organisational self-renewal.

(b) The likelihood that decentralisation may have brought about greater efficiency and accountability needs to be investigated further in the next phase.

(c) The new methodology for monitoring community participation, applied on a small sample during this phase needs to be tested in the entire operation zone and beyond.

(d) The analysis of productivity data, planned to be underway soon, will pave the way for economic analysis and impact assessment.

Output

Publications

Omolo E.O., Ssennyonga J.W., Ngugi A.N., Kiros F.G. and Okali C. (1995) Community mapping exercises: An evaluation. Agricultural Administration (Research) Network. *Network Paper* 52. ODI London.

Ssennyonga J.W. (1996) Community-based tsetse control, pp. 99–107. In *Partnerships for Safe and Sustainable Agriculture* (Edited by L.A. Thrupp). World Resources Institute, Washington, DC.

Ssennyonga J.W., Goodell G., Lako G.T. and Tedla S. (1994) Social and economic aspects of integrated pest management in the tropics. *Insect Science and Its Application* 15(6), 663–648. (Published in 1996).

Ssennyonga J.W., Mohamed-Ahmed M.M. and Kiros F.G. (1996) The development and validation of a model for community-managed tsetse trapping technology in Lambwe Valley, Kenya. *Research Methodology Paper No. 20*, May 1996. Social Sciences Department, ICIPE.

Conferences attended

Ssennyonga J.W. Partnerships for Sustainable Agriculture. Organised by the World Resources Institute, Washington DC, USA. 18–22 November 1995. Invited paper presented: 'Farmers' evaluation of the participatory and collaborative approaches to the effectiveness and sustainability of community-Managed tsetse control'.

Ssennyonga J.W. Integration of Rural Development through Sustainable Management of Tsetse and Trypanosomosis: The Way Forward. Organised by ICIPE and Ethiopian Science and Technology Commission. Axum, Ethiopia, 2–8 February 1997. Invited paper presented: 'Does community management have a role in future trypanosomosis control?'

Ssennyonga J.W. 24th Meeting of the International Council for Trypanosomosis Research and Control, Maputo, Mozambique, 29 September–3 October 1997. Invited paper presented: 'Incorporating socio-cultural factors into the research and control of trypanosomosis'.

Ssennyonga J.W. Management of Trypanosomosis through Community-Based Approaches: The Way Forward. Organised by the Nairobi Cluster, Nairobi, Kenya, 28 November 1997. Invited paper presented: 'Status of community-based tsetse control in southern Lambwe Valley, Western Kenya'.

Proposals written and funded

Evaluation of the Contribution of Collaborative and Participatory Approaches to the Effectiveness and Sustainability of Community Management of Trypanosomosis in Lambwe Valley, Western Kenya. Prepared in 1995 and funded by USAID through the World Resources Institute,Washington DC, USA.

Capacity building

A participatory workshop was organised for 36 KISABE farmers in September 1996 to evaluate the contribution of participatory and collaborative approaches.

A workshop for 40 farmers was organised in 1997. Topics covered included book-keeping, managing meetings and organisation of trap work.

Integration of Concepts and Methods for Assessing Trypanosomosis Control Technologies and Their Impact on Agricultural Production, Human Welfare and Natural Resources. Organised by ICIPE and ILRI, Nairobi, Kenya, 23–27 September 1996.

Two groups of farmers were sponsored to attend workshops, one of which was on apiculture and sericulture at ICIPE Headquarters in 1997.

KISABE organised one course each in 1995 and 1997 for its members. Four communities engaged in various IPM activities visited KISABE for 1–2 days to exchange ideas and experience. In turn, KISABE visited a pastoralist Maasai community in Nguruman in December 1996.

PhD students

Charles Manyara, doctoral student at Michigan State University, supervised by J.W. Ssennyonga and J.M. Maitima, carried out a field study on the effects of trypanosomosis control on land-use in the Lambwe Valley in 1996/97.

Ms Karen Barret, doctoral student, University of East Anglia, carried out part of the field work on 'Comparative Management of Tsetse Control in Eastern and Southern Africa' in Lambwe Valley, August–November 1996.

Collaborative research work

The World Resources Institute, USA, implemented a project titled "New Partnerships for Sustainable Agriculture", funded by USAID and selected the Lambwe Valley among eight case studies relying on sustainable IPM technologies to reduce the use of chemical inputs, while increasing productivity and health, and using collaborative and participatory approaches. The objective of the project was to document the specific ways in which user participation and collaboration, contribute to the success of the project.

Impact

The main report has highlighted the results on adoption and social marketing as well as their impact on tsetse population, trypanosomosis and social institutions. Here below is a cross-section of the views of reviewers and visiting academics:

- In a book critically reviewing the monitoring and evaluation strategies used in farmer participatory research projects, Okali and Sumberg (1994) made seven references, including a two-page summary of the objectives, strategies and achievements of this project.
- Prof. C. Getzel of Curtin University of Technology, Australia, wrote a paper in a journal about this project and concluded, "The Lambwe project reflects one successful outcome of ICIPE's approach: a very simple, but highly effective technology for tsetse control that is sustainable, and has engaged the local community. The use of odour-baited NGU traps is now firmly established in tsetse control; and hopefully philosophical underpinning that informs not just that project, but ICIPE's larger 'dual mandate'."
- Prof. R. Bernsten, in a review of SSD, commissioned by the Rockefeller Foundation, wrote (1996), "The evolution and impact of this project is very impressive. ICIPE should document the project on video for distribution to public TV stations in the US and Europe and for use in ICIPE's tsetse control training program."
- Prof. M. Demment, reviewing this project for IFAD concluded, "ICIPE scientists have done an excellent job of interacting with the farmers to develop a sustainable tsetse fly control program. The knowledge and organisation of the farmers is strong, well developed and effective. It should be a model for farmers' organisations elsewhere. The combination of technology and participatory involvement is something that IFAD should support, not only as a model, but also to understand the principles of this approach to facilitate its transfer to other areas in the region."

Finally, these views, taken in conjunction with the three collaborative projects described above, manifestly show the growing international recognition of the achievements of this project.

2. MONITORING AND EVALUATION OF TSETSE POPULATION AND TRYPANOSOMOSIS

2.1 METHODS

Tsetse flies were collected from a total of 24 biconical monitoring traps placed in Nyaboro thicket (20) and inside RNGP(4) for a period of four days each month from January 1995 to March 1996 and thereafter in alternate months upto December 1997. The data were used to estimate: (i) apparent tsetse density (tsetse flies/trap/day), (ii) age, (iii) sex, and infection by trypanosomes.

Four types of data were collected from a sentinel herd of 60 head of cattle and 190 cattle farmers once every month from 1995 to March 1996 and thereafter once every other month upto December 1997: (i) Blood samples were taken and screened for identification of trypanosomes and their species; (ii) animals with positive cases of trypanosomosis were treated ; (iii) all cattle were weighed; (iv) farmers took daily records of milk offtake.

2.2 SUMMARY OF RESULTS

2.2.1 *Apparent density of tsetse (ADT)*

THE CATCH/TRAP/DAY (APPARENT DENSITY OF TSETSE) FROM JANUARY 1995 TO DECEMBER 1997

ADT declined from 0.12 and 0.13 for males and females, respectively, to 0.4 and 0.3 for males and females, respectively, by March 1996. Between April and July 1996, there was no monitoring due to staff constraints. From August 1996 to December 1997 no fly was caught, indicating a tsetse suppression of over 99% which is a virtual disappearance of the flies from the control zone (Figure 2.1).

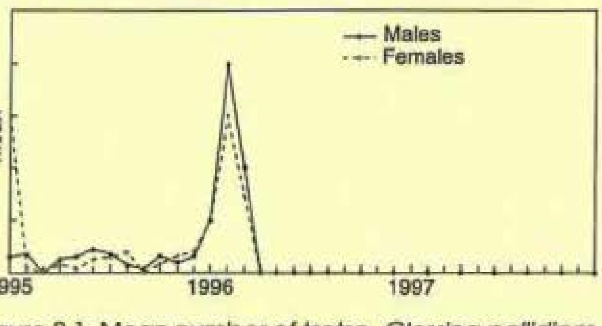


Figure 2.1. Mean number of tsetse, *Glossina pallidipes*, Lambwe Valley, 1995–1997

2.2.2 *Trypanosomosis infection of* Glossina pallidipes

Starting at a very low level of 0.1 for both male and female flies in January 1995, infection declined to 0.06 and 0.09 for males and females by November 1995, but rose from December to 0.4 and 0.3 for male and female flies, respectively, due to the combined effect of removal and theft of 35 farmers' traps (Figure 2.2). From the time monitoring started again in August 1996 to December 1997, no infections were recorded.

2.2.3 *Trypanosome infection rate of cattle*

In August to December 1995, *Trypanosoma vivax* was dominant, compared to *T. congolense* in farmers' cattle. *Trypanosoma congolense* also appears in the sentinel herd for 6 months: September–November 1995 and

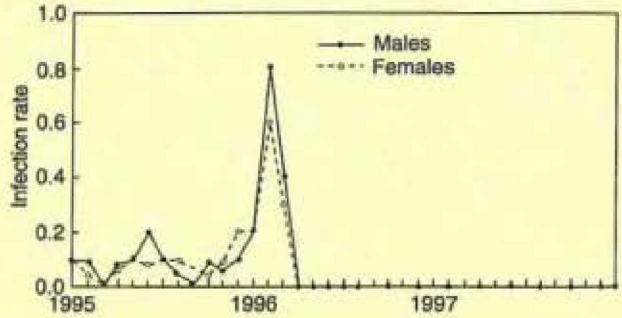


Figure 2.2. Trypanosome infections in male and female *Glossina pallidipes*, Lambwe Valley, 1995–1997

January–March 1996 and *T. brucei* was virtually absent in both herds. The challenge level, except for two clusters of months April–July 1995 and January–March 1996, has been zero since October 1994. This indicates that trypanosomosis has been effectively brought under control, but very low levels of infections persist, probably due to biting flies or inability of traps to suppress a small residual tsetse population.

2.3 CONCLUSIONS

The data presented show that community trapping has reduced tsetse by up to 99%. Nevertheless, even during the months with zero tsetse trap catches, disease involving the three species of pathogenic trypanosomes persisted, albeit at low rates. This indicated presence of an ultra-low residual tsetse population which probably our monitoring failed to detect. Alternatively, cattle might have ventured and grazed along the boundary of RNGP which was not closely monitored for tsetse, or that some infections were maintained by blood-sucking flies other than tsetse.

Finally, three entomological issues need urgent resolution:

(a) The periodic floods in the control zone, exacerbated by the El Niño rains has raised the question whether farmers should place some of the traps on trees. If so, how high?
(b) Now that tsetse population density is so low, should trap density also be reduced? If so, to what level?
(c) Should the current (very) low level of animal trypanosomosis be maintained or lowered?

3. ASSESSMENT OF THE CONTROL ON AGRICULTURAL PRODUCTION AND NATURAL RESOURCES

Work in progress

The ecological component of this project aimed at evaluating impacts of trypanosomosis control using NGU odour-baited traps on land and natural resources use, biodiversity and ecosystems structure and function. The general objective of this study was to quantify the consequences of changes in cultivation (land use) and natural resource use on selected components of the natural resource base and for the structure and function of ecosystems.

3.1 ASSESSING IMPACTS OF TSETSE AND TRYPANOSOMOSIS CONTROL ON LAND USE

Analyses of changes in vegetation cover in Lambwe Valley between 1977 and 1993 was done based on air photo interpretations. From a key to distinguish vegetation cover types on air photographs, six vegetation cover types were identified and their absolute area cover calculated in all the 15 tsetse control blocks of Lambwe Valley. Comparison of the area cover between the two years has given estimates of relative changes in area coverage in each of the six vegetation types studied. Over the 16 years covered in the study period, cultivated land increased nearly 10 times from a mere 4% of the total land cover in 1977 to over 37% in 1993. Analysis of changes between low and high trypanosomosis risk areas, indicate that of all the changes in land cover in Lambwe Valley, it is only 20% that is attributable to tsetse control.

3.2 ASSESSING IMPACTS OF TSETSE AND TRYPANOSOMOSIS CONTROL ON NATURAL RESOURCES USE

Natural resources (soils and woody plants) were selected, based on their importance to socioeconomic activities in the area. Impacts of human activities on soil fertility and the abundance of woody resources have been studied. Variabilities in physical and chemical soil properties have been studied between different land use patterns. The soil physical parameters studied include: organic matter content; moisture content, water holding capacity, capillary rates and pH. A number of soil chemical parameters were selected for analysis. These include: sodium, potassium, calcium, nitrogen, magnesium, manganese, carbonates, bicarbonates, chlorides, sulphates and sodium adsorption ratio.

3.3 ASSESSING IMPACTS OF TSETSE AND TRYPANOSOMOSIS CONTROL ON ECOSYSTEM STRUCTURE AND FUNCTION

Parameters selected for this study are vegetation structure, plant species diversity and the abundance and diversity of selected fauna. Like other sites of Africa where this project is underway, impacts on diversity and distribution of bird species have been studied between the tsetse control area and areas that are physiognomically closely similar in vegetation structure within the adjacent National Park. This project also studied a selected number of arthropod species to understand the effects of land use change on their composition and distribution. To understand impacts on ecosystem structure a total of 16 transects, each measuring 500 m long have been studied from various land use systems and land cover types, in both the tsetse control area and the adjacent Ruma National Park. Land use and cover systems studied include, thickets, wooded grasslands, open grasslands, fallow land and cultivations. In each transect, vegetation has been sampled at 11 plots at 50-m intervals. In each plot, species count, species distribution, similarity between adjacent plots, canopy cover and canopy stratification were enumerated. Preliminary results indicate that grazing lands in tsetse control areas have higher diversity of shrub species than in physiognomically similar places in the National Park.

Output

Publications

Much of the data collected from these studies is being analysed for publication.

Maitima J.M. (1995) An ecological baseline study of Lambwe Valley. A Consultancy Report for NRI, & Social Science Department ICIPE, 92 pp.

Conference attended

Maitima J.M. International Workshop on 'Integrated Rural Development', held in Addis Ababa—Axum, Ethiopia, 3–8 Feb 1997.

Proposals written

Assessing impacts of land use change on insect diversity to optimize strategies on biodiversity conservation. Draft proposal under internal review, for Biodiversity Megaproject.

Developing methodologies for assessing impacts of insect pest and vector management (IPVM) technologies. (Concept note for SSD Megaproject).

Capacity building

Maitima J.M. (1995). Resource speaker on 'Environmental and Land-Use Impacts of Tsetse Control' at the International Group Training Course on Tsetse Management Monitoring and Control. ICIPE, Nairobi, Kenya.

Maitima J.M. (1997). Resource speaker on 'Environmental and Land Use Impacts of Tsetse Control' at the International Group Training Course on Tsetse Management Monitoring and Control. ICIPE, Nairobi, Kenya.

Maitima J.M. (1997). Farmers' training on environmental management in Lambwe Valley.

Animal Health

TICKS

XIII. Development of Biological Control Components for Tick Control (TIC-2)

A. EVALUATION OF ENTOMOGENOUS FUNGI, FOR THE CONTROL OF TICKS

Background, approach and objectives

The rapidly rising costs of chemical acaricides, the ever growing problem of tick resistance to the conventional acaricides, their environmental pollution and their contamination of meat and milk, have stimulated research into new alternative methods of tick control. The use of myco-acaricides delivered by a tick luring device could be cost effective, efficient, environmentally-safe and may reduce the problem of contamination of animal products. Most of the 3-host African ticks spend most of their time in the vegetation and yet most of the control measures so far, have been directed to the parasitic stages of ticks. It is therefore important to develop effective and environmentally-friendly methods of controlling the free-living, non-parasitic tick stages in their environment. In the 1994 *ICIPE Annual Report*, we reported results of our evaluation of the entomogenous fungi, *Beauveria bassiana* and *Metarhizium anisopliae* for the control of two African ticks, *Rhipicephalus appendiculatus* and *Amblyomma variegatum*, using both aqueous and powder formulations. We reported high mortalities, reduction in fecundity and egg viability in engorged *R. appendiculatus* feeding on cattle and in unfed *R. appendiculatus* in the laboratory. We also reported mortalities in all life stages of *R. appendiculatus* and *A. variegatum* in vegetation, when treated with the fungal aqueous formulation.

Since ticks of *Boophilus* spp. also cause great economic losses in cattle through transmission of diseases, (e.g. babesiosis and anaplasmosis) and mechanical damage to cattle, the fungi tested earlier on *R. appendiculatus* and *A. variegatum* were also tested on *B. decoloratus* feeding on zebu cattle in the field.

The fungi used in earlier studies had been isolated from arthropods other than ticks. Since then, efforts were made to search for pathogenic strains of the fungi from naturally-infected ticks. Strains of *B. bassiana* and *M. anisopliae* were therefore successfully isolated and tested on all life stages of *R. appendiculatus* and *A. variegatum* in vegetation. Efficacies of aqueous and oil-based formulations were also compared.

Participating scientists: *G. P. Kaaya*, S. M. Hassan* (*Project Leader)

Assistants: *E. A. Ouna, J. N. Odhiambo*

Donors: *UNDP and ICIPE Core Funds*

1. ASSESSMENT OF PATHOGENICITY OF *M. ANISOPLIAE* AND *B. BASSIANA* TO *BOOPHILUS* TICKS ON CATTLE IN THE FIELD

Work in progress

During 1995–1997, *B. bassiana* and *M. anisopliae* previously isolated from banana weevil and locust, respectively, were tested on *Boophilus* ticks, the vectors of babesiosis and anaplasmosis. *Boophilus* ticks are one host ticks and develop acaricide resistance faster than *R. appendiculatus* and *A. variegatum* (both 3-host ticks). Entomogenous fungi may be used instead of or alternately with acaricides to reduce resistance. Since in *Boophilus* ticks, the larva is the only host seeking stage, killing of larvae in vegetation with entomogenous fungi may provide a longer term control in farms than acaricides, which are only applied on cattle to kill the relatively few on-host ticks. The fungal conidia were sprayed on ticks engorging on zebu cattle in farms at Muhaka, south coast of Kenya. In these farms, cattle were infested by a mixture of *Boophilus decoloratus* and *B. microplus* which are difficult to distinguish from each other in the field. Aqueous formulations containing 10^9 conidia per ml were prepared and sprayed on the engorging ticks, which were then covered with udder bags. After engorgement and dropping, the ticks were placed individually in nylon tetrapacks, sealed and left in the grass under a tree for 6 weeks, after which mortalities and egg viability were assessed.

Both fungal isolates induced mortalities which were significantly higher than those in controls, although lower than those previously induced in *R. appendiculatus* by the same isolates. Mortalities were 10, 40 and 50% in control, *B. bassiana* treated and *M. anisopliae* groups, respectively. There were also significant reductions in viability of eggs produced by the surviving ticks. In the control group, egg viability was 98%, and in the *B. bassiana*- and *M. anisopliae*-treated groups, it was 30 and 50%, respectively. The impact of these fungi on populations of *Boophilus* ticks is likely to be high when both tick mortality and reductions in egg viability are considered, for instance in *M. anisopliae* where mortality of 50% and loss of egg viability of 50% were induced. If there is also a reduction in fecundity (not examined) as observed in other tick species, then the impact of fungi on *Boophilus* populations is likely to be even greater. The two *Boophilus* spp. will be reared in our insectary to allow testing of the fungi on them separately. Experiments to evaluate the efficacy of *B. bassiana* and *M. anisopliae* on larvae of *B. decoloratus* in vegetation are in progress.

2. PATHOGENICITY OF TICK-ISOLATED STRAINS OF *B. BASSIANA* AND *M. ANISOPLIAE* AGAINST TICKS IN VEGETATION

Work in progress

Engorged female *Rhipicephalus appendiculatus* and *Amblyomma variegatum* were collected from zebu cattle in Rusinga island and incubated (28°C and 93% RH) in the laboratory for egg production. A few ticks failed to lay eggs and died of fungal infection. One *A. variegatum*, was found to be infected with *M. anisopliae* and another with *B. bassiana* while one *R. appendiculatus* was infected with *B. bassiana*. The fungi were isolated and preserved for pathogenicity tests against ticks. One isolate of *B. bassiana* and that of *M. anisopliae*, both isolated from *A. variegatum*, were cultured in Sabouraud Dextrose Agar at room temperature for 2 weeks and conidia harvested using the standard procedure.

Concentrations of 10^9 conidia/ml were then prepared in water or 15% peanut oil/water emulsion. All life stages of *R. appendiculatus* and *A. variegatum* were sealed in nylon tetrapacks (200 larvae; 50 nymphs and adults per tetrapack), immersed in the fungal suspension for three seconds, placed in potted grass and left in the field for 6 weeks, after which mortalities were recorded.

Both aqueous and oil-based formulations of *M. anisopliae* and *B. bassiana* isolates induced high mortalities in both tick species, especially in larvae where mortalities reached 100% (Figures 2.1 and 2.2). The oil-based formulation, however, induced higher mortalities than the aqueous formulation in both tick species (Figures 2.1 and 2.2).

The results indicate that both of these tick-isolated fungi are pathogens with potential for biological

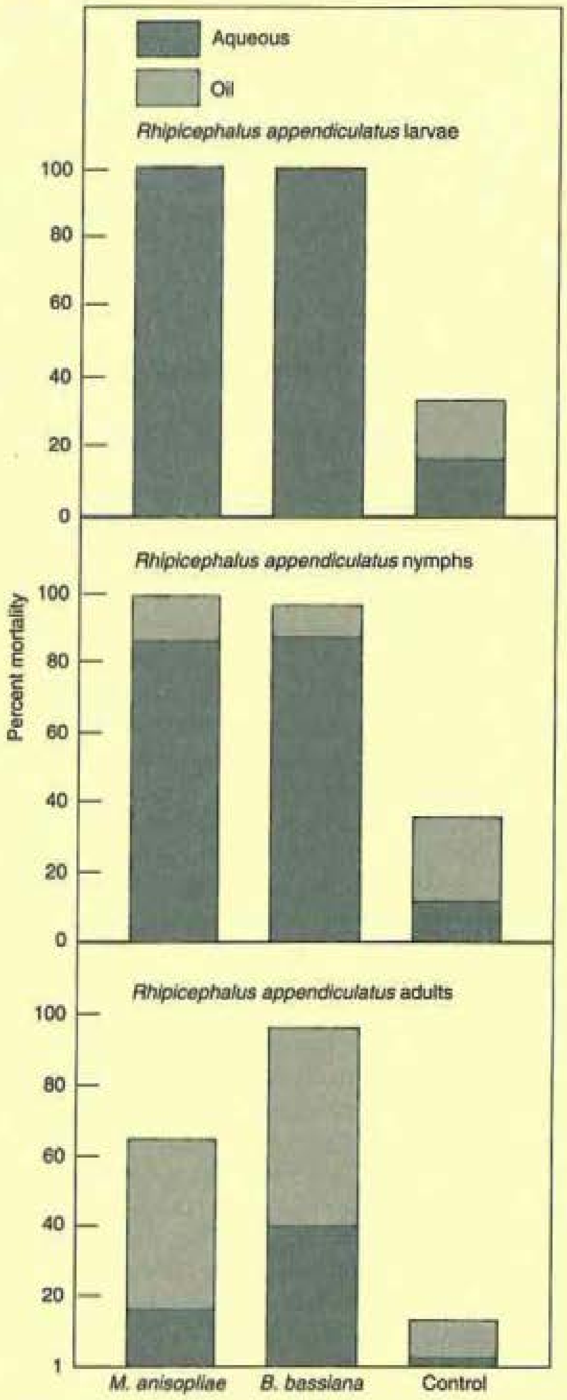


Figure 2.1. Mortality in larvae, nymphs and adults of *R. appendiculatus*, caused by tick-isolated *B. bassiana* and *M. anisopliae* and applied as aqueous and oil-based formulations in vegetation

control of ticks. Field testing of these fungal isolates has been initiated at Kuja River field site in Western Kenya (Figure 2.3) and research aimed at identifying cheap local raw materials for fungal mass production is also in progress.

We believe that fungal isolates capable of inducing such high mortalities in all life stages of ticks will have significant impact on tick populations, as well as on tick-borne and tick associated diseases. Their use will reduce the amount of acaricides and curative drugs used for control of TBDs, as well as the costs and environmental pollution by chemical acaricides.

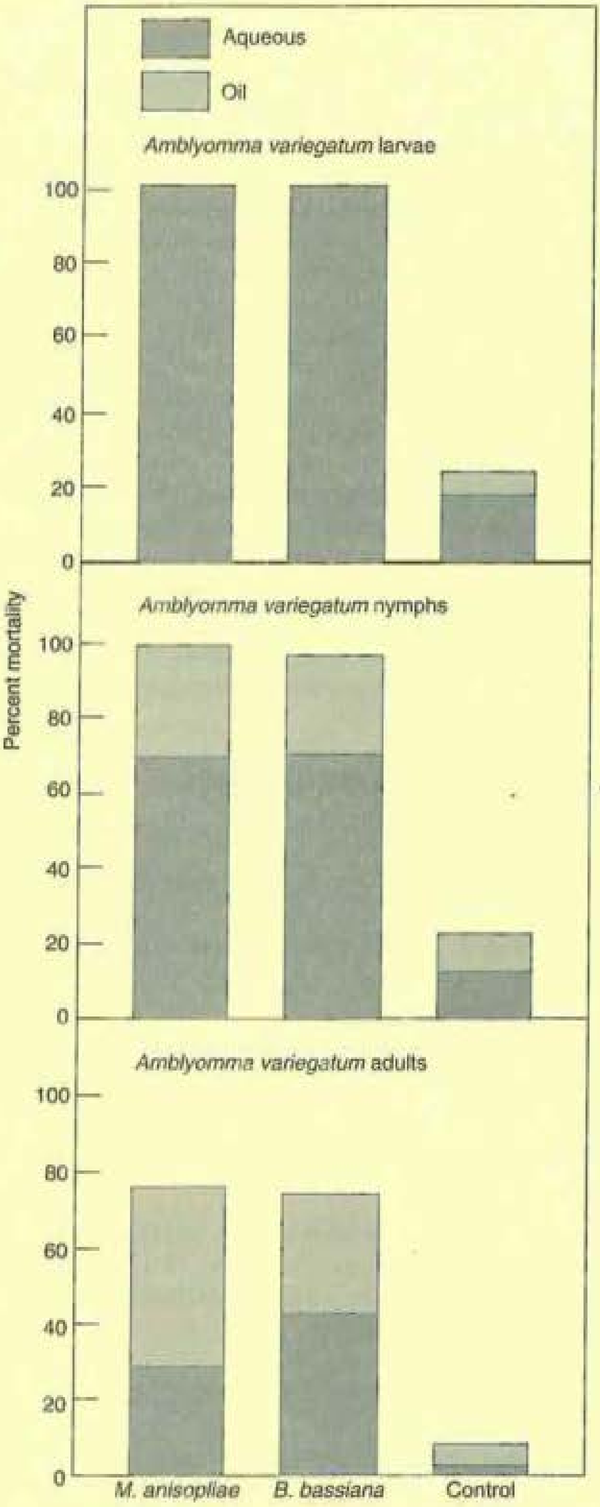


Figure 2.2. Mortality in larvae, nymphs and adults of *A. variegatum* caused by tick-isolated *B. bassiana* and *M. anisopliae* aqueous and oil-based formulations in vegetation

Our earlier observation that acaricides and neem oil do not affect viability of the fungal conidia when incubated together for several hours, suggests that it may be possible to develop an integrated approach for tick control using low levels of acaricides, entomogenous fungi and neem oil.

Figure 2.3. Spraying fungus in the field at Kuja River to kill ticks questing in vegetation

3. INNOVATIVE CONTROL METHODS FOR *A. VARIEGATUM* USING ENTOMO-PATHOGENIC FUNGI IN TRAPS BAITED WITH THE ATTRACTION-AGGREGATION-ATTACHMENT PHEROMONE (AAAP)

Participating scientists: *R.O. Maranga, G. P. Kaaya, A. Hassanali*

Donors: *DAAD and ICIPE Core Funds*

Collaborator: *JKUAT*

Work in progress

The objective was to investigate the potential of the fungi *B. bassiana* and *M. anisopliae*, baited with the attraction-aggregation-attachment pheromone (AAAP), for the control of *A. variegatum*.

Two to three-month-old adult *A. variegatum* marked with artists paint were released from distances of 1, 2, 3, 4, 5 and 6 m in circular plots containing different concentrations of the AAAP at Mbita Point Field Station. Ticks attracted to the AAAP from each distance were recorded. In another experiment, AAAP was used together with 500 g of dry ice as a source of CO_2. Some ticks were treated with a water formulation of the fungi, others with the oil formulation and the controls with distilled water. They were then placed in tetrapacks which were sealed and placed in vegetation in the field for 3 weeks, while others were incubated in the laboratory for 3 weeks at 28°C and 75% RH after which mortalities were recorded.

Ticks released in the field from 1, 2, 3, 4 and 5 m from the source of the synthetic AAAP were attracted to the pheromone with no ticks being attracted beyond the 5 m mark. An AAAP concentration of 6.6 mg / ml of hexane attracted significantly higher numbers of ticks compared to higher and lower concentrations. The addition of 500 g of CO_2 to the AAAP significantly increased the number of ticks attracted to the synthetic AAAP in the field. About 78% of the released ticks were attracted to the combination of AAAP and CO_2

within three hours, while only 19, 0.3 and 0.1% were recorded for AAAP alone, CO_2 and paraffin oil, respectively, within the same period.

During the dry season, the water formulation induced very low tick mortality, reaching a maximum of 16.7% with a concentration of $1x10^{11}$ spores/ml of *B. bassiana* mixed in equal proportions with *M. anisopliae*. The highest tick mortality due to *B. bassiana* and *M. anisopliae* individually was only 11 and 10%, respectively, at the same concentration. The oil formulation (15% peanut oil in water) showed a similar trend, except that the highest tick mortality was attained by *M. anisopliae* (30%) 1×10^9 spores/ml, followed by *B. bassiana* mixed with *M. anisopliae* (24%) $1x10^{11}$ spores/ml and *B. bassiana* alone induced a mortality of 15.5 ($1x10^{11}$ spores/ml).

During the wet season, the water formulation induced its highest tick mortality of 49% (1×10^{11} spores/ml) using a cocktail of *B. bassiana* and *M. anisopliae*, while *B. bassiana* and *M. anisopliae*, separately induced their highest tick mortality of 42 and 39%, respectively, at the same concentration. The oil formulation induced its highest tick mortality of 92% with the mixed fungi and that of the separate fungi were 66.6 and 73.3% for *B. bassiana* and *M. anisopliae*, respectively. Distilled water controls had tick mortalities of between 0–3%. The AAAP and CO_2 traps that were set up in the vegetation attracted and exposed up to 79% of the released ticks to fungi and 78% of them were killed by the cocktail of *B. bassiana* and *M. anisopliae*.

Results obtained from this study indicate that the incorporation of 500 g CO_2 (an equivalent of CO_2 emitted by one bovine for 8 h), to the AAAP, increased the number of ticks attracted. Fungi have not yet been used for the control of livestock ticks although they are widely used in the control of agricultural and forest pests. In earlier work done at ICIPE, 73 and 35% mortality by *B. bassiana* and *M. anisopliae*, respectively, were reported in unfed adults of *R. appendiculatus*. In the same study, the mortality in engorged *R. appendiculatus* was 74% for *B. bassiana* and 81% for *M. anisopliae*. In our study, 92% mortality of *A. variegatum* due to infection by a cocktail of *B. bassiana* and *M. anisopliae* (oil formulation) was achieved during the wet period.

Future plans are to carry out on-farm studies on the efficacy of the tick trap in small hold farms.

B. BIOLOGICAL CONTROL WITH TICK PARASITOIDS AND PREDATORS

4. FIELD RELEASE OF THE PARASITOID *IXODIPHAGUS HOOKERI*

Particiapting scientists: *E. N. Mwangi, S. M. Hassan*

Assistant: *J. Mugane*

Donor: *UNDP*

Background

During 1995, an on-station field experiment which had been started in 1993 was in progress at ICIPE's Mbita Point Field Station to investigate the impact of the parasitoid, *Ixodiphagus hookeri* on the tick, *A. variegatum* on 10 animals. The pre-release infestation was an average of 44 nymphs per animal. A total of 125,000 parasitoids were released over a period of 12 months, which reduced numbers of *A. variegatum* by over 80%. The recovered nymphs (51%) were found to be parasitised during the time of release. However, the recovery rate of the parasitoids after the releases were stopped was only 9 %. During the same period, the number of *R. appendiculatus* which were not affected by the parasitoids, increased. This experiment showed how the parasitoid would affect ticks in a closed situation where animals do not leave and no new ticks are introduced from outside. The control animals, which were about 2 km away on Rusinga Island, showed no decline of *A. variegatum*, and had the usual seasonal variations of the number of ticks on the animals.

5. *IN-VITRO* REARING OF TICK PARASITOIDS

Participating scientists: *E. N. Mwangi, S. Yagi*

Assistants: *J. Mugane, B. Wabwoba, H. Lilech, O. Olukhohe*

Donor: *Toyota Foundation*

Collaborator: *JIRCAS*

Work in progress

The objective was to conduct an exploratory study for developing methodologies for rearing of *Ixodiphagus hookeri*, a parasitoid of the tick *A. variegatum* using artificial media.

5.1 OBTAINING EGGS OF *I. HOOKERI*

To obtain fertilised eggs of *I. hookeri*, parasitised nymphs of *A. variegatum* were dissected in sterile conditions on day 4 post-parasitisation, by cutting open the ticks in 0.01M PBS at pH 7.4. The released eggs into the buffer were concentrated by centrifugation. In a second method of obtaining eggs of the parasitoid, female wasps were dissected immediately after mating. The collected eggs were centrifuged in PBS buffer and placed in centrifuging tubes.

Three cell culture media were tested in various combinations, namely the insect medium IPL-41, host tick haemolymph and bovine serum. These components were then filtered in a 0.45 m filter, under sterile conditions. Several sterilising agents were tried including 70% alcohol, 2% sodium hypochlorite (NaOCl), 0.8% NaOCl. Physiological saline solution was used to rinse out the steriliser. After several trials, 0.8% NaOCl was found to be the best steriliser.

Various combinations of artificial media were tried for growing eggs. Hatching of eggs only occurred when host tick haemolymph was present. No development occurred when haemolymph was used alone.

5.2 SURVIVAL AND GROWTH OF LARVAE IN ARTIFICIAL MEDIA

Freshly hatched larvae were placed in 20% host haemolymph and 80% culture medium (IPL-41). Pupae were obtained 11 days after. However, it was not possible to reproduce these results in subsequent experiments. This could have resulted from minor variations in the culture media such as pH, osmotic pressure or other chemical contaminants.

5.3 SURVIVAL OF PUPAE IN ARTIFICIAL MEDIA

The last instar larvae were removed from a parasitised nymph at day 20 post parasitisation, and placed in sterile glass wells. The liquid artificial medium used for larvae was unable to sustain pupae. Dry technical grade agar or dry *Bombyx mori* haemolymph did not sustain any growth of the pupating larvae. However, by trial and error, it was found that placing moist technical grade agar in wells containing pupating larvae, sustained them through the stages of pupae and adults, 18 days after the last instar larvae were placed in the wells. The emerging adults were, however, weak compared to those reared *in vivo*.

6. STUDIES ON THE DEVELOPMENT OF *IXODIPHAGUS HOOKERI* IN *A. VARIEGATUM* NYMPHS

Participating scientists: *N. Mwangi, S. Yagi*

Assistants: *J. Mugane, B. Wabwoba, H. Lilech, O. Olukhohe*

Donor: *Toyota Foundation*

Collaborator: *JIRCAS*

Work in progress

To study the development of parasitoids in nymphs of *A. variegatum*, parasitised nymphs were kept at constant conditions 28° C and 80% humidity, and dissected in groups of five every alternate day starting with day 1 post-parasitisation. The integument of the nymphs was opened, and the contents of the tick emptied into a Petri-dish containing 10 ml of 0.01M phosphate buffered saline solution (PBS), pH 7.4. To observe the eggs, 50% Giemsa stain was added to the PBS to make them visible. Larvae, pupae and adults of *I. hookeri* were observed without staining. Photographs of each stage of the development of *I. hookeri* were taken using a Stereo Wild M5A dissecting microscope with an MPS51 Wild Camera.

Freshly hatched eggs of *I. hookeri* (day 1) were 7.6 Fm long, ellipsoidal with a stalk at one end. They were found in clusters of 5–8 eggs (Figure 6.1a). Day three, the clusters dispersed and the eggs increased in size to 30.0 Fm and are without a stalk (Figure 6.1b). In the fifth and sixth day, they have enlarged by a factor of about five, (39.9 Fm), compared to freshly laid eggs, have a characteristic centrally located white mark surrounded by a transluscent coat. The eggs at this stage are square rather than oval with visible cell divisions (Figure 6.1c). Apart from blackening of the legs at this point, the nymph appears normal from the outside.

At the end of day 6, the eggs had hatched to semi-transparent, maggot-like larvae with a distinct head region (Figure 6.1d). From day 9, the larvae grew rapidly, making the nymph look rounded, soft and swollen, with a mottled appearence on the outside of the nymph, contrasting the uniform grey of a normal nymph (Figure 6.1e). By day 11, the larvae appear dark brown, except for the anterior and posterior regions which remain transparent (Figure 6.1f). They start to shorten slightly from day 13 onwards and become less active (Figure 6.1g). Their brown colour turns brown/black by the seventeenth day (Figure 6.1h); the browning (death) of the integument of the nymph is now complete. The integument of about 10% of the parasitised nymphs, black at this stage, still contained developing larvae of *I. hookeri* inside (Figure 6.1i). Pupation started at about the end of day 18.

Voiding of the intestinal contents of the larvae starts around day 19 (Figure 6.1j) . The dark brown pellets, each covered with a glistering membrane covering, are arranged neatly in the anterior part of the tick cavity, while the pupae are arranged neatly towards the posterior part (see top arrow, Figure 6.1j). Voiding takes several days as the pupae become white. Voiding is completed by day 21, when the pupae have well-developed wing pads, thoracic legs and antennae (Figure 6.1k–o).

At around day 30, the parasitoids are fully developed and can walk if the nymphs are dissected (Figure 6.1p). They are also slightly bigger than the adults. Fully grown adults gnaw one or more holes on the dorsal side of the tick, through the tick integument and emerge at around day 30–35 (Figure 6.1q). Mating takes place immediately and females look for fresh ticks to oviposit into within hours. Adult parasitoids have a life span of 12–24 h.

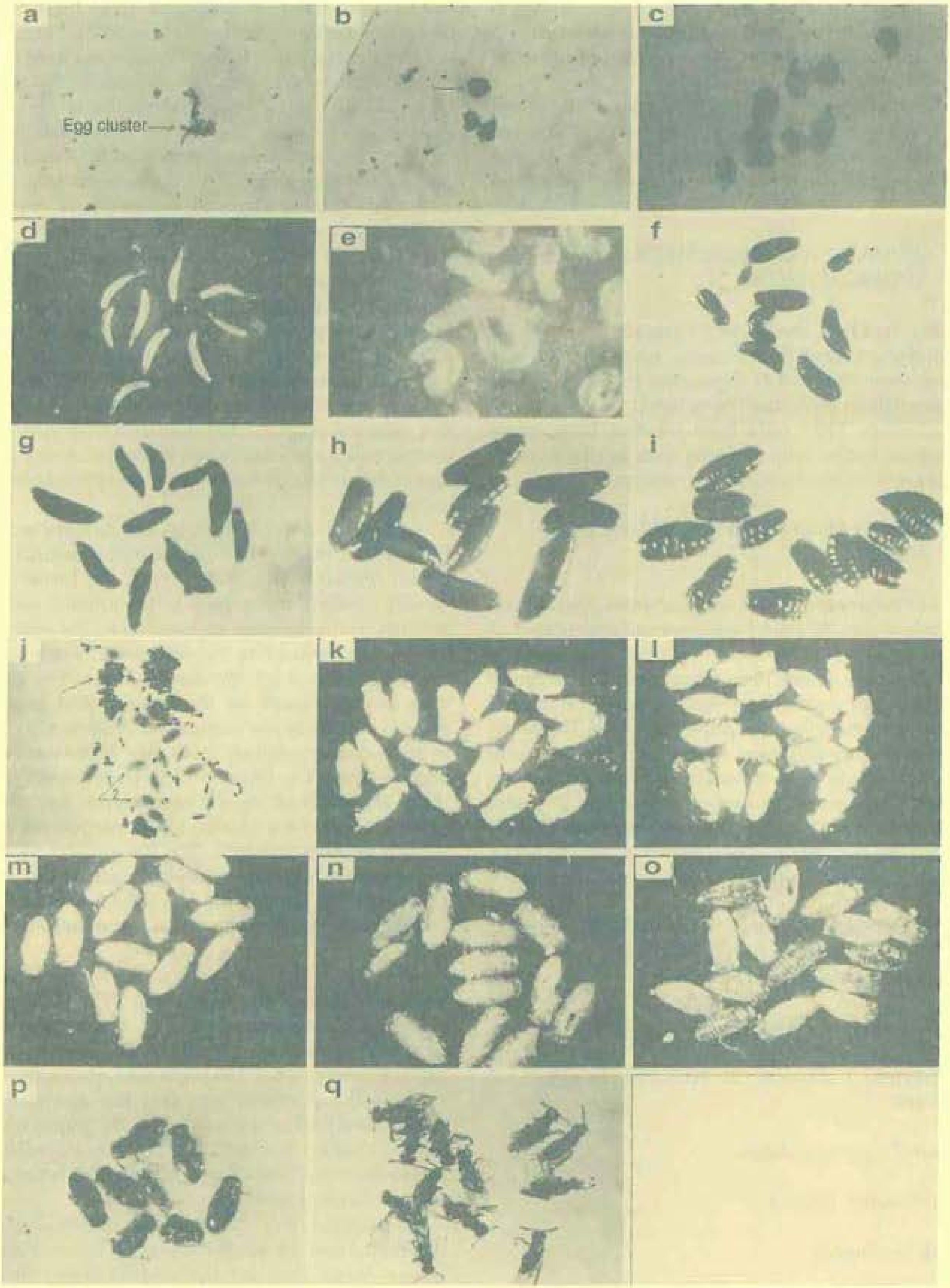


Figure 6.1. Developmental stages of the tick parasitoid, *Ixodiphagus hookeri* in artificial media

7. PREDATION OF TICKS BY CHICKENS

Participating scientist: *S. M. Hassan*

Assistant: *J. N. Odhiambo*

Donor: *ICIPE Core Funds*

Collaborators: *Rusinga island farmers*

Background

Previous research at ICIPE has shown that chickens are natural predators of ticks, and therefore may be available biological control technology in Africa. To study chicken management and identification of number of chickens required to reduce effectively tick infestation, cattle were enclosed with chickens at a ratio of 1:1 in different farms on Rusinga Island. The percentage reduction in tick infestation was found to be 47% compared to the control group. Following the studies, a group of 42 farmers were given training on ticks and tick-borne diseases, indigenous husbandry factors constraining tick control.

Work in progress

The study is currently being implemented by farmers with resource inputs provided from the project funds. It is conducted in 30 farms divided into 5 equal groups as follows:

1. Chickens treated against lethal diseases and housed in close proximity to cattle at a ratio of 1:1.
2. Chickens treated against lethal diseases and housed in close proximity to cattle.
3. Chickens treated against lethal diseases and kept at a ratio of 1:1.
4. Chickens treated against lethal diseases.
5. Chickens left with no interventions.

The experiment was designed to assess the impact of using chickens on tick infestation, incidence of tick-borne diseases, liveweight gain in calves and milk yield. The following parameters are regularly collected on a monthly basis: calves weight, tick infestation on cattle, incidence of TBDs, daily milk yield, changes in chicken population and farmers management of treatments.

Preliminary results indicate that cattle are infested with fewer ticks where chickens are kept in close proximity. Milk yield of lactating cows in groups in close proximity to chickens at a constant ratio of 1:1 was higher, compared to control groups. The investigation is still in progress.

C. BOTANICALS FOR TICK CONTROL

8. EVALUATION OF NEEM PRODUCTS FOR THE CONTROL OF THE AFRICAN TICKS *RHIPICEPHALUS APPENDICULATUS, AMBLYOMMA VARIEGATUM* AND *BOOPHILUS DECOLORATUS*

Participating scientists: *G. P. Kaaya, R.C. Saxena*

Assistant: *E. A. Ouna*

Donors: *UNDP and ICIPE Core Funds*

Background, approach and objectives

In the *1994 ICIPE Annual Report,* progress on evaluation of botanical extracts for control of ticks was reported. Since then, work has focused mainly on neem compounds, especially neem oil. Derivatives of the neem tree, *Azadirachta indica*, a native of Burma and the arid regions of the Indian sub-continent, have been used for medicinal and pest control purposes for millennia. The effects of neem on pests include repellence, feeding and oviposition deterrence, growth inhibition, mating disruption, chemosterilisation, etc. Neem compounds have been shown to induce minimum side effects in non-target organisms; there is minimum risk of resistance since many of the compounds differ in modes of action. There is rapid breakdown to harmless metabolites, and neem is non-toxic to warm-blooded organisms and relatively less expensive. Neem derivatives have been used to control over 200 species of phytophagous insects, but little information exists on application of neem products in the control of human and animal disease vectors.

The objective was to evaluate the potential of neem oil for the control of livestock ticks and its suitability as a component of integrated tick management strategy.

Work in progress

Application of undiluted neem oil (0.08% aza) on rabbit skin with a brush, inhibited attachment by larvae of *R. appendiculatus* by 90%, *B. decoloratus* by 98% and *A. variegatum* by 98% (Figure 8.1). It also inhibited attachment by *R. appendiculatus* nymphs by 100%. Applying undiluted neem oil (0.08% aza) on *B. decoloratus* larvae, nymphs and adults feeding on rabbits, inhibited larval engorgement by 88%, larval moulting by 92%, and nymphal moulting by 97%, while in adults, it reduced egg mass by 30% and egg hatchability by 50% (Figure 8.2).

In de-ticked zebu cattle, grazing in heavily tick-infested pastures at the Kenya coast, spraying 25% neem oil diluted in water (plus 1% emulsifier), deterred larval attachment by 37–61%, nymphs 24–65% and adult ticks 44–62% (Figure 8.3). There was

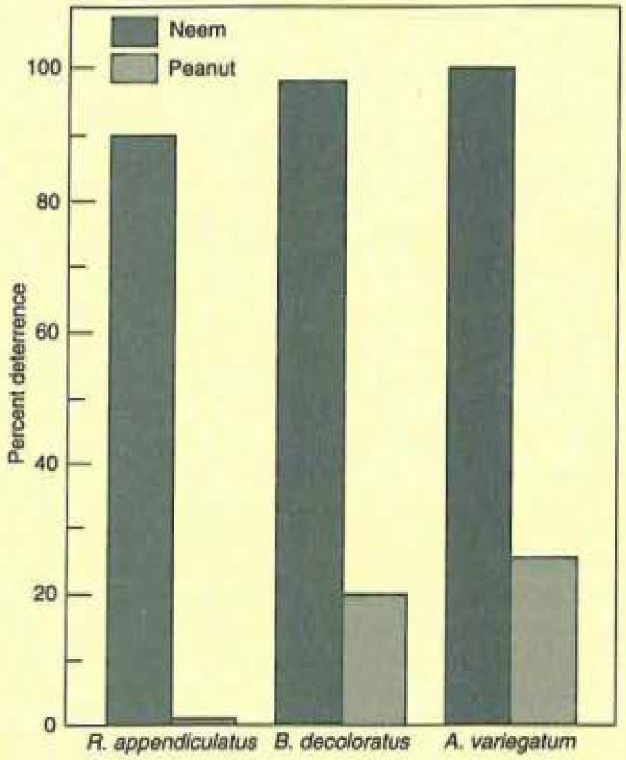


Figure 8.1. Deterrence of attachment of tick larvae on rabbits by undiluted neem oil (peanut oil control)

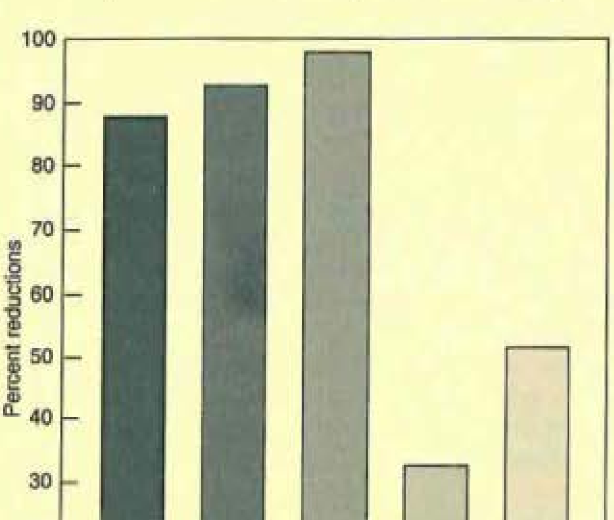


Figure 8.2. Effects of undiluted neem oil on *Boophilus decoloratus* feeding on rabbits

no significant loss of viability in conidia of *B. bassiana* and *M. anisopliae*, when incubated in undiluted neem oil for 24 or 48 h and then cultured in Sabouraud dextrose agar medium for 48 h, as compared to control peanut oil.

Neem oil appears to have potential for tick control. The fact that neem oil did not affect viability of the conidia of the entomogenous fungi, suggests that both neem oil and the fungi may be used together in integrated tick control programmes.

Further field studies will be conducted with neem oil containing different concentrations of limonoids and with other neem products, e.g. seed kernel, water extract, ethanolic extract and neem cake, on ticks feeding on domestic ruminants.

Output

Conferences attended

Kaaya G. P. (1997) Invertebrate Pathology Conference, 24–29 August Banff, Canada: Paper presented 'Biocontrol potentials of entomogenous fungi for the control of *Rhipicephalus appendiculatus* and *Amblyomma variegatum*'.

Kaaya G. P. and Saxena R.C. (1997) Uganda Veterinary Association Annual Scientific Conference, 20–21 Nov., Kampala, Uganda. 'Prospects for the control of ticks using neem compounds'.

Kaaya G. P. (1996) Tanzania Veterinary Association Scientific Conference, 3–5 December 1996, Arusha, Tanzania: Paper presented 'Mortality and pathology in tsetse flies (*Glossina* spp.) treated with neem extracts'.

Kaaya G. P. (1996) Tanzania Entomological Association Conference, 24–26 September, 1996, Arusha, Tanzania: Paper presented 'Insect immune mechanisms: Their roles in vectorial capacity and efficacy of biological control agents'.

Kaaya G. P. (1995) Tanzania Veterinary Association Scientific Conference, 5–7 December 1995. Arusha, Tanzania. Paper presented 'Biological control of livestock ticks using entomogenous fungi, *Beauveria bassiana* and *Metarhizium anisopliae*'.

Kaaya G. P. and Mwangi E. N. (1995). Tick Host Pathogen Interaction, A Global Perspective Conference, 28 Aug.–1 Sept. 1995. Kruger National Park, South Africa: Paper presented 'Control of livestock ticks in Africa: Possibilities of biological control using the entomogenous fungi *Beauveria bassiana* and *Metarhizium anisopliae*'.

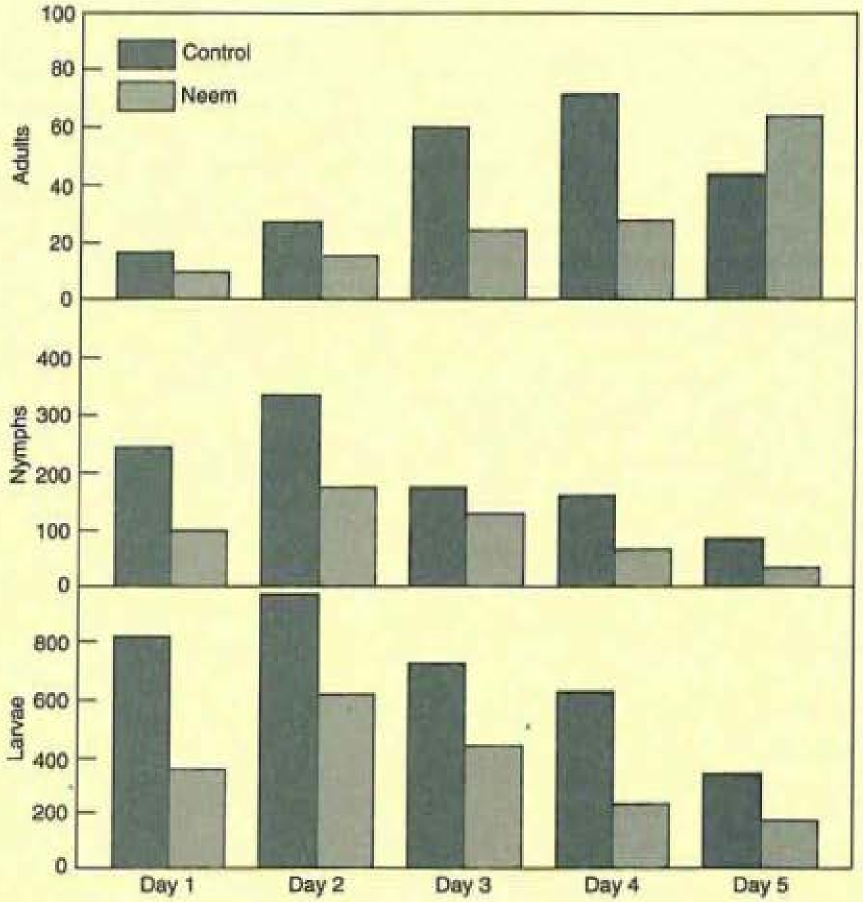


Figure 8.3. Mean number of tick larvae, nymphs and adults on previously deticked zebu cattle on various days after spraying with 25% neem oil (peanut oil control)

9. AWARENESS BUILDING AND FACILITATING THE USE OF NEEM AS A SOURCE OF NATURAL PESTICIDES AND OTHER USEFUL PRODUCTS IN SUB-SAHARAN AFRICA (TIC-1)

(See the report about Neem Awareness, Social Science Department for details on background, funding, collaboration, publications and impact).

Participating scientists: *G.P. Kaaya, R.C. Saxena*

Work in progress

Neem oil was tested against *Rhipicephalus appendiculatus*, *Amblyomma variegatum* and *Boophilus decoloratus* by applying directly on the ticks or on the skin of the animal hosts. In rabbits, the oil was effective against all the three species, deterring larval and nymphal attachment, inhibiting development and feeding (90–100%), reducing fecundity (3–55%), larval (22–93%) and nymphal moulting (98%). Eggs were sterilised when exposed to neem oil. The oil also repelled all stages of the three tick species. Neem oil (25%), sprayed on deticked zebu cattle grazing on heavily tick-infested natural pastures, reduced infestation by tick larvae by 37–61%, nymphs by 24–65% and adults 44–62% for 5 days.

The deterrence of tick attachment with neem oil might have a significant impact, especially in *Boophilus* ticks (a one-host tick) since the larva is the only host-sucking stage. Besides neem oil sprays, aqueous neem cake, and kernel extracts and neem oil as a 'pour-on' are being tested. Multilocational field trials are in progress.

D. ANTI-TICK VACCINE DEVELOPMENT: USEFUL TICK IMMUNOGENS FROM *R. APPENDICULATUS* AND EVALUATION OF THEIR IMMUNOLOGICAL EFFECTS (TIC-4)

Background, approach and objectives

Research on immunisation of livestock using tick immunogens to make them resistant to tick infestations, has attracted considerable attention. This is because, as a control method, it would be specific for the target organism, leave no toxic residue in the environment and therefore pose no threat to biodiversity. The antigens from the gut of the tick are of particular interest in this exercise. As immunogens, some of these antigens induce unique immune responses, the effects of which are used independently as prospective vaccines and also as synergists.

The mechanisms underlying the synergism are that the immune effects modify the integrity of the gut wall and thereby enhance permeability of active molecules into the haemocoel. The immune response induced by the gut antigens (artificially induced immunity) in the host is different from that induced due to exposure of the host to tick infestations (naturally induced host's immunity). Therefore, these two immune responses can be expressed at the same time in the same host, resulting in additive protective effects.

These characteristics have been used as parameters for selection of useful gut antigens and for formulating intervention regimes. Appropriate adjuvant is crucial for the potentiation of immune effects of immunogens. This report includes initial studies on the search for an appropriate adjuvant for membrane -bound proteins of the gut.

Participating scientists: S. Essuman, N. N. Massamba, S.M. Hassan

Assistants: P. Muteria, T. Mbulo

Donors: UNDP and ICIPE Core Funds

10. ISOLATION OF 'GLYCOPROTEIN FRACTION' AND 'PURER GLYCOPROTEIN FRACTION' AND EVALUATION OF THEIR EFFECTS ON ON- AND OFF-HOST TICK POPULATIONS OF *R. APPENDICULATUS* IN THE FIELD

Work in progress

The details of preparations and laboratory evaluation of the different intervention regimes are in the *1994 ICIPE Annual Report*. The field experiment described is part of the process of selecting useful gut immunogens. This report describes the impact of the interventions on the on- and off-host populations of *R. appendiculatus*. The animals used were zebu cattle.

The intervention regimes were the following :

(i) Immunisation with gut antigens, a 'glycoprotein fraction'. This fraction was obtained after gut membrane pellet had been treated with Triton X-114 and the proteins in the detergent phase ran through lectin affinity.

(ii) Immunisation with gut antigens, a 'purer glycoprotein fraction'. This immunogen was prepared as that in intervention (i) except that it was further run through an anion exchange column and the active fraction selected after a series of laboratory immunisation experiments.

(iii) Combination of immunisation with the 'glycoprotein fraction' and a systemic anti-tick compound, ivermectin.

Before the intervention was started, proportional numbers of resistant and susceptible zebu cattle had been put in each of the four paddocks and seeded with *R. appendiculatus*. To monitor on-host population, all visible ticks on the left side of each animal were counted on a monthly basis. The off-host population (larvae) was monitored on the vegetation also on monthly basis using drag sampling method.

About 6 weeks before the intervention, the mean half-body counts of adult ticks on an animal in each paddock ranged between 36 and 44. The total off-host larvae counts were between 415 and 688 (Table 10.1). However, on the time of initial immunisation, the

Table 10.1. Mean half-body (hb) counts of adults and total off-host larval (LL) counts in the paddocks, 6 weeks before intervention

Paddock no.	Mean halfbody (hb) tick count	Total off-host larval (LL) counts
1	44.1	688
2	36.8	490
3	34.4	525
4	36.0	415

mean on-host counts had dropped to about 9–11 (Table 10.2). The drastic decrease in on-host tick population from 3 months after reshuffle of cattle, to the time of immunisation, was due to severe dry conditions in the area. This increased drastically the mortality of the ticks. Off-host tick counts, using dragging method, was therefore, not possible for some time. Nevertheless, in all the paddocks with treated animals both on- and off-host tick counts were significantly lower than those in the control paddock (Table 10.2) . The effects of immunity in cattle alone reduced the population to about 50–60% in the paddocks, 1 and 2. The reduction was higher in paddock 3, where approximately 70% reduction was recorded most of the time. The treatment also affected the off-host population. The larval and nymphal counts in the treated paddocks were significantly lower than those in the control paddock.

The combination of immunisation and ivermectin was found to be more effective. A month after the administration of the ivermectin the on-host tick population in paddock 2 was reduced to over 50% as compared to the previous tick counts in the same paddocks and other paddocks. It would be interesting to observe the long term effect on the population.

The animals in paddocks 1, 2 and 3 were treated according to the various interventions. In paddock 1 the animals were each immunised with 50 µg of the 'purer fraction' emulsified in Freund's complete adjuvant for the initial immunisation and then with the same immunogen dose in Freund's incomplete adjuvant for every booster injection. Two booster injections were given. Both intramuscular and subcutaneous routes were used for administering the immunogen.

Table 10.2. Mean half-body (on-host) and total larval (off-host) counts on the day of various treatments (immunisation), in the course of treatments and after treatments

Paddock no.	Initial immunisation	1. Booster	2.Booster	1 Month after+ last treatment	2 Months after last treatment
No.1 (treatment 1)	11.0	5.3	3.6 (39)	3.3 (29)	5.0 (8)
No.2+ (treatment 2)	10.0	6.0	2.0 (3)	3.4 (19)+	1.5 (10)
No.3 (treatment 3)	9.2	2.0	2.8 (3)	4.3 (19)	3.0 (14)
No.4 (control)	9.0	10.8	14.3 (163)	13.0 (338)	14.3 (951)

+Where and when ivermectin treatment was done.
( ) = Figures in brackets are total larval counts.
Treatment 1 = Immunisation with 'glycoprotein fraction'.
Treatment 2 = Immunisation with 'glycoprotein fraction and ivermectin'.
Treatment 3 = Immunisation with'purer glycoprotein fraction'
Treatment 4 = Control.

Animals in paddock 2 were treated the same as those in paddock 1. However, in addition to that, each animal received a total ivermectin dose of 3.15 mg (1.5 µg/kg body weight) administered intravenously on 3 alternative days. The animals in paddock 3 were immunised with the 'glycoprotein fraction'. The immunisation schedule, the adjuvant and the immunogen dose were the same as those described. Paddock 4 served as the control. Then changes in on- and off-host populations of *R. appendiculatus* and in any skin reaction were observed.

The results of the intervention regimes show that the regimes have the potential for tick control. They would be feasible because the immunogens used, especially the glygoprotein fraction, can be obtained through a simple two-step isolation process. However, the studies need to be conducted for a longer time and on a larger scale. Preferably they should be conducted at an area where it is not very dry at a certain time of the year.

11. EFFECT OF DIFFERENT ADJUVANTS (FREUND'S AND SAPONIN) ON PROTECTIVE EFFICACY OF GUT MEMBRANE ANTIGENS

Four groups of zebu cattle (three in each group) were used for this experiment. Injection was through both subcutaneous and intramuscular routes. The first group, the control, was injected with a phosphate buffered saline (PBS, pH 7.2) containing 1 mg /ml of saponin. The second group was immunised with the 'glycoprotein fraction'. The initial immunisation was done with 50 µg of the immunogen emulsified in complete Freund's adjuvant. Two booster injections at 2-weekly intervals were done with the same dose of immunogen, but emulsified in incomplete Freund's adjuvant. The group of three animals were treated the same as those in group two, except that the immunogen was dissolved in PBS containing 1 mg/ml of saponin. Animals in group four were immunised with the 'purer fraction'. The immunogen was dissolved in PBS containing 1 mg/ml of saponin. The dose of the 'purer fraction' and the immunisation scheme was same as those used for groups two and three. Ten days after the last booster, each animal in all the groups was challenged with 50 adult *R. appendiculatus* (25 females and 25 males) on one ear. Evaluation of effects was based on engorgement and egg batch weights of ticks which dropped.

Briefly, it was observed that with saponin as adjuvant, immunity induced by the glycoprotein fraction reduced the engorgement and egg batch weights to about 69 and 75.6%, respectively (treatment 3) compared to the control (treatment 1) (Table 11.1). However, the immune effects of the same immunogen, when emulsified with Freund's Adjuvant, reduced the engorgement and egg batch weights to about 37 and 11%, respectively (treatment 2). When the purer fraction was used to immunise with saponin as adjuvant, the immune response induced resulted in about 80% reduction in both engorgement and egg batch weights. This preliminary observation showed that saponin may be an adjuvant of choice for the membrane-bound antigens. However, there are several other adjuvants which need to be tested.

12. DEVELOPMENT OF IMPROVED METHODS FOR PRODUCTION OF TARGET TICK ANTIGENS FOR ANTI-TICK STUDIES

Participating scientists: *N.N. Massamba, S. Essuman*

Assistant: *R.K. Rotich*

Table 11.1. Effects of different adjuvants (Freund's and saponin) on protective efficacy of membrane-bound antigens

Treatments	Anim. No.	Engorgement weights (mg) X/Indv. Anim.⁺	Total X	& (%Reduc.)	Egg weights (mg) X/Indv. Anim.⁺	Total X	& (%Reduc.)
1	9	302.2 ± 76.0			105.8 ± 99.8		
	160	272.7 ± 96.5			169.3 ± 78.7		
	14	302.1 ± 76.0	292.3	(-)	63.2 ± 81.3	112.8	(-)
2	10	176.7 ± 153.9			79.4 ± 67.5		
	152	242.8 ± 136.9			165.3 ± 103.8		
	146	133.0 ± 107.6	184.2	(37%)	57.9 ± 66.0	100.9	(11%)
3	154	89.1 ± 11.0			48.8 ± 67.3		
	149	99.1 ± 107.1			24.5 ± 38.5		
	7	81.0 ± 63.2	89.7	(69%)	9.3 ± 13.9	27.5	(75.6%)
4	114	63.4 ± 18.1			10.6 ± 18.1		
	5	66.6 ± 73.7			38.7 ± 50.2		
	140	44.1 ± 7.3	58.03	(80%)	18.2 ± 21.1	22.5	(80%)

Treatment 1 = Controls.
Treatment 2 = Glycoprotein fraction + Freunds's adjuvant.
Treatment 3 = Glycoprotein fraction + saponin.
Treatment 4 = Purer fraction + saponin.
%Reduction relative to Treatment 1.
⁺X±(SD)/Indv. Anim.= Mean of engorgment and egg batch weights of individual animals.

Donor: ICIPE Core Funds

Work in progress

Previous immunisation studies using a glycoprotein fraction (F_2) from the tick gut tissues showed that the F_2 induces a significant protective immunity in laboratory animals and in the field. Progress has, however, been limited by difficulties encountered in purifying sufficient amount of immunogens for statistically meaningful immunisation trials. By constructing cDNA expression libraries of tick midgut tissues from *R. appendiculatus*, immunologically important antigens could be cloned and expressed in *E. coli* and then produced in large quantity.

Work concentrated on the construction of cDNA expression libraries and the immunoscreening of the resulting libraries. Synthesis of double stranded cDNA from tick *R. appendiculatus* midgut tissue was conducted according to standard procedures. The first strand cDNA was synthesised from oligo(dT)-primed mRNA using AMV reverse transcriptase. Following *E. coli* RNase H treatment, the second strand was synthesised using DNA polymerase I. The cDNA was treated with T_4 DNA polymerase to generate blunt-ended cDNAs. These cDNAs were ligated to synthetic EcoR I adaptors (Promega) and then size-fractionated by chromatography over Sepharose CL-4B (Pharmacia). The cDNAs were mixed with 1 µg of EcoR I cut lambda gt 11 vector DNA and ligated overnight at 4° C with T_4 DNA ligase.

Ligated DNAs were assembled into bacteriophage *in vitro* (Amersham). The resulting recombinant phages were analysed on *E. coli* Y1090 on LB plates containing IPTG and X-Gal. The tick midgut cDNA libraries primed by both oligo(dT) and random primers and consisting of 1.5×10^6 independent clones with an average insert size of 0.2–1.0 kb was plated at a low density of 1×10^4 plaque forming / 150 mm Petri dish. Putative positive plaques were purified through several rounds of screening at low densities using anti-F_2 serum. Antigen-antibody complexes were identified by application of goat anti-rabbit conjugated to alkaline phosphatase (or peroxidase). Sixteen clones were consistently positive during two rounds of purification, they were retained for further analysis. Specific lambda gt 11 forward and reverse primers were used to amplify insert sequences, present in the isolated recombinant lambda gt 11 clones by PCR technique. Thirteen out of the sixteen clones showed DNA inserts whose size ranged around 300 bp. Lambda gt 11 recombinant lysogens were generated in *E. coli* Y 1089 from the recombinant phage clones.

Fusion proteins were prepared from the lysogens and 22 preparations of fusion proteins were obtained and could be arranged in 4 groups according to their electrophoretic patterns in SDS-PAGE. Western blotting of the fusion proteins with the anti-F_2 serum revealed few specific protein bands of various molecular weight. Fusion proteins could be resolved from other proteins by affinity chromatography through APTG-agarose (Aminophenyl-β-D-thiogalactopyranoside agarose). Western blotting analysis of purified fusion proteins is in progress.

E. MODELLING

13. TICK POPULATION ECOLOGY AND MODELLING

Participating scientists: *S. M. Hassan, G. P. Kaaya, A. Odulaja*

Assistant: *J. N. Odhiambo*

Donor: *ICIPE Core Funds*

Work in progress

The most economically important ticks in Africa, *Rhipicephalus appendiculatus* and *Amblyomma variegatum*, are widespread in central and East Africa, particularly in the region of Lake Victoria. Inadequate ecological information about these ticks is available, however. The aim of this study was to obtain ecological data pertaining to population dynamics of *R. appendiculatus* and *A. variegatum*, to explore weak points in their life cycle for control purposes. The studies were also to generate data needed to build tick population prediction models. The specific objectives were to

(i) determine the diurnal drop-off rhythms of *R. appendiculatus* and *A. variegatum* engorging on zebu cattle under range and zero grazing husbandry;
(ii) determine the rate of development and survival periods under natural habitats;
(iii) investigate the diurnal activity and seasonal abundance of host-seeking ticks and to study the seasonal population dynamics of the parasitic stage.

Diurnal drop-off rhythms of *R. appendiculatus* and *A. variegatum* engorging on zebu cattle were studied under range and zero grazing conditions by monitoring detachment at 2-h intervals. Effects of seasons, site and vegetation cover on rate of development were investigated. Pre-oviposition and pre-eclosion periods, number of eggs laid and hatchability, and moulting periods were recorded. To determine longevity of unfed ticks, newly moulted and hatched ticks were released in different seasons in open and shaded habitats. Survival was monitored twice a month for larvae and once a month for nymphs and adults. Host-seeking ticks were collected from pasture three times daily for 3 years to determine their diurnal activity and seasonal abundance. Seasonal population dynamics of the parasitic stage were also investigated by collecting ticks from cattle once a month.

The results indicate that diurnal detachment rhythms were exhibited by ticks feeding on zebu cattle under range conditions. Maximum drop-off occurred between 1400 and 1800 hrs but no ticks dropped at night. Under zero grazing, ticks dropped throughout the day and night with no obvious peak drop-off time. Cattle movement after a period of quiescence influenced the drop-off rhythms. Detachment and duration of feeding were not affected by husbandry regime and season. The results also indicate that ticks took longer in the shaded habitats to develop, but females laid more eggs. In open habitats, high ambient and soil temperatures caused desiccation of eggs, particularly during the dry seasons. Desiccation of eggs was considered to be a limiting factor in the drier margins of *R. appendiculatus* distribution. Oviposition was, however, not affected by dry season. Pre-oviposition and pre-eclosion periods were longer during cool and rainy seasons, though ticks did not enter into diapause. Moulting was less affected by weather. It was concluded that more than two life-cycles of *R. appendiculatus* can be completed in one year, whereas only one generation of *A. variegatum* is possible.

Unfed adult ticks survived longer than nymphs, which in turn lived longer than larvae. *Rhipicephalus appendiculatus* adults survived longer than adults of *A. variegatum*. All developmental stages lived considerably longer in shaded habitats, but mortalities were high during the dry months. Adults released during or immediately before the dry seasons survived longer, but immatures released during these seasons survived for short periods. It was also found that ticks engage in host-seeking activities mostly during evening hours followed by morning hours. This pattern was consistent over years, seasons, locations, and sites. Ticks were most abundant in pasture on Rusinga Island from July to September and at Kuja River Field Site (KRFS) from May to August. At both locations, host-seeking ticks were prevalent throughout the year.

High infestations of *R. appendiculatus* adults on cattle in Rusinga Island were observed from September to March, followed by a sharp decline at the start of rains. Females were well synchronised with males at ratios of 2.5:1 (males to females). Immature population, steadily built up from May to September preceding peaks of adults. *Amblyomma variegatum* patterns were similar, but their peaks were preceded by those of *R. appendiculatus*. At KRFS, the population built up at the start of rains reaching a peak in August.

The study provides information on understanding population dynamics of ticks as a prerequisite for adoption of integrated tick management packages. Engorged ticks could be allowed to drop in areas unfavourable for their development and survival. The results indicate that rotational grazing for management of ticks is possible. Restriction of animal grazing during peaks of diurnal activity of host-seeking ticks could reduce their numbers in pasture and on animals. Habitat modification including reduction of bushes and prescribed burning offer best promise of success. The study also provides information for building tick population prediction models for the purpose of control.

Work still in progress includes:

1. Studies on pick-up rates of host-seeking ticks, *R. appendiculatus* and *A. variegatum* by cattle kept under range conditions.
2. Improvement of cloth-dragging method for sampling adult and nymphal stages of host-seeking ticks.

14. VALIDATION OF THE AUSTRALIAN MODEL OF THE TICK *R. APPENDICULATUS* IN KENYA AND COLLABORATION WITH NARS

Participating scientists: *S. M. Hassan, G.P. Kaaya, A. Odulaja*

Assistant: *J. N. Odhiambo*

Donor: *ACIAR*

Collaborators: *• CSIRO • KARI*

Collation of ecological and epidemiological data published in Kenya and neighbouring countries and computerisation for validation of the Australian model of *R. appendiculatus* was undertaken during 1996 and 1997. Gaps in the available ecological and epidemiological data were identified for future studies.

Output

Workshops

A tick-modelling workshop was held from 9–19 September at Duduville. Participants came from Ethiopia, Sudan, Kenya, Uganda, Tanzania and Malawi. The workshop was part of an ongoing ICIPE-KARI-CSIRO project, funded by ACIAR. The participants were taught how to use the tick models DYMEX and CLIMEX in tick control programmes.

Conferences attended

Hassan S. M. The Australian Society for Parasitology Conference, Australian National University, Canberra ACT, Australia, 14–18 July 1997.

Hassan S. M. International Workshop on Tick Modelling sponsored by ACIAR, Australia, held at the International Centre of Insect Physiology and Ecology, Nairobi, Kenya, 9–19 September 1997.

Hassan S. M. Global Change Impact Assessment Approaches for Vectors and Vector-Borne Diseases. An International Workshop sponsored by GCTE, ICIPE, IRI, WHO and FAO, held at ICIPE Headquarters, Nairobi Kenya, 3–6 September, 1997.

Capacity building

A PhD degree was awarded to Dr S. M. Hassan in 1997. The title of his thesis was: 'Ecological studies on *Rhipicephalus appendiculatus* Neumann and *Amblyomma variegatum* Fabricius (Acari: Ixodidae): Drop-off rhythms, development, survival, and seasonal population dynamics'. PhD Thesis, Kenyatta University, Nairobi, 206 pp.

15. REFINEMENT OF ICIPE'S TICK POPULATION MODEL

Scientists: *A. Odulaja, S.M. Hassan, D. M. Munyinyi*

Donors: *ICIPE Core Funds, UNDP*

Work in progress

The computer-simulated 3-host tick population model developed at ICIPE is based on the simple life cycle of *R. appendiculatus*. The model was essentially a preliminary exercise, initially applicable to Rusinga Island, Lake Victoria, Kenya. Hence the parameterisation of the model was basically tailored and less flexible to many changes.

There is need for the refinement of the model when data is available on the density of tick in the pasture at Rusinga island. This will particularly allow the incorporation of population growth rates into the model. There is also need for the re-parameterisation of some of the factors of the model using statistical distribution functions, rather than means and variances, for wide applicability and easy adoption. The incorporation of the tick population growth rates into the model is essential for generalisation purposes.

Some aspects of the model were reconsidered or redefined during this review period in view of available information. These aspects include:

15.1 TICK LIFE CYCLE

We have extended the life stages to 10 instead of the 7 considered earlier. The free living stages have been increased to 7, viz: eggs, host seeking larvae, moulting larvae, host seeking nymphs, moulting nymphs, host seeking adult and ovipositing female adult. The host seeking and development stages were not considered separately in the earlier model. The parasitic stages remain the same as in the earlier model, viz: feeding larvae, nymphs and adult. Average number of days spent in each of the stages (apart from the 3 host-seeking stages) under averagely favourable conditions, were estimated from our field data.

The number of host-seeking days (HSD) was obtained using the equation

$$\begin{aligned} HSD &= MAXD(1-HD) + MIND \times HD, \quad HD \le 1 \\ &= MIND, \text{ otherwise} \end{aligned}$$

where HD is the host density (no. of host/m²) MAXD is the average maximum number of days the instar can live without finding a host and MIND is the hardening days —first few days after dropping when it will not respond to any host. From our field data, MAXD was estimated as 90, 300 and 420 days for a host seeking larva, nymph and adult *R. appendiculatus* respectively, while MIND was 8 days for all the three stages.

15.2 RESISTANCE GROUPING OF CATTLE

The earlier model requires the user to give the numbers of high, moderate and low resistant cattle in the field. This may be difficult to know or find out. Moreover the deferential resistance levels of the cattle may not be consistent over days, seasons and years.

In improving the model, we replace this requirement with a very simple one—the supply of the total number of cattle. This is easy to obtain. We then use a probability distribution function, the Beta distribution, to partition the total number of cattle into resistance classes. We chose the Beta distribution because of its flexibility in representing a wide range of situations, e.g. most cattle highly resistant, equal number of cattle in all resistant groups, no cattle is highly resistant, etc. The distribution also allows for the re-grouping of the cattle in the light of any new information.

15.3 RANGES OF TICKS ON CATTLE

Lower and upper limits of larvae, nymphs and adult ticks carried by cattle in the different resistance groups are required to be supplied in using the earlier model. This is also not an easy exercise and may be very subjective.

We replace this requirement by only demanding the maximum number of larvae, nymphs and adult ticks found on any cattle. Fixing the minimum at zero and using the logistic function, we partition this range into non-overlapping intervals for the different resistance groups. The parameters of the function may always be changed to fit different situations.

15.4 MORTALITY FACTORS

We have made two additions to the mortality factors in the earlier model. These are predators and catastrophic events. Catastrophic events (burning, flooding, ploughing, etc.) have been found to be important in the regulation of tick off-host population. We incorporate this into the ground intervention effect as a complement of planned control interventions provided for in the earlier model.

Predation occurs regularly at all stages of the ticks. In introducing this as a mortality factor in the refined model, we employ the relation.

$$\text{ppre} = 1 - (\exp^{(-\beta t)})$$

where ppre is the probability of predating a tick at any stage, t is the average number of days spent in the stage, and β are positive constants less than unity. The implication here is that the probability of being predated at a stage, increased exponentially with the number of days spent in that stage.

Simulation results using the refined model, generally agree with those of the earlier model. The present results, however, seem more reliable in that the free living population was always higher than the parasitic phase population for all the tick stages, unlike in the earlier model. The simulation results also show clearly that the larval population is more difficult to control than the other stages as obtained by the earlier model. Furthermore, the results also suggest greater difficulty in controlling the free living population for all the stages of the tick.

Output

Publications

Dossa S. C., Essuman S. and Kaaya G. P. (1997) Characterisation of *Amblyomma variegatum* tick salivary gland antigens inducing anti-tick immunity in Boran cattle. *International Journal of Acarology*. (In press).

Dossa S. C., Kaaya G. P., Essuman S., Odulaja A. and Assoku R. G. K. (1996) Acquisition of resistance to the tick *Amblyomma variegatum* in Boran cattle, *Bos indicus* and the effects of *Trypanosoma congolense* and *Babesia bigemina* on host resistance. *Veterinary Parasitology* 62, 317–330.

Kaaya G. P., Mwangi E. N. and Ouna E. (1996) Prospects for biological control of livestock ticks, *Rhipicephalus appendiculatus* and *Amblyomma variegatum* with entomogenous fungi, *Beauveria bassiana* and *Metarhizium anisopliae*. *Journal of Invertebrate Pathology* 67, 15–20.

Latif A. A., Rowlands G. J., Punyua D. K., Hassan S. M. and Capstick P. B. (1995) An epidemiological study of tick-borne diseases and their effects on productivity of zebu cattle under traditional management on Rusinga Island, western Kenya. *Preventive Veterinary Medicine* 22, 169–181.

Mwangi E. N. and Kaaya G. P. (1997) Prospects of using parasitoids (Insecta) for tick management in Africa. *International Journal of Acarology* 23, 215–219.

Mwangi E. N., Hassan S. M., Kaaya G. P. and Essuman S. (1997) The impact of *Ixodiphagus hookeri*, a tick parasitoid of *Amblyomma variegatum* (Acari: Ixodidae) in field trial in Kenya. *Experimental and Applied Acarology* 21, 117–126.

Nyindo M., Essuman S., Chesang R. and Muteria P. (1996) Immunity induced by vaccination of *Rhipicephalus appendiculatus* salivary gland antigens does not augment the immunity acquired naturally by exposing rabbits to adult ticks. *Journal of Medical Entomology* 33, 559–565.

Sebitosi E. , Kaaya G. P. and Agbede R. I. (1997) Detection of lectins in the hemolymph and gut of *Rhipicephalus appendiculatus. International Journal of Acarology* . (In press).

Solomon G. and Kaaya G. P. (1997) Development, reproductive capacity and survival of *Amblyomma variegatum* and *Boophilus decoloratus* in relation to host resistance and climatic factors under field conditions. *Veterinary Parasitology*. (In press).

Solomon G., Kaaya G. P., Gebreab F., Gemetchu T. and Tilahun G. (1997) Population studies of ticks feeding on indigenous cattle and incidence of tick-borne parasites in Didtuyura ranch in southern Ethiopia. *Insect Science and Its Application*. (In press).

Ssennyonga J.W., Hassan S., Ragama P., Ayugi M. and Yogo R. (1997) The grazing behaviour of livestock managed under indigenous husbandry in western Kenya: Its relevance to the management of livestock ticks, p. 173. In *Insects in African Economy and Environment* (Edited by H.G. Robertson). Proceedings of the Joint Congress of the Entomological Society of Southern Africa (11th congress) and the African Association of Insect Scientists (12th congress), Stellenbosch, 30 June–4 July 1997. Entomological Society of Southern Africa, Pretoria.

Ssennyonga J.W. (1997) Resource allocation in polygamous families in the Lake Victoria Basin, Kenya: Its implications for development, pp. 268–282. In *African Family: Response to Ecological Changes* (Edited by S. Wisner and C. Bradley). Greenwood Press, USA.

Zulu F. P. , Okello-Onen J., Punyua D., Essuman S. and Malonza M. M. Ticks (Acari: Ixodidae) of wild and domestic animals from the Coast Province of Kenya. *Insect Science and Its Application*. (In press).

Research proposals

Title	Partners	Status
More milk for the tropics: Development of integrated, environmentally-friendly control methods for ticks and tick-borne disease in small holder dairy farms	ILRI, KARI	Submitted to ADB in 1997
Development of neem products and entomogenous fungi for the control of ticks and tick-borne diseases in small holder dairy farms in Africa	KARI, SUA, CABI	In final preparation (NORAD)
Development of vaccines for sustainable management of ticks and tick-borne diseases in Africa	KARI, CSIRO, Victoria University, Utrecht University, Vrije Universitet (Brussels)	Submitted to VU (Brussels) for forwarding to Belgian Govt.
Ticks and Livestock in Tigray, Ethiopia (Modelling)	Bureau Agric. Nat. Res. Ethiopia, Oxford University	In final preparation
Validation of the Australian model of the tick, *Rhipicephalus appendiculatus* and investigation of its use to facilitate collaboration with NARS	CSIRO, KARI	Funded till mid-1998. (ACIAR)
Development of integrated strategy for management of ticks	JIRCAS	Funded till Nov. 1998. (Toyota Foundation)
Evaluation of entomopathogenic nematodes for tick control	Kimron Veterinary Institute, Israel	Funded from 1998 to 2001. (USAID)

Capacity building

Dr S. M. Hassan attended training, on 'the Australian models, CLIMEX for population prediction and DYMEX population explorer for the tick, *R. appendiculatus* and LucID identification tools for biology", at the Centre for Tropical Pest Management, the University of Queensland, Brisbane, Australia from 19 July to 1 August 1997.

Mr Odero G. Miakumba and Mr Owuor G. Okello from AHITI, Kabete attended training at ICIPE on various aspects of tick ecology from 9 June 1997 to 9 July 1997.

Mr John Mukasa, an entomologist from Uganda, attended training at ICIPE on 'Tick taxonomy, identification, survey and monitoring techniques' from 15 January to 15 March 1996.

Forty-two Rusinga Island farmers attended training on 'How to increase livestock productivity through the use of chickens as biological control agents for ticks at Mbita Point Field Station', from 4 to 8 June 1995.

Impact

- Our work on control of ticks using fungi has inspired tick scientists from other continents (America and Australia) to initiate similar research for control of their tick species.
- Three PhD and 2 MSc African scholars were successfully trained on innovative methods of tick control.
- Ninety-four African farmers were trained on tick management.

16. GENETIC DIVERSITY OF *RHIPICEPHALUS APPENDICULATUS* POPULATIONS IN KENYA IN RELATION TO THEIR SUSCEPTIBILITY TO *THEILERIA PARVA* INFECTIONS

Background, approach and objectives

The use of chemical acaricides is the main method for tick control. Other methods being evaluated include pasture spelling, destruction of tick breeding sites, the use of biological control agents (parasitoids, fungi and predators), anti-tick pastures and natural tick resistant breeds. Available data suggest that no single control strategy is likely to provide effective control of ticks and tick-borne diseases. Rather, an integrated approach encompassing several different methods may have the best chance for the successful management of ticks.

Whatever methods are adopted, it is critical that there should be understanding of the basic ecology of ticks, including the genetic diversity that may exist among different populations. A clear understanding of such diversity has several levels of application. For example, it can contribute to a better understanding of the vectorial capacity of ticks.

One of the methods currently being evaluated for the control of *Theileriosis* involves infection and treatment. In this method, homogenised *T. parva*-infected adult ticks are used as stabilates for immunisations. In order to standardise the procedure, it is critical that ticks that give the same levels of infection are used. This underscores the need to develop reliable markers for susceptibility to parasite infection. Such markers can also be used in developing a super-refractory line of ticks that could be used for 'natural immunisation' of animals.

The second aspect involves extrapolation of research results. How relevant is a study conducted in West Africa to the East or South African situation? Awareness of how much diversity exists among local populations within and between geographical regions will help both in the interpretation of studies on tick biology, while also contributing to a better understanding of population dynamics, habitat characteristics and dispersal patterns.

Another important application of the knowledge on diversity involves the interaction between ticks and their natural enemies. For example, differences in tick behaviour may influence the efficacy of parasitoids. Similarly, the existence of biotypes may result in differences in performance of the fungal pathogens such as *Metarhizium anisopliae*.

Scientist: *E. O. Osir*

Technician: *S. Obuya*

Donor: *Toyota Foundation*

Collaborators: *• Kenya Agricultural Research Institute (KARI) • University of Nairobi (Kenya) • Onderstepoort Veterinary Institute (OVI) • International Livestock Research Institute (ILRI)*

Work in progress

Approximately 100 engorged females were collected from several geographical locations (Lanet, Baragoi, Maralal, Embu, Kitale, Kakamega, Rusinga, Muguga and Marikebuni) in Kenya. Nymphs were fed on steers that had been previously infected with *Theileria parva* Marikebuni. After moulting into adults, the salivary glands were dissected and infection rates determined microscopically. Ticks from the same locations were used for DNA extractions. Universal primers (Operon) were used for random amplified polymorphic DNA-polymerase chain reaction (RAPD-PCR). The optimal amplification conditions were: 94° C (4 min), 45° C (2 min) and 94° C (1 min). Amplification was repeated for 40 cycles with an extension (72° C, 10 min.). After amplification, the

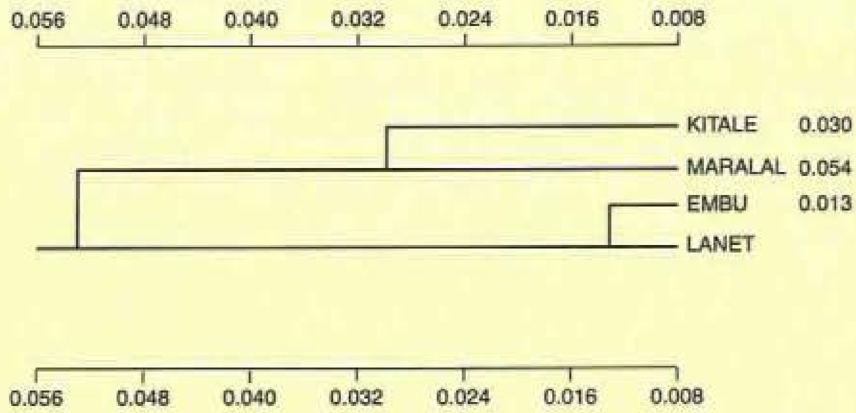


Figure 16.1. UPGMA dendrogram representing genetic relationship in *R. appendiculatus* populations

samples were separated using 2% agarose gels, stained with Ethidium bromide and examined under UV light.

There were wide variations in infection rates among ticks collected from different parts of Kenya. Generally, the Embu and Lanet stocks were comparatively susceptible, while the Kakamega, Kitale, Maralal and Baragoi stocks were refractory to *T. parva* infections. Marikebuni, Rusinga and Muguga populations showed intermediate susceptibility. Based on this observation, two susceptible (Lanet and Embu) and two refractory (Kitale and Maralal) populations were selected for PCR analysis. Five primers (OPA 1, OPA 18, OPO 03, OPO 6 and OPO 10), produced 38 polymorphic bands with the four tick populations (Kitale, Maralal, Embu and Lanet). The bands generated were between 1.3 and 0.2 kb.

Considerable variations were observed within and between the different tick populations. Based on the presence/ absence of bands, a genetic distance matrix was constructed. This information was subsequently used to construct a UPGMA dendrogram, representing the genetic relationships of the four populations (Figure 16.1). It was observed that Kitale and Maralal formed one cluster and Embu and Lanet formed the other. This was a particularly interesting observation since it conformed with the data on infection rates that showed Kitale and Maralal to be refractory and Embu and Lanet to be susceptible. Between the susceptible and refractory populations, a larger divergence was observed.

In order to identify population specific markers, pooled DNA samples were amplified using different primers. The results showed that primer OPA 12 yielded a band specific for Baragoi population and primers OPO 10 and OPO 19 yielded bands specific for Embu and Lanet populations, respectively. Efforts are still underway to find a primer that can yield a band specific for the Maralal population.

Current efforts are aimed at analysing the remaining tick populations. In addition, the population specific bands will be purified from the gels and cloned into suitable vectors (e.g. pMOSBlue). The next step will involve sequencing of the bands and designing of specific primers for detailed analysis of the populations. Collaboration with Colorado State University will result in the development of mini- or micro-satellite markers for studying the tick populations in more detail.

Output

Project proposals

Development of Integrated Strategy for the Management of Livestock Ticks. Toyota Foundation.

Studies on the Biodiversity of African Ticks. Wellcome Trust Foundation.

Capacity building

One MSc Student, Fred Baliraine (DRIP): Thesis title 'Genetic variation in two populations of the brown ear tick, *Rhipicephalus appendiculatus*, in Kenya', University of Nairobi.

F. SOCIOECONOMIC STUDIES

17. INTERACTIVE SOCIOECONOMIC RESEARCH FOR BIOINTENSIVE PEST MANAGEMENT TECHNOLOGY DEVELOPMENT (ISERIPM): TICKS COMPONENT

(See Report VIII for on the crops component of this project.)

Background, approach and objectives

Tick and tick-borne diseases (T&TBDs) constitute the second most important constraint (after tsetse) to livestock production in Africa. Unfortunately, conventional methods of managing T&TBDs are both costly and environmentally unsafe. This is why two low-cost and environment-friendly control strategies were incorporated into this project. First, biological work focused on two related cultural control strategies, namely, the generation of information on tick host-seeking behaviour and the drop-off rhythms of engorged ticks. Complementary socioeconomic studies investigated the grazing behaviour of livestock to determine the feasibility of farmers modifying the grazing behaviour of their livestock so as to use the biological information for tick control.

Second, the potential of chickens as biological control agents of livestock ticks had been demonstrated by finding that chickens, under experimental conditions, reduced up to 47% of ticks on cattle through predation. Complementary socioeconomic research had also shown that: (i) chicken population managed under indigenous husbandry was unstable due, largely to endemic lethal diseases; (ii) chickens, owned and managed by women, were housed in 2–5 different shelters, making it difficult to achieve significant predation.

Farmers were trained in 1995 in key aspects of tick biology, TBDs and management of chicken health. Following this, researchers in close collaboration with farmers, designed two interventions in the health and housing of chickens. Starting in October 1995, through 1997, farmers implemented these interventions, while researchers monitored results.

Participating scientists: *F. G. Kiros*, J. W. Ssennyonga, S. M. Hassan (*Project Leader)*

Assistants: *M. Ayugi, R. Yogo*

Donor: *The Rockefeller Foundation*

Collaborator: *Ministry of Agriculture, Livestock Development and Marketing (MOALDM), Kenya*

Work in progress

17.1 STUDY OF THE GRAZING BEHAVIOUR OF LIVESTOCK

The grazing behaviour of indigenous breeds of cattle, goats, sheep and donkeys, managed under indigenous husbandry, was observed to determine the seasonal and diurnal patterns and factors influencing them. Parameters observed include: (i) livestock movement, (ii) grazing time, (iii) grazing methods, (iv) grazing sites, (v) watering, and (vi) herdspersons. Factors influencing these variables are: (i) rainfall, (ii) grazing resources, (iii) cropping systems, (iv) number and composition of livestock species, (v) land use, (vi) labour dynamics.

The results show sharp seasonal contrasts. During the only cropping season, March–July, total grazing time for all species was 3–4 hours shorter than in the non-cropping season. Animals are also released later due to labour constraints and are brought back to the yard before the afternoon rains. Labour scarcity, due to high dependence ratios and the competition between fishing, wage labour, crop and livestock production (all of which have a peak in labour demand in the cropping season), is compounded by the small livestock holding size and low productivity.

Farmers therefore minimise grazing labour through tethering (64% for cattle at weeding time) and allowing animals to graze all-day on their own and anywhere during the non-cropping months. Because of shorter grazing hours and tethering, on-host tick population is lower in the wet months, contrary to established patterns elsewhere. Pasture constraints also drastically reduce the feasibility of farmers using the information on the drop-off rhythms of engorged ticks in the non-cropping months. However, farmers in other farming systems can use this information to disrupt tick life cycles.

17.2 ASSESSMENT OF FARMERS' MANAGEMENT OF CHICKENS AS BIOLOGICAL CONTROL AGENTS OF LIVESTOCK TICKS

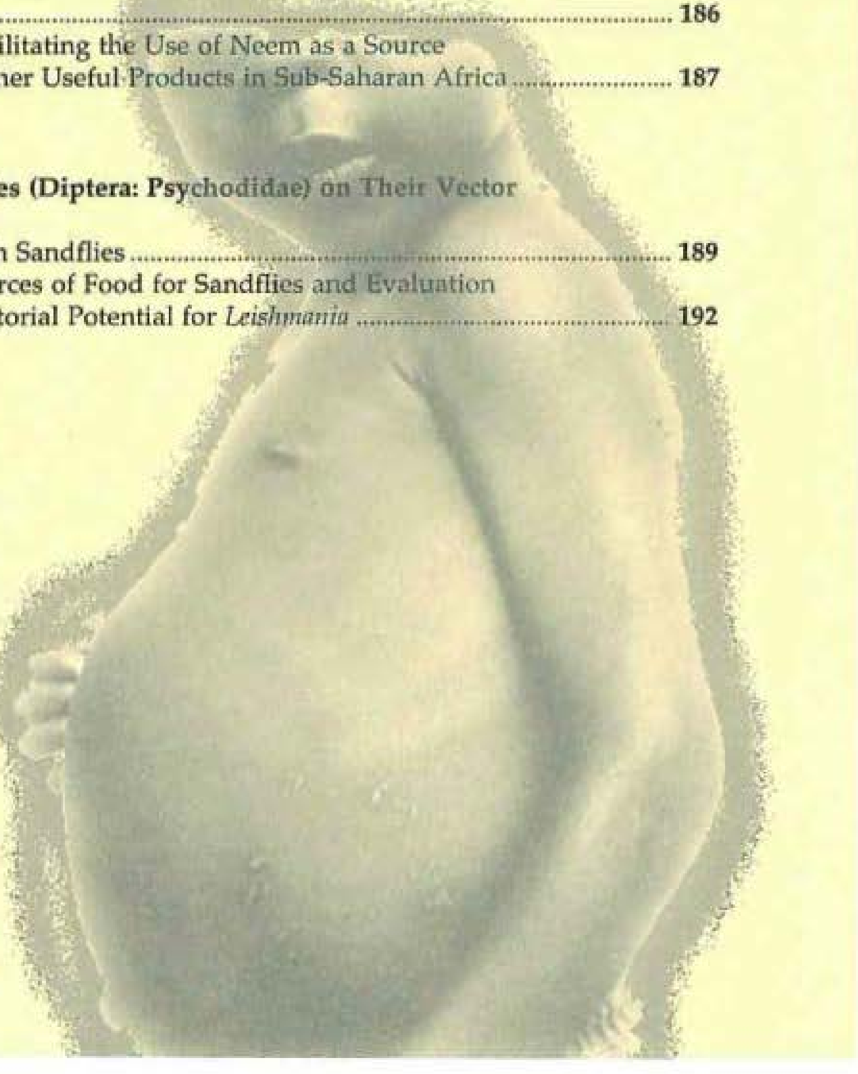
Five activities were carried out in 30 farms divided into six groups: (i) biannual census of chickens, (ii) recording of all vital events (births, deaths, offtake and acquisition of chickens), (iii) recording of milk offtake, (iv) with the biologists, recording of calve liveweight gain, (v) monitoring farmers' management of the interventions.

After registering a sharp increase of 35% in 1995, the population of chickens receiving treatment became stable in 1996–97, increasing by only 2%, mainly to maintain a one-to-one chicken/cattle ratio in two of the groups, in contrast to that without treatment, which declined by 20%, a trend consistently recorded before interventions. Regarding management issues, we rated 77% of farmers as good/very good, the rest poor/very poor. Two thirds of cattle structures are poorly kept (by men) while 83% of chicken structures are maintained very well (by women). Most of the problems come from farmers who were not trained.

This work has focused on the assessment of the effects of interventions in chicken health, on its population trends. Future work will focus on analysing the effects of interventions on the productivity of both cattle and chickens. This will pave the way for carrying out the economic analysis which will in turn determine whether the technology will move to the final phase, namely, when farmers will fully finance and manage the technology on their own, while researchers monitor results.

CONTENTS

Human Health Research



HUMAN HEALTH RESEARCH

HUMAN HEALTH MANAGEMENT

I. MOSQUITOES

The traditional methods used for malaria vector control and treatment that were previously effective in controlling malaria are now largely ineffective due to insecticide-resistant mosquitoes and drug-resistant parasites. Resistance to anti-malarials is emerging and spreading faster than new drugs are being developed and deployed. In addition, efforts towards community health education and vaccine development have shown little promise in providing solutions to control of this most important vector-borne disease. Effective and sustainable malaria control in most parts of Africa cannot realistically be accomplished without new tools and approaches for fighting both the parasites and the mosquito vectors. Currently, there are very few examples of effective and sustainable integrated malaria management strategies anywhere in Africa.

Recent field trials of insecticide-treated bednets in Africa have demonstrated dramatic reductions in densities of mosquito populations (up to 95% in some areas) but variable reductions in human mortality. However, even though treated bednets (and also residual spraying of insecticides) kill mosquitoes effectively, the overall impact on human infection is not sufficient. Thus, a need exists for the development of new control tools that can supplement the mosquito killing potential of measures such as treated bednets.

The joint efforts of ICIPE's Malaria Vectors Project together with those of national and international research institutions are aimed at developing improved integrated approaches for malaria control in the East African region. A series of strategic studies on the ecology and behaviour of the vectors will address issues relating to the transmission of malaria to humans. The project involves three inter-related study areas, namely,
(i) eco-epidemiology,
(ii) vector ecology and behaviour, and
(iii) community-based intervention studies.

II. SANDFLIES

The leishmaniases are a group of protozoan diseases caused by parasites of the genus *Leishmania*, transmitted to man by the bite of several species of phlebotomine sandflies. About 12 million people are afflicted with human leishmaniasis, with 400,000 new cases annually. The visceral form (kala-azar) enters the spleen, liver and bone marrow and is usually fatal if left untreated. Recent epidemics in the Bihar region of India and southern Sudan have left tens of thousands dead. The social cost of the disfiguring of the skin and face is beyond estimation.

Control strategies based on chemical insecticides for the sandfly vectors and chemotherapy for the parasites have proved unsuitable, due to their high cost, human toxicity and detrimental environmental effects. The life cycle of *Leishmania* takes place in the sandfly gut in an environment which includes food, digestive enzymes and their products. The competence of the fly to support the parasites may be influenced by components in its natural diet, especially sugars, for which it has a special predilection (*see 1994 ICIPE Annual Report*).

The overall goal of the ICIPE-Hebrew University of Jeruasalem (HUJ) project is to identify natural sources of food for sandflies and to evaluate the effects of different diets on the vectorial potential for *Leishmania*.

Human Health

MOSQUITOES

XIV. Identification of Factors in the Ecology and Behaviour of Anopheline Mosquitoes Regulating the Transmission of Malaria (Mos-2)

A. ECOLOGICAL AND BEHAVIOURAL EVALUATION OF ANOPHELINE MOSQUITOES AND MALARIA PARASITE TRANSMISSION FOR THE DEVELOPMENT OF NEW APPROACHES AND TOOLS FOR MALARIA CONTROL IN AFRICA

Background, objectives and approach

Malaria is by far the most serious public health threat of the major vector-borne diseases compared to filariasis, dengue, yellow fever and encephalitis. The World Health Organisation (WHO) estimates that malaria affects 300 to 500 million and kills 1.5 to 2.7 million people each year. Despite tremendous efforts to control this disease, malaria remains a public health problem in more than 90 countries inhabited by 40% of the global population. More than 90% of all malaria cases occur in sub-Saharan Africa. The public health consequences of malaria are far-reaching and have an impact on both social and economic development. The worsening malaria situation has led the WHO to declare malaria control a global priority.

Current strategies for malaria control involve the treatment of infected individuals with anti-malarial drugs to kill the parasites and vector control to kill mosquitoes. Malaria control is difficult because the malaria parasites are becoming increasingly resistant to anti-malarial drugs, and vector species of mosquitoes develop resistance to insecticides. Efforts to develop new anti-malarial drugs and malaria vaccines have proved disappointing.

A major problem with malaria control is the emphasis on treatment rather than prevention. In endemic areas, individuals who become infected and receive treatment become re-infected again due to their exposure to infected mosquitoes. Human exposure depends upon the number of mosquitoes biting humans and the proportion of mosquitoes harbouring infective-stage sporozoites in their salivary glands. In endemic areas of Africa, residents are exposed to between 1 to >1000 infective bites per year. Even in areas of low-level transmission where humans are exposed annually to fewer than 10 infective bites, 10% or more of the children can experience severe disease before they reach the age of 10 years. The efficiency of transmission in Africa is high because vector species of mosquitoes are highly susceptible to the parasite; they feed primarily on humans, and they live relatively long.

In Kenya, malaria is generally characterised by perennial transmission along the coast and the Lake Victoria basin. Transmission in other parts of the country is seasonal and occasionally occurs in epidemics that have recently been associated with high mortality rates. The recent El Niño weather phenomenon has caused widespread epidemics in the East African highlands and thousands of people have died of malaria. Within zones of prolonged transmission, marked variations in malaria prevalence may occur due to local differences in certain entomological and parasitological parameters.

Without appropriate prevention strategies to interrupt the cycle of transmission, the problem of malaria cannot be managed with existing tools within the framework of current health systems. It is therefore necessary to appreciate the biological aspects of the problem and to develop control strategies accordingly.

In February 1996, ICIPE together with WHO and the Netherlands Government, sponsored a Task Force Meeting of mosquito and malaria experts from Africa, USA, Europe and Asia. The objective was to review the status of malaria vector research and to identify critical gaps which ICIPE could address. A unanimous conclusion of the meeting was that much of the information needed for effective vector control is incomplete. The Task Force Meeting participants unanimously endorsed ICIPE's role in malaria vector research in four general areas. These include: (1) basic strategic research with output relevant for malaria control, (2) operational research through networking with African national institutions, (3) research capacity building, and (4) provision of services to support national and regional malaria control programmes.

A 5-year workplan has been developed that includes seven components or general objectives. Following is a brief summary of each component, the specific aims, and the activities carried out from June 1997, when data collection started.

Participating scientists: *J. Beier (Project Leader), J. Githure (Project Coordinator), C. Mutero, C. Mbogo, Guiyun Yan and B. Knols, N. Minakawa (supported by the Japan Society for the Promotion of Science), B. Frei (supported through a Swiss Government Fellowship)*

Assistants: *P. Seda, B. Ondondo, M. Wanjiru, B. Njiru*

Donors: *DANIDA and OPEC*

Collaborators: *• Kenya Medical Research Institute (KEMRI) • Ministry of Health, Kenya • University of Nairobi, Kenya • Jomo Kenyatta University of Agriculture and Technology, Kenya • Kenyatta University, Kenya • Medical Res. Training Centre, Mali • Ministry of Health, Uganda • Nat. Inst. for Med. Res., Tanzania • ICIPE, Ethiopia • Institute Pasteur, Senegal • Min. of Agri. and Forestry, Sudan • Tulane University, USA • State University of New York, USA • German Mosquito. Control, Germany • Yale University, USA • University of Aberdeen, Scotland • University of Wageningen, the Netherlands • WHO PEEM, Switzerland • Liverpool School of Tropical Medicine, UK • IIMI, Colombo, Sri Lanka*

Work in progress

1. UPGRADING OF MALARIA VECTOR LABORATORIES

In April–June 1997, two offices and two laboratories in Nairobi were allocated to the Project. In addition, six rooms including two large mosquito rearing rooms have been renovated at the Animal Rearing and Quarantine Unit. At Mbita Point, an office, an insectary and a laboratory are being used for mosquito work. A large greenhouse has been allocated for use in mosquito behavioural studies. In Kilifi at the coast, ICIPE is utilising a large entomology laboratory that has been allocated by KEMRI for this Project.

2. COUNTRYWIDE SPATIAL AND ECO-EPIDEMIOLOGICAL ANALYSIS OF ANOPHELINE MOSQUITOES RELATIVE TO MALARIA ENDEMICITY IN KENYA AND THE EAST AFRICAN REGION

The specific objectives were to:

(i) determine the country-wide distribution of *Anopheles* mosquitoes and malaria parasite transmission throughout Kenya;

(ii) identify environmental and climatological parameters that are associated with distributions of *Anopheles* mosquitoes and malaria parasite transmission;

(iii) develop and validate models for predicting current and climate-affected distribution patterns of malaria vector species and malaria parasite transmission;

(iv) improve regional capabilities for evaluating and predicting countrywide distributions of malaria vectors and transmission.

The database on malaria prevalence in Kenya is now being prepared for operational use by the Division of Vector-Borne Diseases (DVBD) as a means of updating the malaria situation in Kenya. ICIPE has taken steps to collaborate in this initiative for the purposes of mapping mosquito distributions. Steps are also being taken to coordinate with the DVBD to obtain historical mosquito distribution records, in conjunction with the National Malaria Control Programme of the MoH. Records will be used to establish the GIS for mosquitoes collected from 30 sites in western Kenya and 30 sites on the coast of Kenya (see items 3 and 4 below). In November 1997, an ICIPE technician received training at Tulane University and also attended a 2-months workshop at the National Aeronautics and Space Administration (NASA) in the USA.

The two initial studies conducted in two ecologically distinct eco-zones, that is, the Lake region and the coast, provide a valuable starting point for the development of the sampling plan for the countrywide analysis of vectors and malaria endemicity. The resulting database for all these activities will be used to generate countrywide GIS maps showing the distribution of *Anopheles* mosquitoes, their relative abundance, the intensity of transmission, and the genetic structure of vector populations. The long-term goal is to develop GIS-based approaches and models for analysing and predicting country-wide distributions of malaria vectors, temporal and spatial variation in transmission intensity and malaria infection/disease in human populations. These models will be adapted for use by scientists involved with the design and implementation of malaria control programmes in the East African region.

A laboratory was established in Nairobi for field processing of mosquitoes and database management. Mosquito specimens from Mbita were analysed for sporozoite and bloodmeal by the ELISA technique.

Potential collaborators were identified, in part through participation in a workshop on global climate change that was held at ICIPE in September 1997. Preliminary discussions were held with collaborators to develop a plan regarding the types of models needed and the parameters for developing the models.

A meeting was held in November 1997 with regional collaborators at ICIPE in Nairobi to plan coordination of research in the region. Participants from the Tanzanian National Institute of Medical Research and the Tropical Pesticide Research Institute and from nine institutions within Kenya attended that meeting.

3. ECOLOGICAL AND BEHAVIOURAL STUDIES OF *ANOPHELES* MOSQUITOES AND MALARIA PARASITE TRANSMISSION IN SUBA DISTRICT, WESTERN KENYA

The specific objectives were to:

(i) determine spatial and temporal relationships between distribution patterns of *Anopheles* mosquitoes and the prevalence of *Plasmodium falciparum* in Suba District, western Kenya;

(ii) conduct longitudinal studies of the ecology and behaviour of vector species of mosquitoes and the transmission of *Plasmodium falciparum* malaria;

(iii) conduct studies of larval ecology of *Anopheles* malaria vectors and pilot larval control experiments in western Kenya;

(iv) design mosquito-proof screens appropriate for local house styles and evaluate their efficacy in reducing vector contact with humans;

(v) maintain and improve community-based programmes to inform residents and school children about malaria and the public health consequences of this disease.

From June 1997, 30 sub-locations (villages) were selected for mosquito sampling in Suba District, western Kenya, representing a wide range of topographical features (Figure 3.1). Ten houses were

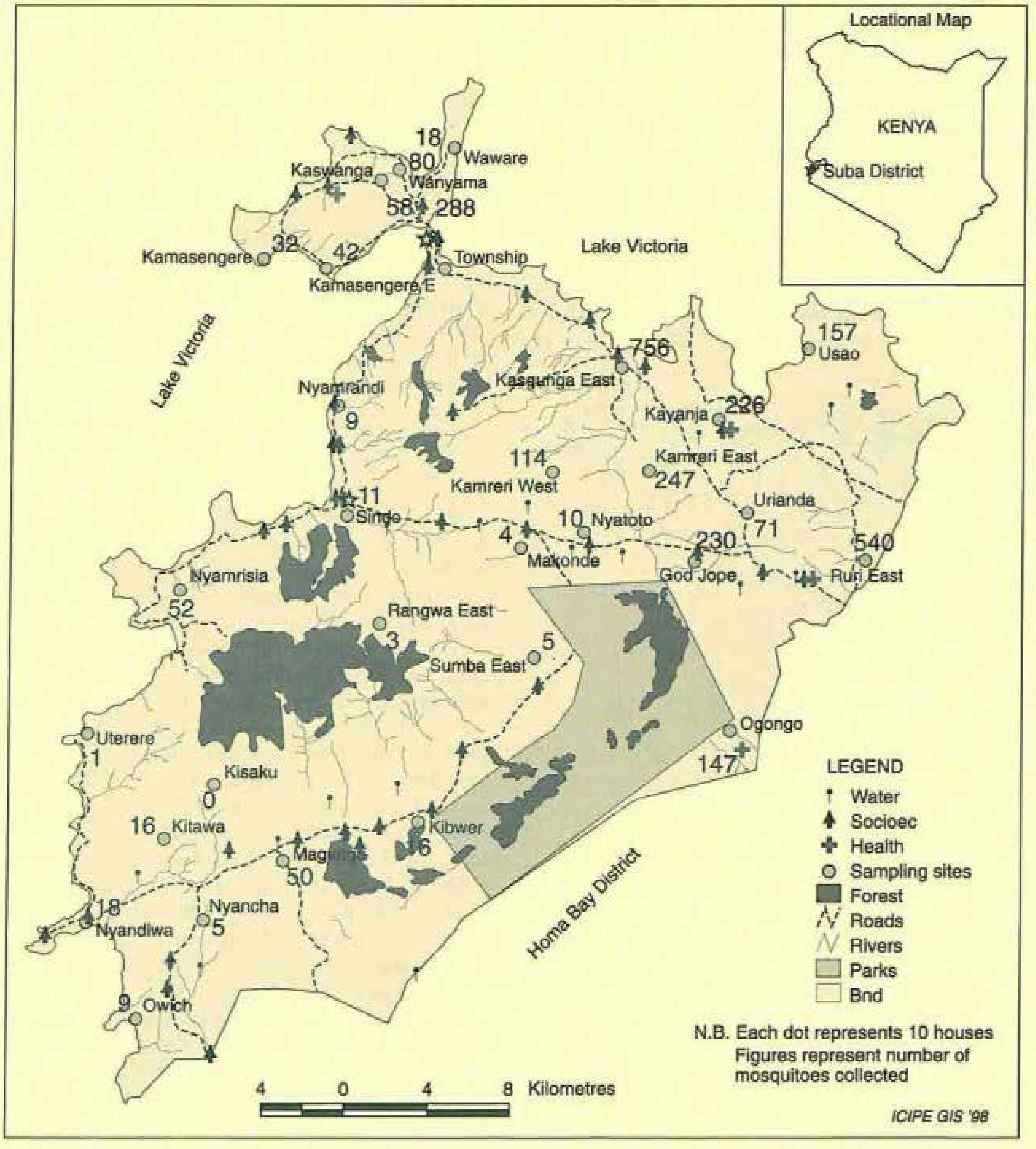


Figure 3.1. Mosquito sampling sites in Suba District, western Kenya

sampled for resting mosquitoes at each site, using indoor space spraying with 0.2% pyrethrum. The spray solution was prepared by diluting 10% emulsifiable pyrethrin concentrate in water. Sampling was conducted at the end of the long rain season in June and August, 1997. All the 30 mosquito sampling sites were geo-positioned using a hand-held Magellan global positioning system (GPS).

A total of 3215 mosquitoes were collected in Suba District with the commonest vector species being *An. gambiae* s.l. followed by *An. funestus*. The commonest mosquito species in the spray catches was *Anopheles gambiae* s.l., followed by *Culex quinquefasciatus* and lastly, *An. funestus*. Preliminary analysis of data, showed a sharp decline in anopheline populations over the 3 months period (Figure 3.2). Generally, the district could be stratified into areas of high, moderate or low anopheline densities represented by Mbita area, Rusinga Island and Gwasi Division, respectively. The average number of anophelines per house ranged between zero and sixty with majority of them being *An. gambiae* s.l. All anopheline specimens were preserved for further laboratory processing to facilitate sibling species identification and determination of sporozoite infection and host preferences using cytotaxonomic, PCR and ELISA techniques.

One hundred and forty aquatic larval habitats have been identified and examined for *Anopheles* larvae. Each site was classified by visual inspection to

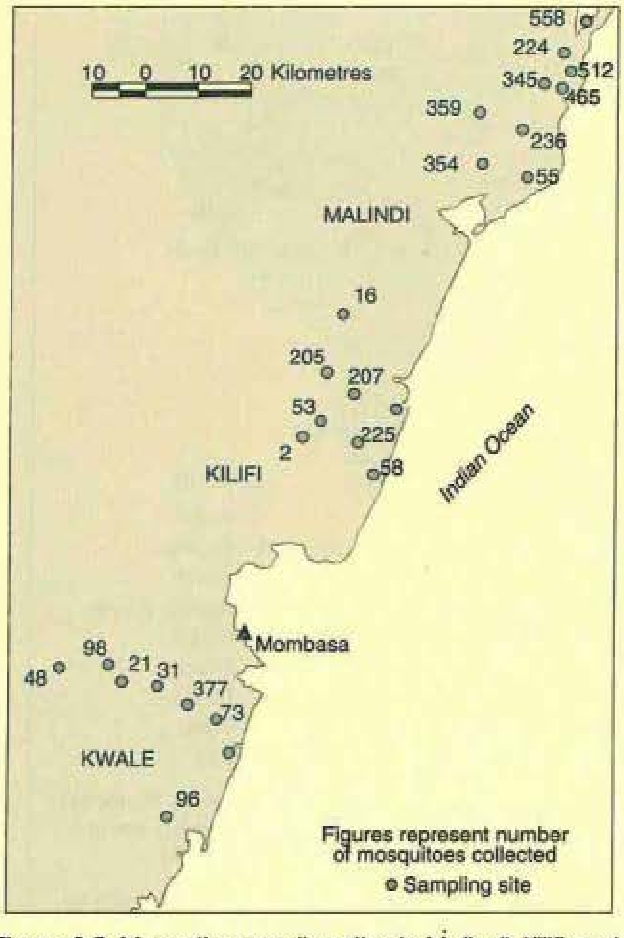


Figure 3.2. Mosquito sampling sites in Malindi, Kilifi and Kwale Districts

record ecological parameters and by standard water chemistry methods. Larvae were identified microscopically and those in the *An. gambiae* complex further identified to the species and sub-species levels by PCR. The goals were to identify environmental determinants of larval development sites for each vector species, determine the basis for population regulation (predation or nutrient competition) and develop models for predicting the abundance of adult mosquitoes.

In preparation for ICIPE's pioneering research on ecology and behaviour of mosquitoes in Suba District, malaria prevalence and status among other diseases were assessed for the district using data collated from past parasitological surveys and hospital records of clinically diagnosed cases. According to hospital records, malaria was the leading cause of morbidity, constituting 42–48% of all illnesses clinically diagnosed in 1995 and 1996. In follow-up to these existing records on malaria endemicity, standardised studies on parasite prevalence were conducted in October/ November, 1997 in the same sites used for mosquito sampling earlier in the year. The target population comprised of primary school children ranging in age from 5–14 years. In each of the 30 schools, thick and thin blood smears were prepared from 100 children for examination for malaria parasites. Parasite infection rates will ultimately be correlated with entomological parameters to provide a basis for understanding local variations in the disease endemicity.

Various methods aimed at reducing contact between mosquitoes and people constitute an effective means of combating malaria. ICIPE's malaria project is keen on promoting self-protection methods that are simple to use and affordable by rural communities. Besides being effective against mosquitoes, such methods should also be safe to use and environmentally friendly. In this regard, a survey was carried out to determine the methods people in Suba District used for self-protection against mosquito bites. The most popular method was mosquito nets, followed by mosquito (pyrethrum-based) coils (Table 3.1). Other methods included insecticidal sprays and plants, traditionally associated with mosquito repellence. In a separate ethno-botanical survey involving secondary school children, a list of the mosquito repellent plants was compiled for Suba area (Table 3.2). Experiments are under way to evaluate the efficacy of the different species when used in their natural state with a view to promoting some of them for use in the community.

An educational play entitled "Mosquito Mask" was staged at different venues by students of Moi Sindo Girls' Secondary School. The play, which was based on the prevailing malaria situation in Africa, helped create awareness about the role mosquitoes play in disease transmission. More important, it highlighted the methods that were currently available for both mosquito and malaria control. "Mosquito Mask" was jointly authored by an ICIPE scientist and

Table 3.1. Percentage of homesteads+ using various methods for self-protection against mosquitoes

Method	Rusinga (n=115) %	Mainland (n=138) %
Insecticide-treated bednets	5.2	11.6
Untreated bednets	26.1	37.0
Mosquito coils	25.2	31.2
Insecticidal sprays	18.3	9.4
Plant smoke	19.1	8.7
Wire mesh screens	2.6	1.4
No intervention	35.7	31.9

+A homestead had an average of three houses and four beds.

Table 3.2. List of plants associated with mosquito repellency in Suba District

Common Luo/ English name	Scientific name
Muen (Mkinga)	*Ocimum americanum*
Miere	*Ocimum suave*
Raywe (Onyalobiro)	*Sckhuria pinnata*
Eucalyptus	*Eucalyptus saligna*
Night Queen	*Cestrum nocturnum*
Apilo	*Capsicum frutescens*
Otati	*Psiadia punctulata*
Nyanjagra	*Tagetes minuta*
Owino	*Senna didymobotrya*
Oinglatiany	*Cassia occidentalis*

teachers from Sindo Girls' School. Dramatisation of the play was within the context of the objective on the promotion of community-based malaria activities using schools as an entry point for awareness creation. The play won the top award during the Suba District secondary schools drama festival and received high acclaim during a similar event at the provincial level. Plans are underway to stage the play in other venues and to also publish it as a book for wider circulation.

4. ECOLOGICAL AND BEHAVIOURAL STUDIES OF *ANOPHELES* MOSQUITOES AND MALARIA PARASITE TRANSMISSION ON THE COAST OF KENYA

The specific objectives of this activity were to:

(i) determine spatial and temporal relationships between distribution patterns of *Anopheles* mosquitoes and the prevalence of *Plasmodium falciparum* transmission;

(ii) conduct longitudinal studies of the ecology and behaviour of vector species of mosquitoes and the transmission of *Plasmodium falciparum* malaria;

(iii) examine dispersal behaviour and gene flow of *Anopheles gambiae* mosquitoes at ecologically diverse sites along the Kenyan coast;

(iv) conduct studies of the larval ecology of *Anopheles* malaria vectors.

Studies to determine the mosquito species composition, abundance and malaria transmission intensity relative to malaria prevalence were initiated at 30 sites extending from Malindi, Kilifi and Kwale Districts at the coast (Figure 3.2). All the 30 sites were geo-positioned using a hand-held GPS. Mosquitoes were collected by pyrethrum spray catch from 10 houses in each site every two months. All collected mosquitoes were morphologically identified using standard taxonomic methods. Blood feeding stages were also recorded. Heads and thoraces of all mosquitoes were examined for sporozoites and the blood fed were analysed for blood meal source. Half-gravid, *An. gambiae* s.l. (734) were identified by cytogenetic method through the assistance of a scientist from Mali and 600 were identified by PCR in Nairobi.

A total of 8773 anopheline mosquitoes have been collected from the 30 sites from June 1997. These comprise of 67.6% *An. gambiae*, 31.6% *An. funestus* and 0.8% other anophelines. The average number of mosquitoes per house was higher in Malindi than in the other two districts. The sporozoite rate in *An. gambiae* s.l. was 13.5% (80/594) and that of *An. funestus* was 6.7% (39/586) out of the 1180 mosquitoes examined for malaria parasites.

5. IDENTIFY POPULATION GENETICS STRUCTURE OF *ANOPHELES GAMBIAE* COMPLEX MOSQUITOES RELATIVE TO SPATIAL-TEMPORAL PATTERNS OF MALARIA PARASITES AND GENETIC LOCI OF MOSQUITOES THAT INFLUENCE VECTOR COMPETENCE

The specific objectives were to:

(i) examine the species composition and population structure of *Anopheles gambiae*, particularly at the locus closely linked to vector competence;

(ii) examine the genetic basis for variation among *Anopheles* species and sub-species of *An. gambiae* complex in susceptibility to malaria parasites;

(iii) select and establish refractory and susceptible colonies of *An. gambiae*, and to map genes conferring refractoriness to *P. falciparum*.

The main vectors of malaria in East Africa are two members of the *Anopheles gambiae* species complex: *An. gambiae* sensu stricto and *An. arabiensis*. On a more local scale, *An. funestus* also plays a significant role in disease transmission. The two, *An. gambiae* sibling species differ in their ecology, behaviour and more importantly, in their relative roles in malaria transmission. Previous studies in certain areas within the malaria holo-endemic zone of western Kenya have demonstrated important local variations in biting rates of anopheline mosquitoes as well as malaria endemicity. Because of the difficulty of differentiating the sibling species, reference to *An. gambiae* sensu lato is often a mixture of several members of the species complex. Knowledge of the species composition of the natural populations would greatly enhance our understanding of the parameters contributing to malaria transmission and prevalence in a region.

A molecular genetics laboratory has been established in Nairobi. It has the capacity to conduct PCR, restriction digestion, cloning and DNA sequencing. The goal is to provide core facilities and technical support for scientists in the eastern African regions, to conduct molecular and cytogenetic analysis of mosquitoes.

Anopheles populations collected from three districts at the coast of Kenya were subjected to DNA extraction. A rDNA-PCR method based on known species-specific sequences was used for species identification. About 630 samples have been analysed. We found that *An. gambiae* s.s. and *An. funestus* are predominant malaria vectors in the Kilifi District and the distribution of *An. funestus* and *An. merus* is primarily confined to small areas. Sub-species identification using PCR, showed that *An. gambiae* s.s. was the predominant species in coastal Kenya. The results also suggest that *An. funestus* is an important malaria vector in coastal Kenya and its biology deserves more attention.

We have initiated experiments to genotype the mosquitoes using the microsatellite markers. Nine microsatellite markers located within and outside the chromosome inversion 2La were used to examine the genetic differentiation for *An. gambiae* s.s. populations at both the macro and micro-geographical scales. We are also screening the microsatellite markers previously developed from *An. gambiae* s.s. to examine the potential of using these markers for population genetic studies of other vector species including *An. funestus* and *An. arabiensis*.

We will evaluate variation among geographically distinct *An. gambiae* populations in susceptibility to *P. falciparum*. The experiments will involve feeding F_1s of field collected *An. gambiae* s.s. on high-gametocyte carriers and dissecting mosquitoes to examine oocyst and sporozoite development. Mosquito carcass will also be genotyped using microsatellite markers with broad genome coverage. Relationship between genotypes or allele frequency of microsatellite loci and susceptibility to parasite will be tested.

6. EXPERIMENTAL AND FIELD STUDIES OF MOSQUITO-MALARIA PARASITE RELATIONSHIPS TO IDENTIFY ENVIRONMENTAL AND MOSQUITO-RELATED FACTORS THAT LIMIT THE MALARIA TRANSMISSION POTENTIAL OF MALARIA VECTORS IN EAST AFRICA

This activity aimed to:

(i) identify environmental, mosquito and parasite-related factors that limit *Plasmodium falciparum* development in African malaria vectors;

(ii) test whether there are seasonal changes in the infectivity of gametocyte-stage parasites of humans that influence patterns of natural transmission;

(iii) evaluate changes in efficiency of malaria parasite development in wild mosquitoes;

(iv) develop a series of improved methods (microscopic, immunologic and molecular) for detecting and quantifying early stages of malaria parasites that occur in the mosquito (i.e., ingested gametocytes, zygotes, ookinetes and early-stage oocysts);

(v) develop research linkages with international investigators developing transmission-blocking vaccines that target: (a) specific stages of the parasite in the vector (e.g., the Pfs25 protein that occurs on gametes and ookinetes), (b) interactions between the parasite and the mosquito (e.g., chitinase of parasites and mosquito trypsin), and (c) the mosquito itself (e.g., anti-mosquito vaccine development).

Through the collaboration between ICIPE and Tulane University, USA, proposals for anti-vector vaccine and transmission-blocking vaccine have been developed. A scientist from Tulane University visited ICIPE for one week in December 1997 to develop a joint proposal that was submitted to WHO in January 1998.

Renovation of the insectary for rearing mosquitoes and maintaining infected mosquitoes for studies on parasite–vector relationship is nearing completion, but is yet to be equipped. Linkages have been established with KEMRI to develop protocols involving malaria-infected human volunteers in Nairobi and Mbita for studies on transmission blocking vaccines.

7. INTEGRATED CHEMICAL AND BEHAVIOURAL STUDIES OF *ANOPHELES* MOSQUITOES TO IDENTIFY CHEMICAL CUES ASSOCIATED WITH HOST-SEEKING AND MATING BEHAVIOUR

These studies were aimed at:

(i) identifying semiochemicals that are integral to the process of mosquito host attraction to human hosts;

(ii) determining behavioural differences in host attraction responses to semiochemicals for the three major malaria vectors in Africa;

(iii) identifying chemicals that represent natural mosquito repellents from plants that naturally occur in malaria endemic areas;

(iv) developing and field-testing odour-baited traps and chemicals that repel mosquitoes;

(v) identifying factors that induce swarming behaviour of anophelines and that serve as pre-copulatory barriers between sibling species of the *Anopheles gambiae* complex.

The scientist responsible for this component of the Project will arrive in January 1998. An insectary for mass rearing of mosquitoes to conduct chemical and behavioural ecology has been renovated. Rearing of *An. gambiae* and *An. funestus* for behavioural and repellency studies has started in Mbita. It is known that certain plants are commonly used at the household and community level to repel mosquitoes, but the chemical basis of these traditional methods is not known. Specific plant species with this property have been collected in Mbita (see item 3 above). Plant oils from these plants will be extracted by hydro-distillation and corresponding chemical compounds tested in a wind tunnel. Active compounds will be identified by GC-EAD and GC-MS techniques. A visiting scientist on a one year Swiss Government Fellowship is currently assisting in identifying plant compounds that repel mosquitoes.

8. AWARENESS BUILDING AND FACILITATING THE USE OF NEEM AS A SOURCE OF NATURAL PESTICIDES AND OTHER USEFUL PRODUCTS IN SUB-SAHARAN AFRICA (AGEC-2)

Participating scientist: *R. C. Saxena (Project Coordinator)*

Collaborator: *SHARE, Kenya*

Donors: *Government of Finland, UNEP*

Work in progress

Neem bark and leaf extracts have traditionally been used as malaria remedies in Asia and Africa. Neem oil has been found to be an effective mosquito repellent. A survey of 175 households with a population of 1085 was conducted in a rural community in Western Kenya to determine the community's perceptions about malaria and the use of neem for its treatment.

Most of the respondents mentioned the use of anti-malarial drugs, while some were already aware of the use of neem for prevention and treatment of malaria. Members of the communities (98%) knew about neem through ICIPE's Neem Project; only 36% respondents actually used neem against malaria. Neem was taken as an infusion of the bark, leaves or roots boiled in water, inhalation of the leaf smoke, or as a concoction of neem seed powder. The mention of alternative preventive and curative strategies such as the use of neem by respondents, shows that the community perceives the need for an alternative approach.

See also the reports on neem under Plant Health (Report IX) and Animal Health (XIII) for details on background, funding, collaborators, publications and impact.

Output

Workshops organised

A regional workshop on mosquito control products was held in Nairobi on 19–20 November 1997. ICIPE with the support of S.C. Johnson Wax, USA brought together researchers involved in mosquito control in the East African region to deliberate on issues that pharmaceutical companies should consider when developing products. It was noted that there are several products that have been introduced in the market in the recent past to control mosquito bites. Unfortunately, most of them are unaffordable to most of the affected rural communities in the developing countries. The discussion centred on the use of bednets, creams and lotions, aerosols, coils, botanicals, electric mats and liquid electric vapours. Although bednets and aerosols are effective in controlling mosquito bites, it was observed that the coils are the only widely used products by the poor communities.

A joint workshop on scientific cooperation between ICIPE and the Ministry of Agriculture and Forestry, Sudan was held on 4–9 December 1997 in Khartoum. Collaborative linkages on malaria research were established with the University of Khartoum and University of Gezira. Plans are underway to develop joint proposals with scientists from these institutions.

Conferences/workshops attended

- International workshop on malaria in Africa, Dakar, Senegal 6–9 January 1997.
- 18th African Health Sciences Congress, Cape Town, South Africa 14–18 April 1997.
- International course on vectors and vector borne diseases in Africa, Bamako, Mali 17–23 July 1997.
- Workshop on Health and Irrigation, Copenhagen, Denmark. Paper presented: 'Evaluation of the role of livestock in malaria transmission risks in irrigation schemes', 18–20 August 1997.
- An International workshop on global change impact assessment approaches for vectors and vector borne diseases, Nairobi, Kenya, 3–6 September 1997.
- ICIPE/WINROCK consultative workshop on a multi-media approach to community pest management, Kampala, Uganda. Paper presented: 'Use of theatre in dissemination of scientific information', 6–7 November 1997.
- Regional workshop on mosquito control products, Nairobi, Kenya 19–20 November 1997.

Proposals written and submitted

PROPOSALS SUBMITTED BY ICIPE STAFF

Towards a sustainable management of malaria vectors, to DANIDA. Budget of US$ 1.2 M for 3 years, submitted in March 1997.

Alleviating poverty in Suba District: A pre-proposal for a community-based enterprise for marketing of pyrethroid impregnated mosquito nets, to UNDP. Budget US$ 150,000 for 2 years, submitted in March 1997.

The Biovillage Initiative—Integrated human health management, to Austrian Govt. Budget US$ 708,000 for 3 years, submitted in November 1997 (see under item 15 of the Tsetse Report).

PROPOSALS SUBMITTED BY COLLABORATORS THAT INCLUDE ICIPE

Encapsulation of *Plasmodium* parasites in *Anopheles gambiae*, to NIH. Budget US $ 173,518 for 3 years, submitted in July 1997.

The development and potential of midgut antigens as vaccine agents for novel mosquito and malaria control, to EU. Budget ECU 167,000 for 3 years, submitted in September 1997.

Impact

Establishment of strong linkages with national research organisations, namely, the Kenya Medical Research Institute (KEMRI) and the Division of Vector Borne Diseases of the Ministry of Health: This has enabled ICIPE to work closely with scientists in these institutions and therefore strengthen the capacity of the national malaria control programme.

A public health drama entitled, "Mosquito Mask" was developed jointly with local schools and used to disseminate information on malaria transmission and prevention. The play, which won several top awards during school drama competitions, will be video-taped and published as a booklet for subsequent wider circulation in Kenya and other African countries.

Human Health

SANDFLIES

XV. Effects of Natural Diets of Sandflies (Diptera: Psychodidae) on Their Vector Competence for *Leishmania*

Background, approach and objectives

In the previous reports the importance of leishmaniasis as one of the major public health problems worldwide in general, and in developing countries in the tropics in particular, was well underscored.

The efforts to control leishmaniasis have been dominated by chemical methods (use of drugs against the parasites and insecticides against the sandfly vectors). The chemical approach yielded encouraging results, but the euphoria was later shattered by the relapse after adequate response of parasites to drugs. The major reasons for the failure of a 'chemical' solution and resurgence of these debilitating and often fatal diseases still remain. The resistance of *Leishmania* strains to first-line drugs (mostly pentavalent antimonials); unsustainability due to cost and/or potential toxicity of second-line drugs (e.g. pentamidine antibiotics); resistance of vectors to primary insecticides and costs and hazardous effects of the replacement ones; and environmental concerns.

Chemotherapy and chemical control of vectors still remain indispensable measures to control mortality and morbidity and to curb epidemic outbreaks. However, long-term control programmes should envisage an integrated strategy based on a good understanding of a variety of natural factors likely to significantly influence the transmission of the disease. Biologically sound approaches ought to be explored.

Until recently, the epidemiology of leishmaniasis had been focusing on insect vectors, human hosts and animal reservoirs, plants being considered a mere habitat component.

The life cycle of *Leishmania* takes place in the sandfly gut, the environment which includes food and digestive enzymes and their products. There is evidence that plant-tissue meals are the common diets of sandflies, whereas blood meals are essential for the parasite's oogenesis. It is therefore important to assess the effects of plant diets on the vector biology and behaviour and the effects of sandfly gut environment (including plant-tissue meals, blood meals from different sources, digestive enzymes and products) on *Leishmania* parasites.

Some of the natural meals of sandflies were found to contain substances (carbohydrates, lectins and proteins), which are able to affect adversely the development of the pathogens and consequently impair the establishment of infection.

The analysis of natural diets of vectors as determinant factors of their vector competence is a novel approach being developed by HUJ and ICIPE. A good understanding of plant–vector–parasite interactions could be useful in the planning of selective and cost-effective methods for the control of sandflies and in providing support to incorporate the plant component in an integrated strategy for the control of leishmaniasis.

Participating scientist: *M. Muhinda*

Assistant: *D. M. Omogo*

Donors: *USAID through the Hebrew University of Jerusalem*

Collaborator: *Hebrew University of Jerusalem (HUJ)*

Work in progress

1. ASSESSMENT OF PHYTOPHAGY IN SANDFLIES

The overall goal of the study was to identify natural sources of food for sandflies and evaluate the effects of different diets on the vectorial potential for *Leishmania*. The objective was to assess the attraction of sandflies to plants in the laboratory and their prevalence in three site types surrounding the breeding sites (vegetation, human habitation and open areas). Laboratory and field experiments were conducted on two phlebotomine sandflies, *Sergentomyia ingrami* Newstead, a suspected potential vector (it has been found harbouring *Leishmania*-like flagellates); and *Phlebotomus duboscqi* Neveu-Lemaire, a confirmed vector of *Leishmania major*, one of the causative agents of cutaneous leishmaniasis.

1.1 LABORATORY COLONISATION AND MAINTENANCE OF *S. INGRAMI* AND *P. DUBOSCQI* AND *LEISHMANIA MAJOR* ICIPE 226

ICIPE's Medical Vectors Research Programme (MVRP), had been maintaining in its insectary different sandfly species, including *P. duboscqi, Sergentomyia ingrami, S. schwetzi, S. bedfordi, S. antennatus, S. garnhami*. Before the closing of MVRP, the sandfly colony was allowed to collapse, necessitating the rebuilding of a new one from scratch. With a lot of effort, *S.ingrami* was able to be revived from a few rescued adults. The Leishmaniasis Department of the Kenya Medical Research Institute (KEMRI) provided some larvae of *P. duboscqi* to start a new colony in January 1995. We were able from June 1995 to have some batches of *S. ingrami* for laboratory and field experiments and some adults of *P. duboscqi* to carry out experiments on phytophagy and artificial blood-feeding.

To ensure the permanent availability of hamsters we restarted our smallscale rearing unit of small mammals so as to meet the daily demand. Passage of parasites into new clean lots of hamsters and BALB/c mice, and regular subcultures, have been intensified to keep a stock of virulent parasites for experimental transmission.

1.2 ASSESSMENT OF PHYTOPHAGY IN SANDFLIES FED ON PLANTS IN THE LABORATORY AND DETECTION OF SUGAR IN THOSE CAUGHT IN THE WILD

1.2.1 *Peridomestic plants*

Crops and fallow plants are termed peridomestic, because they grow close to human dwellings. Their interaction (attraction/repellency) with anthropophilic vectors and/or their possible effect on *Leishmania*, is of growing interest in the epidemiology of leishmaniasis. The same reason applies to the potential role of the plants surrounding the breeding sites of sandflies, which are at the same time the habitat of animal reservoirs (e.g. rodents) for *Leishmania*.

A fallow plant, castor oil, *Ricinus communis* (Euphorbiaceae) was offered overnight to *S. ingrami* and *P. duboscqi*, whose guts were then tested with anthrone reagent for the presence of sugars. It proved less attractive to both *S. ingrami* (23.04%) and *P. duboscqi* (8.54%) (Table 1.1), compared with the feeding rate reported on *P. papatasi* (71%), fed on the same plant from the Jordan Valley, Israel.

The first crop plant tested, sweet potato (2 varieties), *Ipomoea batatas* (I & II) (Convolvulaceae) was more attractive to *S. ingrami* than it was to *P. duboscqi* (Table 1.1). Both sandfly species favoured variety I (erect, small leaves; 65.52% in *S. ingrami* and 32.00% in *P. duboscqi*) than variety II (creeping, large leaves; 48.48% in *S. ingrami* and 24.68% in *P. duboscqi*).

1.2.2 *Plants from breeding sites*

The plants *Acacia tortilis* (Mimosaceae), *Acalypha ciliata* (Euphorbiaceae), *Achyrenthes aspera* (Amaranthaceae), *Capparis tomentosa* (Capparaceae), *Cissus rotundifolia* (Vitaceae), *Maerua subcordata* (Capparaceae), were collected around sandfly breeding sites (termite hills or animal burrows) in Marigat, Baringo District. They were exposed overnight to *S. ingrami* and the anthrone test performed to detect the presence of sugar in the guts of the test sandflies. The results (Table 1.2) show a moderate feeding rate of 12 and 50% on *Cissus rotundifolia* and *Achyranthes aspera*, respectively.

1.2.3 *Presence of sugar in wild-caught sandflies from breeding sites in Marigat*

Flies caught with miniature CDC-light traps in animal burrows and human dwellings were tested with anthrone for the presence of sugars in their guts. From the results in Table 1.3, sugar-feeding was demonstrated in all the sandfly species examined. The sample size is generally too small to allow a definitive comparison. The plant-feeding of *S. ingrami* in the field seemed to be even higher than in the laboratory, when the same sandfly was offered the most frequently occurring plants found around breeding sites. That would mean that in the field *S. ingrami* takes sugar meals from a variety of sources or that the most suitable source is still to be discovered.

Table 1.1. Feeding of *P. duboscqi* and *S. ingrami* on two plant species (*Ricinus communis* and *Ipomoea batatas*)

Insect	Plant	No. tested specimens			
		Females	Males	Total	% Positive
S. ingrami	*R. communis*	95 (23)⁺	93 (21)	188 (44)	23.04
P. duboscqi	*R. communis*	75 (5)	124 (12)	199 (17)	8.54
S. ingrami	*I. batatas* I	24 (17)	5 (2)	29 (19)	65.52
S. ingrami	*I. batatas* II	27 (15)	6 (1)	33 (16)	48.48
P. duboscqi	*I. batatas* I	55 (20)	95 (28)	150 (48)	32.00
P. duboscqi	*I. batatas* II	63 (10	91 (28)	150 (38)	24.68

⁺ Values in brackets are positive; I and II are varieties.

Table 1.2. Feeding of *S. ingrami* on plants collected around the sandfly breeding sites (termite hill/animal burrow)

	No. fly specimens examined			
Plant species	Females	Males	Total	% Positive
Acacia tortilis	33 (6)+	33 (8)	66 (14)	21.2
Acalypha ciliata	35 (16)	34 (15)	69 (31)	44.9
Achyranthes aspera	6 (4)	4 (1)	10 (5)	50.0
Capparis tomentosa	61 (11)	37 (9)	98 (20)	20.4
Cissus rotundifolia	27 (2)	20 (4)	47 (6)	12.8
Maerua subcordata	83 (28)	52 (16)	135 (44)	32.6

+Values in brackets show positive anthrone tests for sugars in the fly gut.

Table 1.3. Anthrone test for the presence of sugar in wild sandflies caught with miniature CDC-light traps from animal burrows and human dwellings

	Animal burrow				Human dwelling			
Sandfly species	Females	Males	Total	% Positive	Male	Female	Total	% Positive
P. duboscqi	3 (3)+	7 (4)	10 (7)	70.00	0	1 (1)	1 (1)	–
S. ingrami	5 (3)	13 (10)	18 (13)	72.00	3 (2)	6 (5)	9 (7)	77.8
S. antennatus	5 (5)	2 (1)	7 (6)	85.71	4 (4)	3 (3)	7 (7)	100.0
S. africanus	1 (1)	2 (2)	3 (3)	100.00	5 (3)	1 (1)	6 (4)	66.7
S. bedfordi	1 (1)	0	1 (1)	–	6 (4)	14 (9)	20 (13)	65.0
S. schwetzi	1 (1)	1 (1)	2 (2)	–	1 (0)	0	1 (0)	0.0
S. clydei	0	0	0	–	1 (0)	1 (0)	1 (0)	0.0

+ Values in brackets are positive.

1.3 *LEISHMANIA* INFECTION IN SANDFLIES FROM BREEDING SITES IN MARIGAT

The sticky-trap method was used to sample sandflies from animal burrows and termite hills. A total of 185 females belonging to the species *P. duboscqi*, *P. martini*, *S. ingrami*, *S. antennatus*, *S. africanus* and *S. bedfordi* (Table 1.4) were dissected and observed under the compound microscope for detection of *Leishmania* infection. Only *S. ingrami* was found with *Leishmania*-like flagellates in 3 females out of 23; after several subcultures, the parasites are now being processed for characterisation.

1.4 ARTIFICIAL BLOOD-FEEDING OF *P. DUBOSCQI*

Several trials were carried out to assess the feeding performance of *P. duboscqi* on rabbit blood, offered through the skin of a 1-day old cockerel using a feeding apparatus designed by Kaddu et al. Out of 164 flies allowed to suck blood through the membrane, only 22 (13.41%) were found engorged within 3 h. The series of experiments using hamster blood in an apparatus originally designed for mosquito blood-feeding was more successful. Out of the 60 sandflies exposed, 48 (80%) were fed within 3 h. The use of a membrane smeared with hamster body-wash (hexane

Table 1.4. Assessment of *Leishmania* infection in sandflies from breeding places (animal burrow and termite hills) in Marigat, Kenya

	Animal burrow		Termite hill	
Species	No. dissected sandflies	No. infected sandflies	No. dissected sandflies	No. infected sandflies
P. duboscqi	31	0	1	0
P. martini	6	0	3	0
S. ingrami	23	3	2	0
S. antennatus	78	0	28	0
S. africanus	7	0	2	0
S. bedfordi	2	0	2	0

extract), did not improve either the starting time nor the feeding rate under the same conditions.

To make the results more significant, some of the experiments which were done in few replicates or with small numbers due to the unavailability of insect materials, will require additional testing carried out in similar conditions.

2. IDENTIFICATION OF NATURAL SOURCES OF FOOD FOR SANDFLIES AND EVALUATION OF THE DIFFERENT DIETS ON VECTORIAL POTENTIAL FOR *LEISHMANIA*

Attraction of sandflies to plants in the laboratory was assessed on the sandfly *Phlebotomus duboscqi*, an important vector of cutaneous leishmaniasis in the Old World and in Kenya in particular. Bioassay tests with plants previously tested for phytophagy assessment on the same sandfly were done using a wind-tunnel olfactometer. The plants included peridomestic (crop and weeds) and wild species. The following plants were tested for both feeding and behavioural responses: *Amaranthus hybridus* L. (Amaranthaceae) (crop), *Azadirachta indica* A. Juss. (Meliaceae) (crop/wild), *Bidens pilosa* L. (Compositae) (weed), *Brassica oleracea* var. *acephala* (L.) Clapham (Cruciferae) (crop), *Ipomoea batatas* I (L.) Lamarck (Convolvulaceae) (small leaf variety), *Ipomoea batatas* II (large leaf variety), *Lycopersicum esculentum* Miller (Solanaceae) (crop), *Melia azedarach* L. (Meliaceae) (medicinal/insecticide), *Ocimum kenyense* Ayobangira ex Paton (Labiatae) (wild/weed); *O. suave* Willdenow (Labiatae) (wild), *Phaseolus vulgaris* L. (Leguminosae) (crop), *Ricinus communis* L. (Euphorbiaceae) (crop/weed), *Rumex usambarensis* (Dammer) Dammer (Polygonaceae) (wild), *Solanum incanum* L. (Solanaceae) (wild), *Solanum tuberosum* L. (Solanaceae) (crop), *Tagetes minuta* L. (Compositae) (weed), *Vigna unguiculata* (L.) Walp. (Leguminosae) (crop).

The sandfly population prevalence in different sites was estimated by trapping with CDC light traps.

2.1 LABORATORY EXPERIMENTS

The results summarised in Figure 2.1 show three groups of plants based on their apparent suitability and attractiveness to *P. duboscqi*. The first group comprises plants with clear cut repellency and/or phagodeterrency (*Amaranthus hybridus, Ocimum kenyense, O. suave, Ricinus communis, Solanum tuberosum, Tagetes minuta* and *Vigna unguiculata*). The second group represents suitable plants for both feeding and attraction (e.g. *Rumex usambarensis* and *Melia azedarach*), and the third group is made of more complex plants in which high feeding rates may be

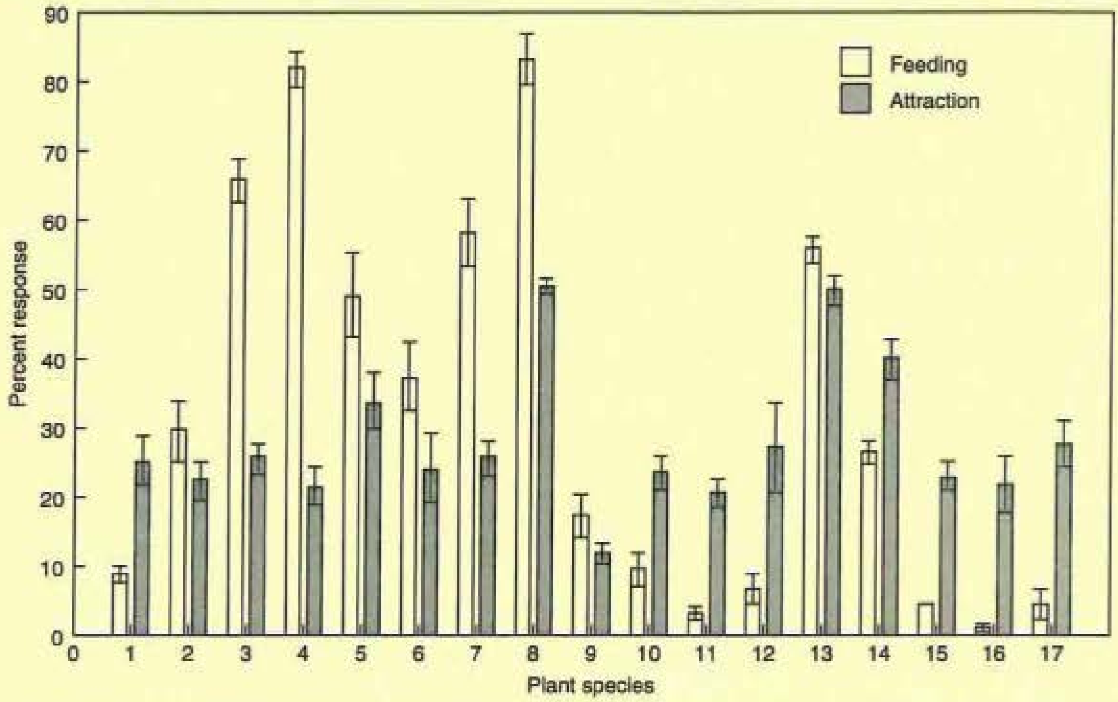


Figure 2.1. Feeding and behavioural responses of the sandfly, *Phlebotomus duboscqi* to different plant species

1. *Amaranthus hybridus*
2. *Azadirachta indica*
3. *Bidens pilosa*
4. *Brassica oleracea*
5. *Ipomoea batatas* I
6. *Ipomoea batatas* II
7. *Lycopersicum esculentum*
8. *Melia azedarach*
9. *Ocimum kenyense*
10. *Ocimum suave*
11. *Phaseolus vulgaris*
12. *Ricinus communis*
13. *Rumex usambarensis*
14. *Solanum incanum*
15. *Solanum tuberosum*
16. *Tagetes minuta*
17. *Vigna unguiculata*

associated with significant repellency and vice-versa (*Lycopersicum esculentum*).

2.2 FIELD EXPERIMENTS

A total of 626 sandflies were caught, comprising four *Phlebotomus* spp. and nine *Sergentomyia* spp.

In the vegetation, the 248 sandflies caught were distributed into four species of *Phlebotomus* and seven species of *Sergentomyia*. The sugar-positive tests ranged from 30.8 to 100% in *Phlebotomus* spp. and from 41.4 to 100% in *Sergentomyia* spp.

From human habitations, 334 sandflies were caught including 3 species of *Phlebotomus* and 2 species of *Sergentomyia*; 51% of the total catch was positive for sugar. Only 44 flies were caught in open areas, with most of the species represented; 77.3% of these flies tested positive for sugar.

These results show that the vegetation attracted more fly species than did human habitation and open areas and the latter had a higher average of flies positive for sugar.

Output

Publications

Muhinda M. Fecundity and longevity of *Phlebotomus duboscqi* and *Sergentomyia ingrami* (Diptera: Psychodidae) maintained on plants. *Medical and Veterinary Entomology*. (In press).

CONTENTS

Environmental Research

ENVIRONMENTAL RESEARCH

ARTHROPOD BIODIVERSITY, CONSERVATION AND UTILISATION

This new programme area was introduced in 1995 to focus on a longstanding concern of ICIPE's—that of conserving the natural resource base, including its diversity. ICIPE's Arthropod Biodiversity and Conservation Megaproject and Commercial Insects Megaproject seek to redress this deficiency. In promoting environmental health, ICIPE hopes to catalyse the process of biodiversity conservation and utilisation and other aspects of environmental health within a broader framework of regional land use and conservation policies and programmes.

I. BIODIVERSITY AND CONSERVATION

A major activity initiated in 1995 was the development of the biodiversity and conservation research plan, involving participation and review by a wide-ranging group of advisers. With the support of a planning grant from the Norwegian government, ICIPE coordinated the following activities:

- A general survey of completed, on-going and planned insect biodiversity projects in Africa (including systematics, ecology, conservation, biogeography, agrobiodiversity and related fields). The survey indicated areas of serious gaps and information needs, which the proposed plan has attempted to address.
- Partnership with the Xerces Society International Invertebrate Conservation Organisation, to develop a new initiative in the African continent.
- Circulation of the draft proposal to more than 60 institutions and individuals worldwide (75% responded with comments).
- African Insect Biodiversity Workshop in Nairobi, in January 1997 sponsored by ICIPE, which brought together African and international biodiversity and conservation institutions to review the proposed programme and to develop strategic partnerships, out of which the final proposal emerged.

II. COMMERCIAL INSECTS

The Commercial Insects Megaproject was initiated in January 1996 at ICIPE. Its aim is to develop and implement improved sericulture and apiculture technologies, which will enhance the productivity of smallscale land-users. The project targets women's groups and stresses the conservation and utilisation of the natural resources of Africa. It is our hope that the successful utilisation of commercial insects at the grassroots level will preserve and safeguard an environment, whose rich resources are being rapidly plundered and lost forever.

The project has three main components: beekeeping, wild and domesticated silkworm rearing, and the conservation of these commercial insects and their habitat. Strategic research was used to resolve technical implementation problems. Through the active participation of a great number of farmers and other end-users, the applicability and success of the improved techniques developed in the laboratory are being assessed in the field.

Environmental Health

BIODIVERSITY AND CONSERVATION

XVI. African Arthropod Biodiversity: Gaining Knowledge for Utilisation and Conservation (BIOCON-1)

Background, approach and objectives

Biological resources are the basis of the prosperity of the developed world; yet, the biologically rich underdeveloped nations of Africa are the economically poorest in the world. Africa's biodiversity, if conserved and developed sustainably, can be utilised to relieve poverty and achieve economic stability.

The challenge lies in rapidly acquiring the required knowledge of the biodiversity resource: knowing what the critical species are, where they occur, obtaining information about their natural history, and establishing sustainable resource use patterns. The Convention on Biological Diversity emerging from the Rio Summit of 1992 recognised this challenge, and the general lack of knowledge for meeting it. ICIPE seeks to fill two key gaps in understanding and utilising the *positive* aspects of the insect contribution to biodiversity:

- Almost all research on insects in tropical Africa focuses on the *negative* aspects of insects (e.g. problems in agriculture, forestry, livestock and human health caused by less than 1% of the species of insects), ignoring the remaining 99% of insect species (Figure 1).
- Most biodiversity and conservation programmes currently operating in tropical Africa focus on flowering plants or vertebrates, ignoring insects which E.O. Wilson has called "the little things that run the world" because of their key roles in ecosystem function (Figure 2).

The Resource: Why insects?

Insects and other arthropods comprise more than 70% of the world's fauna. Insects contribute by far the largest number of taxa to biological diversity both in Africa and the world. Many major impacts on human welfare—human and animal diseases carried by insect vectors, migrant pest outbreaks such as locust and armyworm, destruction of food by plant pests, toxic residues from pesticides, overuse and depletion of agricultural lands and adjoining forests—are problems for which the answers lie well within the area of biodiversity, and more specifically within the area of

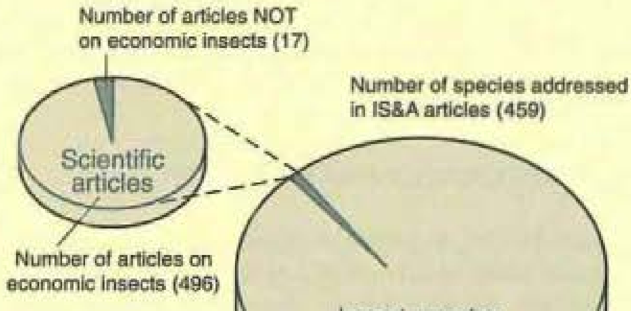


Figure 1. Subject matter of articles in *Insect Science and Its Application*, 1990–1995

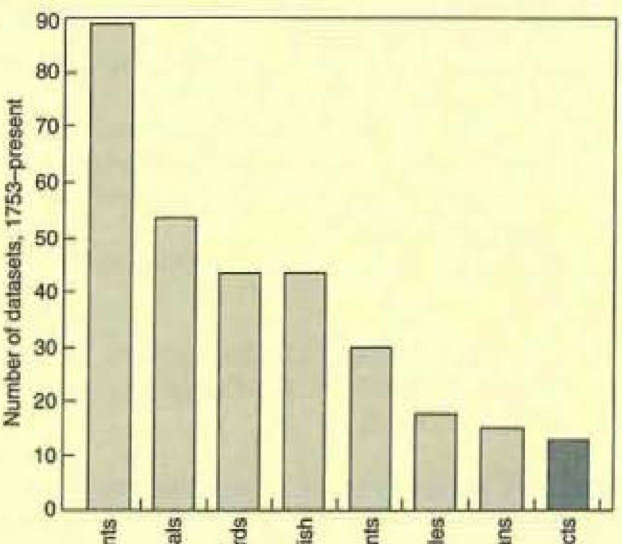


Figure 2. Biodiversity data in East Africa, as of 1994 (WCMC, 1994)

insect diversity. By performing critical 'service' functions within ecosystems, insects are key to ecosystem stability. An estimated US$ 20 billion is spent worldwide every year on pesticides. Yet insect parasites and predators existing in natural ecosystems provide an estimated 5–10 times this amount of pest control.

Many insects provide a direct economic return (e.g., silkworms, bees); others produce chemicals for medicinal use. Some constitute an important protein source in the diet of people; others play predatory and parasitic roles which regulate pests. Arthropods are key in providing pollination services to natural and man-made ecosystems. About 33 % of the world's food production relies either directly or indirectly on insect pollinators.

1. MAJOR ELEMENTS PLANNED UNDER THE BIODIVERISTY AND CONSERVATON MEGAPROJECT

1.1 INFORMATION MANAGEMENT

One of the first, and most important, steps in managing African insect biodiversity is to find out and organise what we already know. An enormous body of information is available, but it is highly dispersed in an extraordinary variety of forms, uncoordinated, and largely unavailable in most of Africa. Recent developments in information technology provide the means to achieving a coordinated information base on the African insect fauna and efficient means of dissemination. The principal outputs of the programme will be:

- a guide to the key publications on African insects;
- a checklist and inventory of the insect species known from Africa;
- a directory to resource centres and expertise for an African insect biodiversity work;
- a handbook of insect biodiversity assessment techniques;
- a database of specimen-level information for butterflies of Africa and termites worldwide;
- a key to the parasitic Hymenoptera of the Afrotropical Region;
- development of insect taxonomic capacity in Africa.

1.2 INSECT-FOCUSED CONSERVATION BIOLOGY PILOT PROJECTS AND APPLICATIONS

These will include a series of experiments, surveys and applications designed to understand the role of key insect groups in ecosystem function and management, and to provide information on conservation and sustainable management of the insect resource. These projects will advance our understanding of African ecosystems, by asking the following questions:

- What ecological processes are important to Africa?
- What insect species are essential to these processes?
- How do these species function across a range of conditions in complex systems? And, given this refined ecological knowledge,
- How might these species and their activities be conserved and enhanced in ecosystems under development?

1.3 TRAINING AND PARTICIPATORY TECHNOLOGY TRANSFER

An important element included throughout the programme is capability building: producing trained technicians and scientists for implementation of the information management and research tasks. Developing, within Africa, an African and overseas reciprocal research exchange ensures a permanent conduit for technology transfer. Many of the students trained through this programme will intern in museums and research centres in Europe and North America, thus effecting the transfer of skills as well as information.

2. GENERATION OF INFORMATION ON THE CURRENT STATUS OF ARTHROPOD BIODIVERSITY RESEARCH IN AFRICA

Background, approach and objectives

Planning for the ICIPE Arthropod Biodiversity, Conservation and Utilisation Megaproject was initiated in 1995. To facilitate the planning of the megaproject and to be able to identify relevant collaborators and existing gaps in arthropod research in Africa, it was essential that existing information on biodiversity research be obtained. This would assist in knowing who was working in the field, where they were working, and would reveal where future resources should be invested. This project was therefore important for decision-making and priority-setting purposes.

Participating scientists: *L. M. Rogo*, Y. Xia (*Project leader)*

Assistant: *J. Lango*

Donor: *Norwegian Government*

Work in progress

Government departments, research, academic and non-governmental organisations worldwide were surveyed for their arthropod research, using standard questionnaire methods. The questionnaire was also posted through e-mail among the relevant discussion groups, such as ECOLOG-L, ENTOMO-L, INFOTERRA-L, CONSLINK-L, DEVEL-L and advertised in the Arid Lands Newsletter Home Page (http://ag.arizona.edu/OALS/ALN/ALN Home.html) and the International Arid Lands Consortium Home Page (http://ag.arizona.edu/OALS/IALC/Home.html). The questionnaire, therefore, had a potential of reaching several thousand subscribers. A 'data source' database was constructed to handle the responses using Microsoft Foxpro 2.5 software package.

A total of 52 responses were received. Out of these, 42 were deemed credible database entries. From the responses, the Insecta was the most highly researched arthropod group, representing 75% of the total projects mentioned. The only other groups represented, the Arachnida and Crustacea, together contributed 13% of the total. Among the Insecta, the Coleoptera (20%) and Hymenoptera (11%) were the groups covered by most projects. Apart from Isoptera (9%), Lepidoptera (7%), Orthoptera (5%) and Homoptera (5%), the rest of the groups were very poorly represented. Even within the Insecta, some orders, e.g. Ephemeroptera, Dermaptera were under-represented. Several groups of the Arthropoda were also under-represented, e.g. Diplopoda (millipedes), Chilopoda (centipedes) and Pauropoda (pauropods).

A total of 37 different institutions responded to the questionnaire. A breakdown of their location and institutional type shows that they are mainly located in Europe (14), North America (12), and a few in Africa (5), implying that institutions involved in arthropod biodiversity research in Africa are mostly located in the developed world. From the responses, universities (15) were very highly represented, followed by governmental organisations (7), museums (6) and research institutions (5). Non-governmental (2) and individual (1) efforts had poor representation.

A large proportion of the projects including those working with museum specimens (43% of the total projects) did not specify the biomes covered by their study. Most of the field projects (28% of the total projects) were done within forest ecosystems. The aquatic system was moderately represented (12% of the total projects). Poorly represented areas but covering large tracts of Africa included the arid and semi-arid lands (6% of the total projects), woodland (4% of the total projects) and savanna (2% of the total projects). Biomes such as grassland savanna, montane areas and coral reefs were under-represented among the responses.

The research objectives involved mainly inventory and general surveys (38% of the total projects), systematics and taxonomic revisions (18% of the total projects), biodiversity and conservation management (14% of the total projects), control and pest management (14% of the total projects), databasing (10% of the total projects), literature review of target arthropods (4% of the total projects) and arthropod rearing (2% of the total projects).

Some projects (3) involving museum collections, among which were those of the International Institute of Entomology initiated at the beginning of the century, were still ongoing. The majority of the biodiversity projects, however, began in the 1990s; 23 were still ongoing and 16 had been completed. The remainder (10) did not state their status. The upsurge of biodiversity projects in the 1990s appears to have been encouraged by the Rio Summit in 1992. During this summit, depletion of biodiversity was acknowledged as a priority environmental concern.

The projects were funded by various funding agencies ranging from research and science foundations (19% of the projects) to organisations like GEF (5% of the projects) that are mandated to fund biodiversity initiatives among other disciplines. The survey found that most of the biodiversity work in museums was sustained by payments from clients requiring identification services. Although half of the respondents willingly revealed the agencies funding their projects, about 50% were unwilling to reveal the amount of funds available to their projects. However, from the information provided, the funds contributed by different agencies for biodiversity research varied from US $ 370 to US $ 200,000 (exclusive of personnel costs).

The findings of this survey that most of the African biodiversity information is stored away in institutions in the North and that only a fraction of the information collected is getting published, justified one of ICIPE's current initiatives: to repatriate the African biodiversity data from over 200 years of African insect information in European and American museums and make it available as a digital library to a variety of on-line users.

3. PILOT STUDIES ON TERMITE SPECIES IN TWO COASTAL FORESTS OF KENYA: SHIMBA HILLS AND MUHAKA FORESTS

Background, approach and objectives

Termites are important within the tropics, both as mediators of ecological processes and as agricultural and silvicultural pests. They have a premier role as decomposers of organic material and through this, contribute significantly to carbon fluxes; they are extremely important conditioners of soil; and, they are the most destructive of all insect pests. Termites are abundant and make up 10% of animal biomass in the tropics. Termites are an indicator group for biogeographical and ecological analysis and monitoring, due to their taxonomic and ecological diversification and relatively sedentary habits which allow them to be sampled directly to give absolute values of abundance and biomass.

Available data show that clearance of forests by logging or for arable use reduces termite species richness. In this report, we present some preliminary data and comparison of termite species from Shimba Hills (a forest reserve) and Muhaka forest (a forest that has undergone some anthropogenic disturbance).

Participating scientists: *L. M. Rogo, J. B. Okeyo-Owuor, R. Bagine*

Assistant: *J. Olela*

Donor: *Norwegian government*

Collaborator: *National Museums of Kenya (NMK)*

Work in progress

Termites were collected from Muhaka (04° 20′ 13″ S, 39° 31′ 19″ E) and Shimba Hills (04° 14′ 29″ S, 39° 25′ 07″ E). Muhaka is classified in this study as a disturbed forest and Shimba Hills, a game reserve, has not undergone as much anthropogenic disturbance as Muhaka forest. Shimba Hills has, however, a very large elephant population. Muhaka is located about 20 km from Shimba Hills.

Sampling was done along a 100-m belt transect of 2-m width. The transects were placed about 500 m from the forest edge to avoid any edge effect. The transect was divided into 20 sections, each 5 m long and 2 m wide, sampled in the following microhabitats found within the transect: surface soil, dead wood, tree trunk and termite mounds. Termite samples from the surface soil were extracted from the soil by the flotation method. Collected termites were preserved in 80% alcohol and transported to the laboratory for identification. The identifications of the termite species were confirmed at the National Museums of Kenya.

Termite species identified from Muhaka and Shimba Hills are shown in Table 3.1. Two families were recorded from both forests, namely Termitidae and Rhinotermitidae. Whilst only three genera of Termitidae were recorded in Muhaka forest, eight genera were recorded in Shimba Hills forest. Two genera and a single genus of the family Rhinotermitidae were recorded in Shimba Hills and Muhaka forest, respectively.

The greater number of species of termites observed in Shimba Hills is likely due to its larger size and less anthropogenic disturbance as compared to Muhaka forest, which has undergone various anthropogenic disturbances. This conforms with previous reports which show that forest disturbance leads to a decrease in insect diversity. The results of the pilot studies so far indicate that Muhaka forest and Shimba Hills are both dominated by termite groups that are soil- and wood feeders.

Table 3.1. Termite species collected from coastal forests of Kenya

(a) Termite species sampled from Muhaka forest

Termitidae
- *Microcerotermes* sp.
- *Microcerotermes masaiaticus* Harris
- *Microcerotermes nemoralis* Harris
- *Nasutitermes infuscatus* Sjostedt
- *Noditermes* sp.

Rhinotermitidae
- *Schedorhinotermes putorius* (Sjostedt)

(b) Termites sampled from a reserve forest (Shimba Hills forest)

Termitidae
- *Amitermes* sp.
- *Cubitermes glebae* Sjöstedt
- *Microcerotermes* sp.
- *Microcerotermes masaiaticus* Harris
- *Microtermes nemoralis* Harris
- *Microtermes pusillus* Silvestri
- *Nasutitermes* sp.
- *Nasutitermes infuscatus* Sjöstedt
- *Nasutitermes kempae* Harris
- *Noditermes wasambaricus* Williams
- *Noditermes cristifrons* Wasmann
- *Odontotermes kibarensis* Fuller
- *Odontotermes tanganicus* Sjöstedt
- *Odontotermes patruus* Sjöstedt
- *Promirotermes* sp.

Rhinotermitidae
- *Coptotermes* sp.
- *Schedorhinotermes* sp.

4. THE CAPACITY OF KENYA COASTAL FOREST FRAGMENTS TO SUPPORT BIODIVERSITY: A CASE STUDY USING BUTTERFLIES

Background, approach and objectives

The main threat to forest biodiversity is the rapid loss of forest habitats due to human interference. This has been hastened by rapid human population growth, which has seen the population of sub-Saharan Africa increase at least fourfold to 500 million since the beginning of the century. The deforestation that has been caused as a result of intensive agriculture, firewood need, and the high value for tropical hardwood has resulted in decreased tree cover in all the main ecological zones. Deforestation has in turn resulted in fragmentation of the forests resulting in islands (or fragments) of forests, left in a sea of non-forested areas.

The coastal forests of East Africa have been reduced to a few large tracts that undergo varying degrees of protection and numerous relatively small, usually degraded, fragments of forests, embedded in extensive areas that have been converted to different land uses, in particular, agriculture.

The inevitable continuation of this trend raises two important conservation-related questions:

(i) How effective are these small forest fragments in supporting biodiversity, and
(ii) How can they be made more effective in maintaining biodiversity? While small forest fragments have been known not to maintain populations of large animals, they have been associated with maintenance of diverse fauna of

insects, frogs, birds and small mammals which also need protection, so as to maintain the Earth's biodiversity.

The proper management and conservation of these small forests is, therefore, essential. Unfortunately, the time and logistic support required for comprehensive ecological investigations on which to base conservation decisions are rarely available, particularly in Africa. Consequently, techniques to rapidly compare the capacity of different sites to support biodiversity are crucial.

The objectives of this project were to take an inventory of butterfly species in two coastal forest fragments, find the extent of invasion by non-forest fauna from the surrounding to detect the importance of forest remnants for biodiversity conservation and also to increase public awareness on the importance of conserving forest patches of all sizes.

Butterflies were used as a surrogate for biodiversity in general, because they are sensitive to changes in ecological conditions and are the most widely used groups of arthropods to indicate forest state. Butterflies are a diverse, highly habitat-specific group that integrates a broad spectrum of ecological interactions, including highly specific relationships with larval food plants. Their sensitivity to environmental quality makes them good indicators of both micro- and macro-environmental changes, such as light level shifts, resulting from habitat alterations. As one of the best known taxa of invertebrates, they provide a good window for incorporating invertebrate information into the natural resource conservation and utilisation picture.

Understanding the implications of fragmentation of forests is essential to national government planning of human settlements and land use in the region, if development is to proceed with minimum disturbance of natural ecosystems.

Participating scientist: *L. M. Rogo*

Assistant: *N. Onyimbo*

Donor: *The Government of Norway*

Collaborators: *• National Museums of Kenya (NMK) • Kenya Wildlife Services (KWS) • African Butterfly Research Institute*

Work in progress

The project investigated the species diversity, richness and abundance of butterflies from two Kenyan coastal forest fragments; namely, Muhaka forest (180 ha) and Mrima forest (350 ha). Both forests have undergone varying levels of anthropogenic disturbance. They represent some of the remaining examples of the Kenya coastal forests that once stretched from northern Natal and Mozambique to southern Somalia. Both these forests are evergreen forests and consist of tall and understorey trees. Comparisons were also made between them with existing butterfly data of other extensive and protected coastal forest reserves of Shimba hills (14,000 ha) and Arabuko Sokoke (40,000 ha) forests.

Butterflies from each forest were collected from three sites: the forest interior, the forest edge and the support zone, which consisted of diverse agriculture surrounding the forests. Attempts were made to collect butterflies at various measured distances (50, 100 and 200 m, etc.) from the edge of the forest. However, this became a fruitless effort in Mrima forest, because the samplers were always confronted with large patches of illegally logged sections in the interior of the forest, rendering sections of the forest interior to have savanna habitats and multiplying edge effects.

4.1 INDICES OF ANALYSIS

Differences between all sites in the density of butterflies was assessed using log transformed data. Species richness was assessed using Margalef's index. The Berger-Parker index was used to provide an index of dominance. Species diversity, which incorporates both the concept of species richness and the evenness of distribution of individuals between species was computed using the log series. Similarity index, based on the number of shared species of the butterfly fauna from different sampling locations and sites, was estimated from Morisita-Horn's index of similarity.

4.2 THE COMPOSITION OF BUTTERFLY GROUPS

The Nymphalidae was the most highly represented family in both forests (Table 4.1). The Lycaenidae and Hesperiidae were the least represented families. The Papilionidae and Pieridae were moderately represented.

4.3 ESTIMATES OF BUTTERFLY DENSITY IN FORESTS AT DIFFERENT LOCATIONS

Differences between all sites (interior, edge and support zones) in the density of butterflies (log, transformed data) were not significant at Muhaka forest. However, in Mrima forest the density of butterflies was significantly higher at the edge than

Table 4.1. Family composition of the butterfly fauna at different forests of Muhaka and Mrima in coastal Kenya

	Muhaka forest		Mrima forest	
Family	Number of species	%	Number of species	%
Nymphalidae	44	62.9	40	59.7
Lycaenidae	2	2.9	3	4.5
Hesperiidae	3	4.3	1	1.5
Papilionidae	7	10.0	11	16.4
Pieridae	14	20.0	12	17.9

the support zone. Densities at both the edge and interior were not significantly different at Mrima forest. The number of butterflies found outside both forests were not significantly different.

4.4 SPECIES RICHNESS AND SPECIES DIVERSITY OF MUHAKA AND MRIMA FORESTS

4.4.1 *Muhaka forest*

The total number of species recorded from Muhaka forest and its support zone was 70 species: Forty-nine species (49) were caught in the forest interior, 29 from the forest edge and 38 from the support zone surrounding the forest. Twelve species were common to all the three different sites, 17 species were found in the forest interior and edge, 21 in interior and support zone and 20 at the edge of the forest and support zone; of these 27 species were typical forest species. The presence of many non-forest savanna species (60% of the total) recorded inside the forest was evidence that conditions suitable for non-forest butterflies could be found inside Muhaka forest, mainly because of its disturbed, open forest condition. This was confirmed by high Morisita Horn's value of similarity between the forest interior and the surrounding support zone (0.93).

Neither the species richness, dominance or diversity per sampling occasion was significantly different between the various locations of Muhaka forest.

4.4.2 *Mrima forest*

The total number of species recorded from Mrima forest and its support zone was 67 species: Species (46) were caught from the forest interior, 51 from the forest edge and 27 from the support zone surrounding the forest. Species (17) were common to all the three sites, 33 in the forest interior and edge, 17 in forest interior and the support zone and 21 in the edge and support zone. There were 23 typical forest species recorded in Mrima forest. As in Muhaka, non-forest savanna species (65% of the total) were able to penetrate the forest interior as confirmed by the high similarity index value between the forest interior and the support zone. This can be explained by the high level of forest disturbance caused by logging. Conditions suitable for non-forest butterflies, for example, lack of canopy cover and presence of paths in the forest provide ideal conditions for savanna butterflies to establish inside the forest.

However, contrary to Muhaka, the edge had the highest number of species, whereas the support zone the lowest. Both species richness and diversity were significantly lower outside the forest than in the interior and edge, whereas species dominance was significantly higher outside the forest.

4.5 COMPARISON OF BUTTERFLY DATA FROM THIS STUDY WITH EXISTING DATA FROM LARGER COASTAL FOREST RESERVES

Table 4.2 summarises the data from this study as compared with some existing information on species richness for larger coastal forest reserves of Shimba hills (14,000 ha) and Arabuko-Sokoke forests (40,000 ha). There is no information on the exact sites where the Shimba Hills butterflies were collected, and it is likely it represents Shimba Hills forest, together with the surrounding area.

The forest fragments of Muhaka and Mrima were characterised by the presence of very few species from two families: Lycaenidae and Hesperiidae. The two families have many species from the larger forest reserves. However, both forest fragments of Muhaka and Mrima support a good variety of species belonging to the other families, namely Papilionidae, Pieridae and Nymphalidae. Muhaka and Mrima forests recorded 50 and 22% butterfly species found in Arabuko Sokoke and Shimba hills forest reserves, respectively.

Some of the species were recorded only from the forest fragments: For example, species unique to Muhaka forest only and not in the large forest reserves were *Acraea cerasa cerasa* Hewitson and *Celaenorrhinus ovalis* Evans and species recorded only in Mrima

Table 4.2. Published information on the proportion and densities of butterflies from different forests at the Kenya coast

Forest	Species number	Reference	Comments
Muhaka forest interior	48	this study	Species recorded in the interior of the forest
Muhaka forest and surrounding area	70	this study	Includes forest interior, edge and support zone species
Mrima forest interior	46	this study	Species recorded in the interior of the forest
Mrima forest interior and its support zone	67	this study	Includes forest interior, forest edge and the support zone
Shimba Hills forest reserve	304	Larsen (1991), KIFCON (1993)	Not indicated whether the species numbers include the support zone
Arabuko Sokoke forest reserve	134	Larsen (1991) Bagine et al. (1993) Ayumba (1995)	Forest interior species only

forest and not in the other larger forest reserves was *Salamis parhassus parhassus* Drury. It was, however difficult from this study to compare the capacity of different forest fragment sizes to support biodiversity. No endemic species were recorded in these two forest fragments of Muhaka and Mrima forests and endemic species have been recorded in Shimba Hills and Arabuko Sokoke forests.

4.6 CONSERVATION IMPLICATIONS OF THIS STUDY

The two forest fragments of Muhaka and Mrima retain an appreciable amount of butterfly species richness and diversity and a few species not recorded from the larger forest reserves. It was, however, noted that Muhaka and Mrima were not as species rich as the larger forest reserves. The implications of this is that these forests should be protected from outright clearing and actions taken to augment the number of species present, by advocating for restoration of the logged patches, particularly Mrima forest. Both forest fragments had butterfly species normally associated with disturbance (Table 4.3) whose numbers would be expected to be reduced and replaced by proper forest butterflies, should forest restoration of logged areas be effected.

Output

Reports

The establishment of databases and pilot surveys as a basis for the development of an applied arthropod biodiversity programme at ICIPE. *Pre-project report to the Norwegian Government* for the period March 1995–1997.

Developing a biodiversity conservation programme at ICIPE: Pilot surveys, databases and workshop. *Final report to the Norwegian Government, 1995–1997.*

Workshops organised

The Biodiversity Workshop, Nairobi, Kenya (27–29 January, 1997). 24 participants.

Workshop on Global Change Impact Assessment Approaches for Vectors and Vector-Borne Diseases, Nairobi, Kenya (September 3–6, 1997). 40 participants.

Conferences attended

Rogo L. M. The International Conference on the Eastern Arc Mountains: Morogoro, Tanzania. 1–7 December 1997.

Herren H. and Miller S. Biodiversity of terrestrial invertebrates in tropical Africa: Needs and strategies at 'Nature and Human Society: The Quest for a sustainable World', National Academy of Sciences, Washington DC. 27–30 October 1997.

Rogo L. M. Kenya Biodiversity Database Management Workshop. 13–17 May 1996, Amboseli National Park.

Rogo L. M. The Living Planet in Crisis: Biodiversity, Science and Policy. An International Conference by American Museum of Natural History. Centre for Biodiversity and Conservation. New York, 9–10 March 1995.

Rogo L. M. Global Environmental Facility (GEF) Information Workshop. 10 February, 1995. UNEP Headquarters, Gigiri, Nairobi.

Rogo L. M. The ICIPE Biodiversity Plan 'The African Insect Biodiversity Initiative: Acquiring Knowledge for Conservation and Sustainable Development'. *Second East African Biodiversity Forum Workshop.* Nairobi, Kenya. 17–18 November 1997.

Rogo L. M. A Review on Cultural Entomology in Africa. The 16th International Congress of Ethnobiology. Nairobi, Kenya. July 1996.

Project proposals

African Insect Biodiversity Initiative: Acquiring Knowledge for Conservation and Sustainable Development. Submitted to donor agencies including Norwegian government, DFID, Ford Foundation, MacArthur Foundation, SAREC, USAID, among others.

African Forest Insect Biodiversity Initiative: Acquiring Knowledge for Conservation and Sustainable Development. Submitted to INCO-DC (European Commission).

Table 4.3. Butterfly species of disturbed areas in two coastal forests

	Mrima			Muhaka		
Species	interior	edge	open field	interior	edge	open field
Papilio demodocus Esper	5	22	8	-	-	1
Appias epaphia Boisduval	-	-	4	3	-	1
Hypolimnas misippus Linneaus	-	3	-	1	0	1
Junonia oenone Linneaus	4	31	6	-	2	3
Junonia terea Drury	-	-	-	8	-	-
Acraea eponina eponina Cramer	1	1	-	-	1	1
Acraea neobule neobule Doubleday	1	0	0	0	0	2

Environmental Health

COMMERCIAL INSECTS

XVII. Development of Sericulture and Apiculture Technologies for Enhancing the Income Generating Potential of Smallholders and Conserving and Utilising the Natural Resources of Africa (COM-2)

Background, approach and objectives

Adaptation of research and extension services to meet the needs of the rural poor is becoming increasingly relevant, as population growth is creating additional stress on the world's forests and marginal agricultural lands. New research and extension techniques are needed, derived from research and the local peoples' traditional conservation practices to provide protection and better utilisation of the natural resource base.

ICIPE has identified sericulture and apiculture as alternative potential income generating opportunities for African farmers. These activities are agro-based, can be managed by smallholders engaged in subsistence agriculture; and do not require heavy investment and large land holdings. It is envisaged that development of sericulture and apiculture in Africa will lead to rural industrialisation, trade and promotion of cottage industries to alleviate poverty and unemployment and thereby improve the living standards of farmers.

Most sericulture (silkworm rearing) and apiculture (beekeeping) development projects have been unsuccessful in Africa, because the technology developed and applied did not comply with the needs or capabilities of the local farmers.

This unfortunate reality has led ICIPE and the International Fund for Agricultural Development (IFAD) to collaborate on research-based technology development of cost-effective methods for sustainable sericulture and apiculture in Africa. The Commercial Insects Megaproject has successfully developed technology packages in three areas of research: wild silkmoth conservation and utilisation; domesticated silkworm rearing for fibre production; and beekeeping for honey and other hive products. Constraints have been identified and methods devised to overcome them. In addition, a revolving fund has been created to assist farmers to purchase the initial facilities for apiculture and sericulture. The project has involved women's groups as active participants and beneficiaries

The Phase 1 programme objective is to conduct collaborative applied research to identify the technological and socioeconomic opportunities and constraints to sericulture/apiculture-based farming systems in East Africa. The Megaproject has developed easily applicable methods and applied them practically through adaptive research, utilising as far as possible, traditional knowledge and procedures. In addition, the project has undertaken:

- socioeconomic impact assessment, with particular reference to income-generation, resource-use, and nutrition enhancement of subsistence farmers;
- research to determine the marketability of silk- and honey-based products and to identify potential locations in Africa for sericulture- and apiculture-based development initiatives; and
- to establish an insect and plant biodiversity monitoring network based on silkmoth and honeybee distribution, in order to evaluate environmentally sustainable agricultural production techniques in the semi-arid tropics.

Production-oriented strategic apiculture research has sought to:

- identify bee diseases and develop methods for their management in the apiary
- relate behaviour characteristics of bees at different altitudes to their honey gathering ability, aggressiveness and absconding tendencies
- study bee swarming and migration patterns
- introduce Langstroth hives made of local materials and compare the economic benefits and honey yield achieved with traditional hives
- develop a regional floral calendar to relate sources and amount of nectar and pollen to monthly climatic conditions
- select and rear the most fertile queen bees through natural and artificial insemination methods; rear queens for the maximal production of royal jClly and other hive products, and pollination services
- assess honeybee efficiency in pollinating selected food and horticultural plants in the field

- grade honey and process and package beeswax, royal jelly and other hive products for marketing.

In the case of sericulture strategic research, the Megaproject has worked to:

- proactively conserve genetic diversity and protection of wild species of silkmoths in different ecologies
- select bombycid hybrids which produce high quality raw silk
- identify diseases which threaten wild and domesticated silkmoths, and develop disease management practices
- survey the distribution pattern of saturniids and lasiocampids to estimate their effective range
- screen and develop various *Bombyx mori* races for commercial exploitation and income generation.
- link biological inventories with professional and local communities
- establish grainage for selective *Bombyx mori* breeding for the commercial production of silk fibres and silkworm byproducts.

Adaptive research in the context of on-site farmer-participatory technology testing and development is linked with strategic research. It has focused on three key areas:

(i) production and market-oriented interventions dealing with sericulture and apiculture technologies that apply to mulberry cultivation, silkworm cocoon production and beehive establishment. In time, the downstream application of these techniques and the resultant apiculture and sericulture products should offer rural employment opportunities, especially for women;
(ii) consumption-oriented interventions that deal with health, nutritional and socioeconomic aspects of the production-to-consumption continuum; and
(iii) organisation-oriented interventions, which deal with institutional networking and training of end-users through NARS and NGOs.

In Phase II of this project, these technologies will be expanded to more regions in Africa, in collaboration with IFAD's development projects or with other regional projects of UNDP and FAO. This should help create a research base for their future commercialisation.

Training and demonstration of sericulture and apiculture techniques is being achieved through activities to develop training modules to deal with sericulture technologies (cocoon production, silk-reeling and weaving technology) and apiculture technologies (honey processing and beeswax, royal jelly, bee venom and propolis production); these techniques will be taught to networking partners who will instruct sericulturists and apiculturists in their home localities. In-service training will be provided at all levels to NGOs, graduate students, scientists, extension officers, smallscale farmers, women groups, school children, etc.

ARPPIS scholars from African Universities, as well as from the developing nations of Asia and South America will be trained at ICIPE.

Training manuals outlining apiculture and sericulture techniques will be published by ICIPE, that focus on the implementation and progression evaluation of the benefits of these micro-enterprises.

Participating scientists: *S.K. Raina*, V.V Adolkar, E.N. Kioko, Shi Wei (*Project Leader)*

Research assistants: *H.G. Muiru, D.M. Kimbu, H. M. Kahoro*

Technicians: *D. Ogolla, J. Auma, J. Omondi*

Donors: *IFAD and UNDP*

Collaborators: *• Ministries of Agriculture and Livestock in Ghana, Côte d'Ivoire, Uganda, Ethiopia, Benin, Malawi, Tanzania, Burkina Faso, Cameroon, Djibouti, Zambia and Chad • KARI • International Bee Research Association (IBRA), UK • New South Wales, Australia • Chinese Academy of Agricultural Sciences (CAAS), China • (ICRAF) • Central Silk Board (CSB), India • Sericulture Research Institute (SRI), China • Centre of Sericulture and Biological Pest Management Research (CSBR), India • FAO • NGOs*

Work in progress

A. SERICULTURE

1. CONSERVATION AND UTILISATION OF WILD SILKMOTHS

1.1 SURVEY ON WILD SILKMOTH DIVERSITY IN EAST AFRICA

Participants: *E.N. Kioko, S.K. Raina, J.M Mueke, D. M. Kimbu*

This study was conducted to investigate the species diversity of wild silkmoths and their distribution in East Africa. The objective was to evaluate the possibility of establishing wild silk production for income generation for resource-poor farmers. The survey focused only on silk cocoon-forming species in three lepidopteran families: Lasiocampidae, Saturniidae and Thaumetopoeidae. These three were selected for this study because the majority of the wild silkmoths so far utilised in different parts of the world belong to these families.

The survey initially targeted museums and national research institutions holding insects collected from Kenya, Uganda and Tanzania to assess the historical occurrence of the different species of indigenous species of wild silkmoths in East Africa. Field trips were made to various localities and different developmental stages of the wild silkmoths were sampled together with data on their host plants.

A total of 58 species were recorded as occurring within 170 localities in the three countries. Uganda recorded 36 of the species in 68 localities, Kenya 32 species in 73 localities and Tanzania 21 species in 29 localities. The species diversity in the three families also varied, with the family Lasiocampidae recording 33 species in 17 genera; Saturniidae 19 species in 6 genera; and Thaumetopoeidae 6 species in one genus.

These preliminary results have indicated a high diversity of wild silkmoth species in the three countries (Tables 1.1, 1.2, 1.3).This is a good indicator of a high potential for wild silk production in East Africa. Introduction of eco-friendly wild silk farming may curb the current unsustainable utilisation of biological resources, while at the same time encourage the conservation of the wild silkmoth species and their host plants to provide an extra source of income.

1.2 BIOLOGY AND POPULATION TRENDS OF AFRICAN WILD SILKMOTHS, *ARGEMA MIMOSAE* (SATURNIIDAE) AND *GONOMETA* SP. (LASIOCAMPIDAE)

Participants: *E.N. Kioko, S.K. Raina, J.M Mueke, D. M. Kimbu*

The biology and population dynamics of two wild silkmoth species, *Argema mimosae* and *Gonometa* sp. were studied in farmers' fields at Sultan Hamud, Makueni District and Nguni in Mwingi District, Kenya respectively. The data collected showed that these wild silkmoth species have two generations each year. The adult moth emergence synchronised with the sprouting of new leaves from the host plant, and was influenced by the prevailing weather conditions. The moth flight period of the first generation was between March and April and that of the second generation was between September and November. The duration of the different developmental stages of these species is shown in Table 1.4.

Some of the field-collected eggs and cocoons of *A. mimosae* and *Gonometa* sp. yielded hymenopteran and dipteran parasitoids. *Mesocomys pulchriceps* and *Pediobius anastati* were identified from the eggs of both silkmoth species though in varying percentages (Figure 1.1). *Telenomus* sp. and unidentified Encyrtidae were recorded from only *A. mimosae* eggs (Table1.5). No parasitoids were encountered from *A. mimosae* cocoons, but from *Gonometa* sp. cocoons, unidentified Tachinidae (Diptera) together with hymenopterans *Goryphus* sp., *Eurytoma* sp. and *Brachymeria* sp. were recorded.

Methods of enhancing the survival of the wild silkworms in the field are being devised. During the short rains of 1996, 82.9 % mortality of silkworm, *Gonometa* sp. was recorded. The mortality for the same species during the short rains of 1997 was 78.9% and that of *A. mimosae* was 80.6%. Protective measures being evaluated in the field include the use of fine net sleeves. Rearing of *Gonometa* sp. larvae in the net sleeves during the short rains of 1997 reduced the silkworm mortality to 23.9 %.

1.3 CHORION STRUCTURE AND EGG SIZE OF AFRICAN SILKMOTHS, *ARGEMA MIMOSAE* AND *GONOMETA* SP. (LEPIDOPTERA: BOMBYCOIDEA)

Participants: *E.N. Kioko, S.K. Raina, J.M Mueke, D. M. Kimbu*

The eggs of *Argema mimosae* and *Gonometa* sp. were studied under light and electron microscopes.Their

Table 1.1. List of silk cocoon-forming genera recorded in the family Lasiocampidae for three East African countries

Genus	No. of species	Cocoon structure	Species in		
			Kenya	Uganda	Tanzania
Bombycopsis	2	small, compact	2	1	1
Ceratopacha	1	small, compact	1	-	1
Chrysopsyche	1	small, soft	-	1	-
Diapalpus	1	small, soft	-	1	-
Gonometa	7	medium-large, compact	4	4	1
Grammodora	1	medium, soft	1	-	1
Haplopacha	1	small, soft	1	-	1
Leichriolepsis	5	small, soft	1	4	1
Leipoxais	2	medium, soft	1	1	1
Mallocampa	1	small, compact	-	1	-
Mimopacha	1	medium, soft	1	1	1
Pachymeta	1	large, compact	-	1	-
Pachypasa	2	large, soft	1	1	1
Pseudometa	1	small, soft	1	-	-
Streblota	2	small, soft	-	2	-
Taragama	3	small, soft	3	2	2
Trabala	1	small, soft	-	1	-

Table 1.2. List of silk cocoon-forming genera recorded in the families Saturnidae and Thaumetopoeidae for three East African countries

Genus	Family	No. of species	Cocoon structure	Species in Kenya	Uganda	Tanzania
Antistathmoptera	Saturniidae	1	medium, compact	–	–	1
Argema	Saturniidae	2	medium,compact	2	–	–
Epiphora	Saturniidae	11	small, compact	9	6	6
Goodia	Saturniidae	2	small, soft	1	1	–
Holocera	Saturniidae	1	medium, rough	1	1	1
Ludia	Saturniidae	1	small, soft	–	1	–
Anaphe	Thaumetopoeidae	6	huge, compact	2	6	2

Table 1.3. Species diversity of cocoon-forming silkmoth species collected during field surveys in Kenya

Species	Family	Locality	Host plant
Gonometa sp.	Lasiocampidae	Nguni in Mwingi District and Sultan Hamud in Makueni District	*Acacia elatior* *A. senegal*
Gonometa sp.	Lasiocampidae	Kamaguti in Uasin Gishu District	*Acacia hockii* and wattle tree
Ceratopacha sp.	Lasiocampidae	Kamaguti in Uasin Gishu District	Cocoons found on *Carissa edulis*
Epiphora vacuna	Saturniidae	Kakamega forest	–
Anaphe panda	Thaumetopoeidae	Kakamega forest	*Bridelia macrantha*
Lechriolepsis pulchra	Lasiocampidae	Kakamega forest	Unidentified shrubs
Argema mimosae	Saturniidae	Wote and Sultan Hamud in Makueni District	*Sclerocarya birrea*, *Spirostachys venenifera* and *Lannea schweinfurthii*
Philotherma sp.	Lasiocampidae	Sultan Hamud	*Sclerocarrya birrea*

Table 1.4. Duration of the different developmental stages in *Gonometa* sp. and *Argema mimosae* in days (Mean ± SD)

Species	Adults	Eggs	Silkworms	Pupae
Gonometa sp.	6.4 ± 3.2	11.3 ± 0.1	53.5 ± 6.2	95.9 ± 16.5
A. mimosae	7.5 ± 2.1	10.9 ± 0.3	32.9 ± 3.8	78.3 ± 29.5

Table 1.5. Per cent parasitism of *Gonometa* sp. and *Argema mimosae* eggs in the field

Silkmoth species	Parasitoid species: *Mesocomys pulchriceps*	*Pediobius anastati*	*Telenomus* sp.	Unidentified Encyrtidae
Gonometa sp.	37 %	0.4 %	–	–
A. mimosae	23 %	3 %	1 %	0.4 %

sizes and chorionic structure were recorded. The mean length of the major and minor axis of the *A. mimosae* eggs were significantly greater than the *Gonometa* sp. eggs. (Table 1.6).

Morphology of the egg shells as observed under the scanning electron microscope (SEM) showed very interesting patterns characteristic of each species. In *A. mimosae*, the micropyle opening is surrounded by petal-shaped cell prints. In *Gonometa* sp. this region is surrounded by star-like cell prints. The surface of the posterior pole region and the sides of the eggs in both species revealed an assembly of numerous knobs, between which small aeropyles were present. The knobs in *A. mimosae* were large in size and more irregular in shape with most taking a round shape. The knobs on the egg surface of *Gonometa* sp. consisted of a raised portion with a crater-like structure. These egg characteristics are being explored for use as taxonomic tools, in combination with taxonomic characteristics of the other developmental stages.

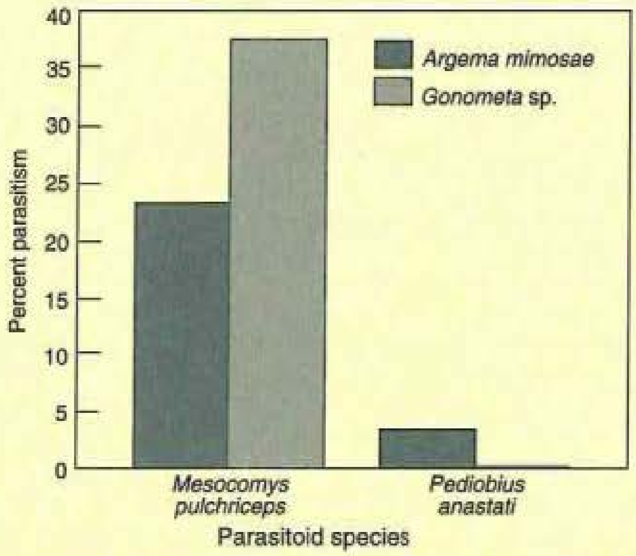


Figure 1. 1. Egg parasitism of wild silkmoth in the field

Table 1.6. Comparison of the mean lengths of eggs for *Argema mimosae* and *Gonometa* sp.

	A. mimosae	*Gonometa* sp.
Major axis (mm)	2.519 ± 0.013 A	2.321 ± 0.007 B
Minor axis (mm)	2.152 ± 0.008 A	2.074 ± 0.008 B

Each value represents mean ±SE. Means followed by the same letter are not significantly different (SNK $P< 0.01$).

1.4 POSTHARVEST CHARACTERISTICS OF *GONOMETA* SP. AND *ARGEMA MIMOSAE* COCOONS

Participants: *E.N. Kioko, S.K. Raina, J.M Mueke*

The maximum yield of raw silk from cocoons is a very important aspect of sericulture. To what extent this aspect is attained depends upon several variable factors, but primarily on the quality of cocoons. This study was conducted to determine some of the commercial qualities of these species of wild silkmoths.

Freshly, field-collected cocoons were used to determine the fresh cocoon weight, size, shell weight, shell ratio percentage and reeling performance. The observations made during this study are quite encouraging as they are in the same range of the other wild silkmoth species being utilised elsewhere in the world for wild silk production (Tables 1.7–1.8).

Table 1.7. Data on weight and size of *Gonometa* sp. and *Argema mimosae* cocoons (Means ± SD)

Species and sex	Cocoon weight (g)	Cocoon length (cm)	Cocoon width (cm)
Gonometa sp.			
Females	8.45 ± 1.47	5.72 ± 0.35	2.39 ± 0.12
Males	3.47 ± 0.53	3.99 ± 0.18	1.72 ± 0.16
A. mimosae			
Females	6.04 ± 0.96	5.4 ± 0.45	2.43 ± 0.29
Males	4.95 ± 1.3	3.92 ± 1.23	2.24 ± 0.96

Table 1.8. Comparison of cocoon weight, shell weight and shell ratio % in *Gonometa* sp.

Sex	Cocoon weight	Cocoon shell weight	Shell ratio %
Females	8.5 ± 1.6	1.8 ± 0.4	21.9 ± 2.2
Males	2.8 ± 1.0	1.2 ± 0.7	35.1 ± 16.9

The *A. mimosae* cocoons are not reelable, but can be spun. *Gonometa* sp. cocoons were easily reeled giving firm golden brown silk fibre. Single cocoon reeling data indicated that 2325 female cocoons compared to 4762 male cocoons are required to make 1 kg of raw silk.

1.5 CONSERVATION OF AFRICAN WILD SILKMOTHS FOR ECONOMIC INCENTIVES TO RURAL COMMUNITIES ADJACENT TO THE KAKAMEGA FOREST IN KENYA

Participants: *E.N. Kioko, S.K. Raina, J.M Mueke*

In Kenya, wild silkmoth habitats and natural ecosystems such as the Kakamega forest have suffered severe encroachment as a result of a growing human population and the demand for agricultural land. About 10–20% of the Kenyan fauna and flora occur only in the Kakamega forest and 75% of all the butterflies of Kenya are found here. Illegal depletion of the forest's resources has demonstrated the need to initiate an economic inducement for the local people to use the forest, while conserving its resources.

This study was designed to survey the diversity of the wild silkmoth species and to study the response of the local community toward utilising the silkmoth resources in the Kakamega forest. Wild silk production is an eco-friendly, agro-based venture with a great potential for environmental amelioration, employment generation, artisans development and export earnings.

Surveys in the forest recorded five species, of which *Anaphe panda* (Boisduval) showed potential, since it has a huge silk-nest that is communally woven by 20–105 silkworms. A ground survey confirmed the availability of the wild silkworm hostplant, *Bridelia micrantha* (Hochst.) Baill in western Kenya. The hostplant is also found in homes adjacent to the forest and 84 % of the questionnaire respondents had the tree in varying numbers on their land. A case study in the East Africa Herbarium on the distribution of *Bridelia micrantha* showed that it is widely distributed in the three East African countries and has already been collected from 103 localities within Kenya, Uganda and Tanzania. A questionnaire distributed to 50 people from two villages, near the forest, Ikuywa and Muhudu, indicated a positive response to the potential of initiating local wild silk production activities as an extra source of income.

2. DEVELOPING A NEW DOMESTIC SILKMOTH HYBRID

After a long search, a new domestic silkmoth hybrid that flourishes in the African environment and produces high quality silk was developed. The hybrid was selected by crossing a number of domestic silkmoth *Bombyx mori* strains and testing their vigour when grown on a variety of mulberry cultivars. The silkworm hybrid cross NB_{18} x NB_7 when grown on the mulberry Kanva 2 cultivar, generated the highest silk yield. Other races which were developed and selected are ICIPE I, ICIPE II, Egyptian and Shanshi. Field tests are being carried out in Nyeri, Kola and Banana in Kenya. In Uganda, Silk Secor Association is using only the Shanshi race and their production has now reached 2–3 tonnes per year. In Kenya, production was initiated in 1997 and reached a mark of 250 kg and is expected to reach 1.5 tonnes by the end of 1998. Tanzania will initiate production in 1998. One kilogram of raw silk was obtained from approximately 5000–6000 green cocoons.

All necessary materials needed to rear domestic silkworms in the rural setting were constructed using local materials and labour.

3. POST-COCOON COTTAGE SILK INDUSTRY BASED ON THE SILKWORM RACES ADAPTED TO AFRICAN ECOLOGIES

3.1 PERFORMANCE OF THE SILKWORM, *BOMBYX MORI* (NB_{18} RACE) DURING LONG RAINS IN NAIROBI, KENYA

Participants: *S.K. Raina, J. Auma, F.K. Kiilu, V.V Adolkar, E.N. Kioko, D. Ogolla, D.M. Kimbu*

Silkmoths, *Bombyx mori* NB_{18} bivoltine hybrids, were reared in Nairobi to evaluate their ability to tolerate the long rainy season. Approximately 10,000 larvae were raised on mixed mulberry varieties (S-41, Thailand and Embu). The total larval duration from 1st to 5th instar was 29 days at 20–24°C temperature and 65–79% relative humidity. The last larval instar stage consumed 1167 kg of leaves and required 11 days. During the experiment, the nuclear polyhedrosis virus problem was managed using a lime powder formulation.

The silkworm NB_{18} performed well, and a pupation rate of 95% was observed. Cocoon yield was 78.82% and about 2560 moths were collected to assess race fertility and fecundity. Out of the cocoons obtained, 5000 were reeled and the average weight of each cocoon was 1.88 g. The average shell weight was 0.369 g and the filament weight was 0.229 g. The average length of a single cocoon filament was 958 m. In the reeling machine, 1 kg of silk was obtained from approximately 6000 cocoons. The silk was cleaned in soapy water and wound in a loose skein; the raw silk was of high quality. Results indicate that *B. mori* NB_{18} race can flourish in a wet climate.

Reeling performance of cocoons obtained from the various *B. mori* and the wild silkmoth races was compared. The reeling and re-reeling units were installed at ICIPE. The cocoons were reeled on bobbins and re-reeled to make skeins, which after the winding, twisting, doubling and bleaching process, were transferred into a warp. (The principle of warping is to construct a sheet of parallel yarns from the bobbins on a roller drum. The drum is fitted at the rear of the powerloom and the handloom. Weaving is the transformation of the yarn into fabric on a powerloom or handloom. The warp runs down the length of the cloth and the weft (shuttle) lies at right to the warp, crossing the fabric selvedge to selvedge.) By fulfilling this objective it is hoped to encourage adoption of textile engineering to cover all aspects of manufacturing from cocoon to fabric for the farmers, to develop an outlet for farmers' raw material.

Out of the four races ICIPE I, ICIPE II, Egyptian and Shanshi, Shanshi proved to be the best and the average fibre length from a single cocoon was 1120 m. However, the least average length of the fibre recovered from an ICIPE II cocoon was 1009 m.

B. APICULTURE

4. DEVELOPMENT OF THE FLORAL CALENDAR FOR MANAGEMENT OF THE AFRICAN HONEY BEE RACES AND FORAGING BEHAVIOUR

Participants: *S. K. Raina, D. M. Kimbu*

Background, approach and objectives

A floral calendar catalogues flower-type, abundance, time and duration of flower bloom. The calendar indicates the season of nectar flow and needs to be produced in ecological regions where beekeeping is practised. The population cycles of *A.mellifera* races in East Africa depend on both altitude and seasonal flowering. In this project, floral calendars were drawn for various regions in East Africa.

In Kenya, in the three geographical locations where the three different honeybee races are found, floral calendars were drawn to establish the flowering season, a period associated with maximal honey flow. This information was used to establish a honey bee management plan.

Work in progress

Bees store surplus honey in a variety of plants and trees and these vegetative stores in East Africa are currently being identified. Trees of the genus *Acacia* and *Eucalyptus* store significant amounts of excess nectar and some species are extremely valuable to bees. In Kitui, Mwingi and Baringo, Kenya and in

Arusha, Tanzania, the *Acacia* genus is the predominant tree. In western Kenya, *Eucalyptus* predominates. In high altitude regions such as Kinangop, *Dombeya burgessiae* is the common tree. In Kampala, Uganda, bananas are a major source of nectar. Tree crops such as coffee, citrus, mango and avocado are widespread in East Africa and produce a large honey yield. Further information is being collected in collaboration with the National Museums of Kenya and the University of Nairobi on the flower species producing nectar and pollen that are important to bees.

In this study, two districts with a high potential for success in apiculture were selected and floral calendars relating the bloom-time of the local flowers were drawn. The two Districts, Mwingi and Kitui, are in the Eastern Province, and at an altitude of 560–1000 m above sea level. In both districts, beekeeping is a traditional major activity. The bloom of the flora depends entirely on the rains. There are two rainy seasons in Kenya. The short rains occur from mid-October to late-December, and the long rains occur from March to May. The nectar-flow period began in mid-October and the honey was harvested in late-December to mid-June, with the exception of February. The peak honey flow from March to mid-June was dependant on the long rains which affect the May–June bloom. Regardless of the amount of rainfall, in late August and early September when riverside *Acacia eliator* flowers, some beekeepers harvest honey.

The nectar flow period is at its peak when the large forest trees, shrubs, climbers, weeds and crops flower. Trees rich in nectar and pollen are: *Acacia* sp. called "Ungu wa nzuki" (Kikamba) and *Terminalia prunioides*, which provide a distinct taste and dark colour to honey. *Acacia nilotica, A. seyal, Entada leptostachya* and millet have a rich pollen supply. Other plants (including weeds) are good nectar and pollen sources. The nectar-flow period is increased when plants do not bloom simultaneously. However, some plants like *Senna didymobotrya* flower all year round. The swarming of bees occurs from mid-September until mid-October, and in mid-February until mid-March. Swarming coincides with the onset of the rainy season.

The honey dearth period usually lasts from mid-June to mid-October, when it is dry and the bee colony population decreases. This is the time when colonies abscond, migrate or die. The exact fate of the bees during this time needs to be elucidated (Table 4.1).

In all these locations, ICIPE has initiated modern beekeeping practices and the land-users have been assigned responsibility of making hives using local timber and employing local carpenters for hive construction.

4.1 FORAGING BEHAVIOUR OF *APIS MELLIFERA SCUTELLATA*

Participants: *B. Nyagode, S.K. Raina*

The honey bee forages for nectar from several thousands of plant species and in the process pollinates a wide variety of crops important for the survival of life.

The rates of secretion and reabsorption of nectar in flowers fluctuate in relation to changing environmental conditions. As a result, the nectar of different plants changes in quantity and composition from hour to hour and from day to day. The pattern of these fluctuations is important as a basis for studies of the foraging strategies of nectar-feeding animals and of the honey value of bee forage plants.

To quantify various elements of bee foraging behaviour, two sampling methods were used to allow standardisation of the observations. The transects method was used to collect the data for sunflower and passion plants and observations were carried out during a standard period of time on the same number of flowers for the mustard plants (fixed sample method). All the readings were taken over a seven-day period (Figure 4.1).

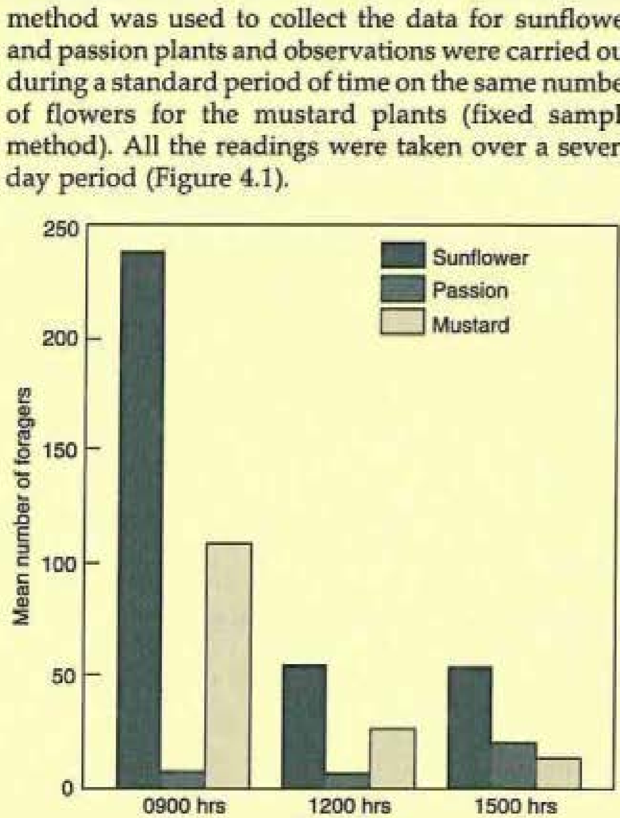


Figure 4.1. Frequency of foraging activity of *Apis mellifera scutellata* over a 7-day period

5. PRELIMINARY STUDIES ON SWARMING AND MIGRATION OF AFRICAN HONEY BEES, *APIS MELLIFERA* IN KENYA

Participants: *S. K. Raina, D. M. Kimbu, H. G Muiru*

At a certain time in the life-cycle of honey bees, a colony produces queen cells and reaches a state that results in colony multiplication. During this period, scout bees (5% of the hive population), search for a new home site. Once this is found, they return and

Table 4.1. Major flowering plants for nectar/pollen in Mwingi and Kitui districts of Kenya

Local name	Scientific name	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
(i) *Acacia*													
Munina	*Acacia elatior*		+	*	*				+	*			
Muaa	*Acacia tortilis*		*	*	+								
Ing'ua	*Acacia seyal*		*	*	*					*			
Muthia	*Acacia mellifera*			*	*								
Muswii	*Acacia horrida*		+	*	*								
Ing'olola	*Acacia etbaica*	+	*	+	+	*							*
Musemei	*Acacia nilotica*		*	*	*	*							*
Mukuswi	*Acacia brevispica*		*	*									
(ii) *Other flowering plants & weeds*													
Mutoo	*Terminalia prunioides*		*	*	*								
Mwaitha	*Entada leptostachya*		*	*		*							
Ungu wa nzuki	?	*	*	*	*							+	*
Iswe (Itulu)	*Cissus rotundifolia*	*		*	*								*
Lendema	?		*	*	*								
Mwinza nguuwe	*Triumfetta tomentosa*	*	*	*	*	*	+					+	*
Nengya	?	*	*	*	*	*						+	*
Mukengesya	?	*	*	*	*	*						+	*
Windia	?	*	*	*	*	*						+	*
Mulawa	*Bauhinia tomentosa*	*	*		*	+							
Ututi	*Thunbergia holstii*	*	*	*	*	+						+	*
Musangala	?	*	*	*	*	*						+	*
Mukokola	*Combretum exalatum*	+	*		*	*							
Musai	*Barleria taitensis*	*	*	*	*	*							*
Muvu	*Zanthoxylum usambarense*		*	+		*							
Inyunganai	*Senna didymobotrya*	*	*	*	*	*	*					+	*
Inyali	?	*	*	+	*							+	*
Mukakaa	*Premna resinosa*			*	*								
Ikuu	*Juniperus procera*		*	*									
Mutiliku	?			*	+								
Lundi	?	*	*	*	+								
Muvolya	?			+	*								
Itangua	?			+	*								
Mukau	*Melia volkensii*		*	*					+	*			
Kirui	*Maerua crasifolia*		*	*							*		
Weeds		*	*	*	*							*	*
(iii) *Major food crops grown in the area*													
Millet		*			*								+
Sorghum		*			*								+
Greengrams		*			*								+
Cowpeas		*			*								+
Maize		*			*								+

* Flowering throughout the month.
\+ Flowering early or late in the month.

perform the wagtail dance on the hive surface to alert the bees that it is time to depart the parent hive or swarm.

In the Mwingi District of Kenya, honeybees swarm in response to the onset of the rainy period and the onset of the dry season. Swarming was observed during October and November at the beginning of the short rains and in February and March, at the beginning of long rains. In these periods, the swarms approached the Mwingi and Kitui areas from the Mount Kenya direction (Figure 5.1). The swarms arose by a division of the adult bee population which was followed by the subsequent migration of a portion of the initial population. Bee migration was followed by a honey-flow period which lasted until May. This was followed by a dearth period that lasted 5–6 months.

Swarming in the absence of adult population division (absconding) was observed in mid-July to mid-September. This process of absconding occurred during the dearth period in Mwingi when there was a shortage of bee flora in the area. Swarming, migration and absconding practices in various areas in East Africa need further study. The reasons for swarm

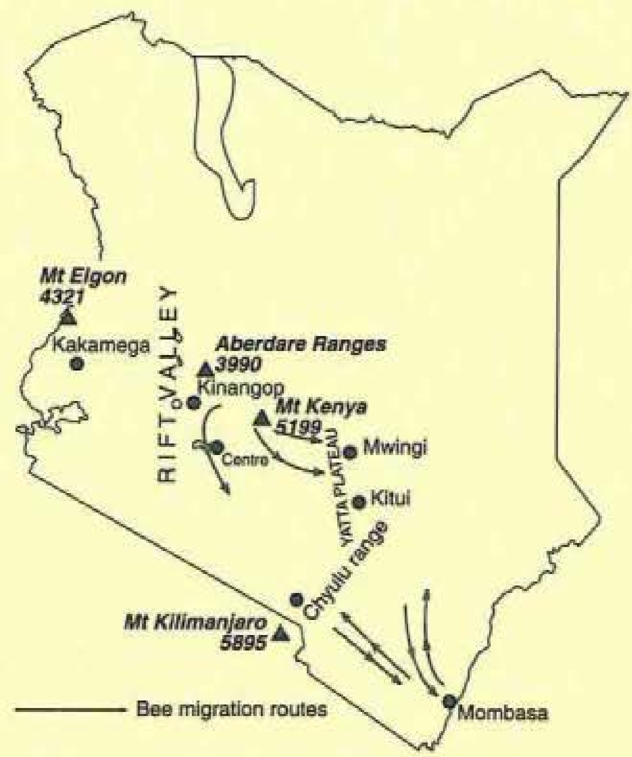


Figure 5.1. Bee migration routes in Kenya

movement from the Kinangop Mountain to Naivasha; Embu to Mount Kenya; Mount Elgon to Homa Bay; Mount Meru to Aru Meru in Tanzania; and from Tigrai Mountains to the lowlands in Ethiopia, need to be elucidated.

6. VARIATIONS IN RACES OF THE HONEY BEE, *APIS MELLIFERA* IN KENYA

Participants: *S. K. Raina, D. M. Kimbu, H. Herren*

There exist three races of the honey bee, *Apis mellifera* in Kenya: *A.m.scutellata, A.m.monticola* and *A.m. litorea,* which differ from each other with respect to size and abdominal colour banding pattern. These differences were used to assess whether interbreeding between the races had occurred. This may be due to interactions among these races, during swarming and migration which may have resulted in hybridisation. This was verified on the basis of selected morphometric traits.

Bees were sampled from seven different geographical locations throughout Kenya, on the basis of altitude ranging from the lowland (Mombasa-coastal region) to the highland (Kinangop ranges). The length and width of right forewings, length of proboscis, right antenna, and right hindlegs were measured and the cubital index was computed for each specimen. The bees were classified according to size and colour banding pattern. Analysis of the data was done using SAS. The results indicated there was a hybridisation between various races of *A. mellifera* in Kenya.

Six morphological parameters (Table 6.1) were measured using a binocular microscope equipped with an ocular micrometer (10 mm x scale):

Table 6.1. Mean values standard error and F ratio of six morphological parameters of *Apis mellifera* races in seven regions of Kenya

Localities (altitude (m))	WL	WW	CI (Ratio I/II)	PL	LL	ANTL
Mombasa	47.513 d	15.350 d	2.439 ab	28.068 c	58.050 d	21.309 cd
75	0.134	0.060	0.078	0.512	0.188	0.100
Mwingi	47.884 d	15.438 d	2.335 b	30.584 b	57.675 de	21.266 cd
650	0.174	0.077	0.079	0.171	0.300	0.125
Kitui	48.000 d	15.859 c	1.941 d	31.416 a	56.963 f	21.490 c
850	0.125	0.056	0.066	0.170	0.240	0.123
Kimana	50.741 a	16.694 a	2.269 bc	32.100 a	60.197 b	22.894 a
1250	0.135	0.063	0.048	0.294	0.220	0.106
Kakamega	51.041 a	16.272 b	2.078 cd	32.213 a	61.056 a	22.988 a
1680	0.198	0.071	0.044	0.268	0.267	0.120
Central	48.853 c	16.063 c	2.558 a	30.175 b	57.391 ef	21.047 d
1950	0.159	0.061	0.068	0.129	0.261	0.056
Kinangop	49.919 b	15.931 c	2.244 bc	31.931 a	58.619 c	21.894 b
3200	0.171	0.114	0.055	0.136	0.145	0.124
F ratio	46.44	21.91	6.89	19.61	31.13	26.40

NB: Means with the same letter are not significantly different.
WL=wing length; WW=wing width, CI=cubital index, PL=proboscis length; LL=length of 3rd leg, ANTL=antennal length

(1) Length of wing (WL): Distance between the two most distal points of the wing.
(2) Width of wing (WW): Transverse length of the wing, measured on the widest portion of the wing at a right angle with WL.
(3) Cubital index (CI): The ratio of the length of cubital veins I & II of the forewing (I/II).
(4) Length of the proboscis (PL): The proboscis was stretched, and measured from the glossa to the end of the post-mentum along its posterior face.
(5) Length of third leg (LL): The sum of the lengths of the femur, tibia tarsus and metatarsus.
(6) Length of antenna (ANTL): The length from base to the tip end.

6.1 STUDY OF MITOCHONDRIAL DNA VARIABILITY IN *APIS MELLIFERA* RACES OF KENYA

Participants: *W. Shi, Y. Guiyun, S. K. Raina*

Subspecies-specific mtDNA variability has been found and repeatedly used to analyse the biogeography of honey bees. In this study, special attention has been given to the length variability within *Atpase6/COIII, Cytochrome b, ND2, COI/COII* and ND1/ND4 coding region, which were sequenced by several authors; the major Kenya honey bee subspecies can be classified by length variability.

Eight different subspecies have been described for Africa south of the Sahara, but there are as yet no specific mtDNA markers that classify individual subspecies. Some claims on subspecies-specific variability are based on a very small sample size or only using one primer to allow for the establishment of race typical markers.

Our study within *Atpase6/COIII, Cytochrome b, ND2, COI/COII* and ND1/ND4 coding region of mtDNA of Kenyan honey bees hopes to establish typical markers to identify the honey bee races in Kenya. We intend to analyse nuclear DNA variations of microsatellite loci to allow precise assessment of the number of patrilines and genetic relations in honey bee colonies in Kenya.

Honey bee polyandry allows the genetic specialisation of workers toward particular tastes. Assessing the exact genetic structure of a colony, i.e. the genetic relationships between all its members, is a critical step in understanding the social biology of honey bees and breeding improved colonies. By using microsatellites, we should be able to identify the subfamilies (patrilines) and the genetic diversity present in a Kenya honey bee colony and also provide a good estimate of the genetic diversity of the local honey bee population.

7. BREEDING OF HONEY BEE QUEENS USING *A.M. SCUTELLATA*

Participants: *W. Shi, H. G. Muiru, S. K. Raina*

Rearing queens is an important part of beekeeping. Beekeepers rear queens to requeen existing colonies, to make new colonies, and to improve the genetic quality of their bees. The importance of queens to the colony and various methods for queen rearing have been widely described using western bee races, but very little research work has been done using African bee races.

From May 1996, queen rearing methods have been tested at ICIPE, where the following topics have been investigated:
(i) preparation of colonies for starting and finishing queen cells;
(ii) the grafting and subsequent handling of queen cells;
(iii) composition of nuclei for successful mating of queens;
(iv) external factors that influence queen rearing success;
(v) most favourable season for rearing queens in Kenya.

A major breakthrough in beekeeping was achieved by developing and improving queen-rearing techniques. Queens were artificially inseminated with specific drones to select desirable behavioural traits in the offspring. Ideally, this technology may resolve the behavioural defects of African honey bees (such as aggressiveness and absconding) and may lead to the development of a better breed of bees for honey production and pollination services.

The rearing of queen bees coincides with the onset of the rainy season in East Africa. Young queens of good origin and character were produced and new colonies were formed. Queens were reared in queen-less and queen-right colonies. The latter method proved to be more advantageous. The results indicated that the peak reception of queen cells was achieved during May to July in both queen-less and queen-right colonies. A comparative performance of egg-laying rate of queens of various races is currently being assessed (Figures 7.1 and 7.2). The chemical characterisation of the queen bee pheromones of three races will be initiated in the next phase in collaboration with other workers. A queen package for farmers is available at ICIPE.

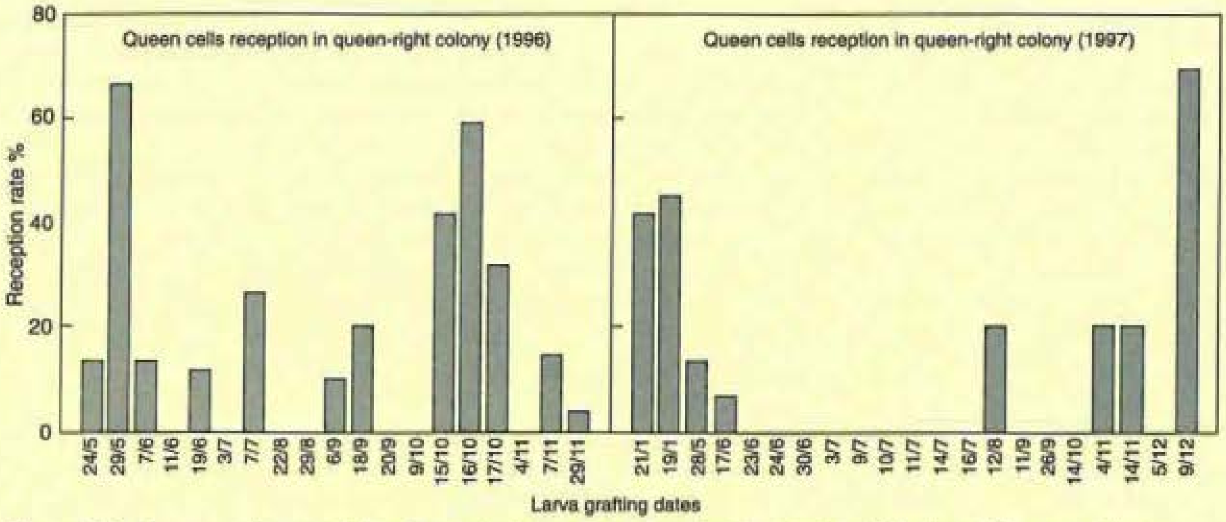


Figure 7.1. Queen cells reception by worker bees in queen-right colonies of *Apis mellifera scutellata*

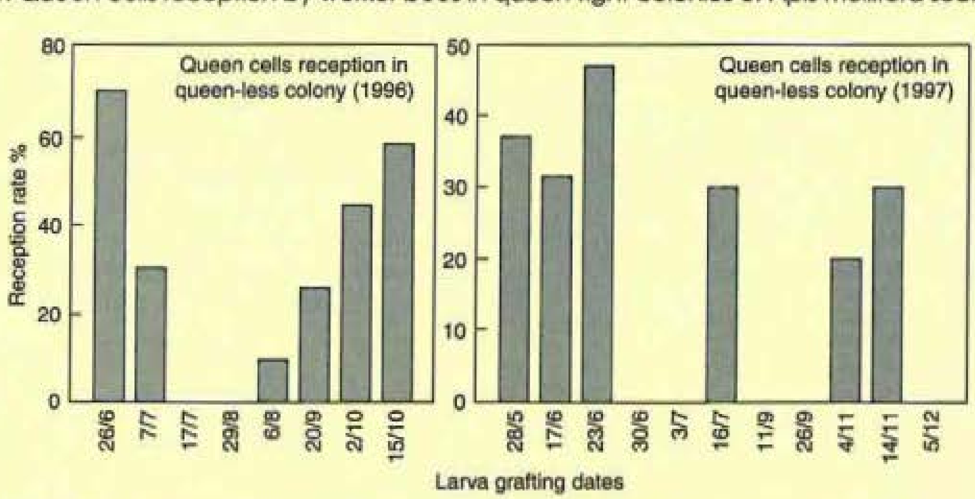


Figure 7.2. Queen cells reception by worker bees in queen-less colonies of *Apis mellifera scutellata*

8. DEVELOPMENT OF BEE HIVE PRODUCTS FOR INCOME GENERATION

Participants: *S.K. Raina, H. Kahoro, H. G. Muiru, D. M. Kimbu, S. Njuguna*

8.1 ROYAL JELLY

Royal jelly is the food fed to the queen larvae in queen cells. It is composed of 'bee milk' from the hypopharyngeal and mandibular glands of the workers, and sugar regurgitated by the nurse bees. It is high in pantothenic acid, biopterin and neopterin. It also contains different proportions of the products of the two glands. Fresh royal jelly has been used for centuries for its remarkable health-giving and rejuvenating properties. The price of 1 kg of royal jelly on the world market is US$ 70–100.

In Phase I of the project, royal jelly production of two different honey bee races, *A.m. scutellata* and *A.m. monticolla*, were compared. The preliminary results indicate that *A.m. monticolla* produces more royal jelly than *A.m. scutellata*. Additional experiments are underway to improve the method of royal jelly production. This will help beekeepers in Africa increase their income by augmenting the returns of bee-related products.

8.2 BEE VENOM

Bee venom is produced in the bee's venom gland and is stored in the venom sac. In European *Apis mellifera* races, venom secretion begins just prior to, or at the time of emergence of the adult worker. The rate of venom production is at its maximum at approximately 12 days and potency is lost when the worker is approximately 20 days old. About 0.3 mg of venom is produced per bee. If secreted, old bees cannot renew their venom store, and in very old bees, the venom may turn dark and solidify and become unusable.

The active ingredients in bee venom are apamine, melithin, approximately 10 phospholipase and hyaluronidase enzymes, and the two sulphur-rich amino acids, methionine and cystine. In humans, bee venom stimulates the heart and cortico-adrenal glands. It induces cortisone production, which makes it suitable for the treatment of rheumatic diseases, especially arthritis.

In Phase I of the Megaproject, a simple technique to collect bee venom was designed. An electrically charged grid plate (2.5 x 2.5 cm) covered on top with synthetic nylon material was used. A glass plate was fitted underneath the grid and a wooden box filled with bees was placed over the electric grid and the bees stimulated to sting with an electric current.

An experiment was designed to evaluate the milking capacity of *A. mellifera scutellata*. Approximately 620 bees were released in the box and a current of 6µA was applied for 5 min. A yield of 7.2 mg of bee venom was obtained. The bees were fed with a saturated sugar solution and milked again after 2 h. A yield of 2.0 mg of bee venom was obtained. The bees were milked a third time and a yield of 2.1 mg was achieved. Following the third milking, the bees were returned to the hive. The dried bee venom was scraped from the glass plate and the underside of the nylon sheet with a razor blade. In total, 81.2 mg of bee venom was collected from 6000 worker bees (Figure 8.1). Further research is currently underway to evaluate the abilities of other *A. mellifera* races in Africa to produce bee venom. In China, 1 g of venom sells for US $100.00. This simple method of extracting venom from bees will provide an additional source of income to African beekeepers.

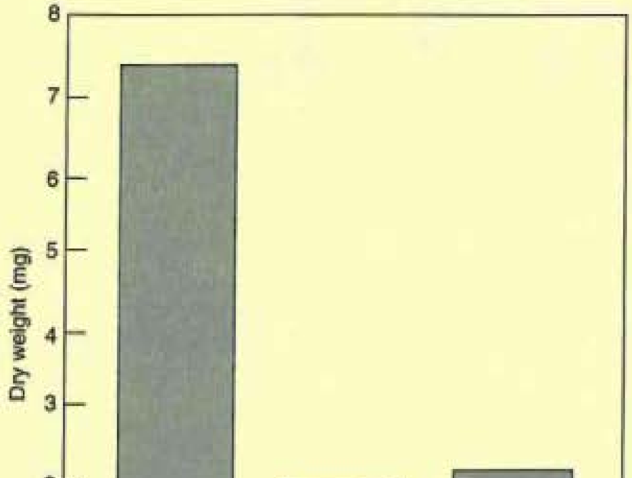


Figure 8.1. Milking capacity of *Apis mellifera scutellata* for bee venom production

9. HONEY ANALYSIS FOR QUALITY CONTROL AND MARKETING

Participants: *B. Nyagode, S.K. Raina, R. Waruiru, D.M. Kimbu*

What is sold as 'honey' should not contain any additives. The honey trade has, however, encountered a succession of problems related to adulteration and/or bad handling of honey. Routine chemical analysis of all honey samples provides diagnostic indicators that detect the adulteration or mistreatment of honey and also makes it possible to differentiate honey from different sources.

Honey imported for table consumption has to conform to national and EU honey legislation. In addition, individual buyers often have their own requirements. Major importers and packers in the Federal Republic of Germany, USA, UK and Japan usually pay special attention to the following points when buying imported honey:

Component	Content
Moisture	21 %
Hydroxymethylfurfural (HMF)	40 mg/kg
Diastase	8 Schade units
Fructose + glucose	60 %
Sucrose	5 %
Ash	0.6–1 %

At the Commercial Insects Quality Control Lab determination of the HMF levels is done by either of two different methods: spectrophotometer or HPLC. Determination of sugars is done by HPLC.

Summary of the preliminary results so far obtained are depicted in Figures 9.1 and 9.2.

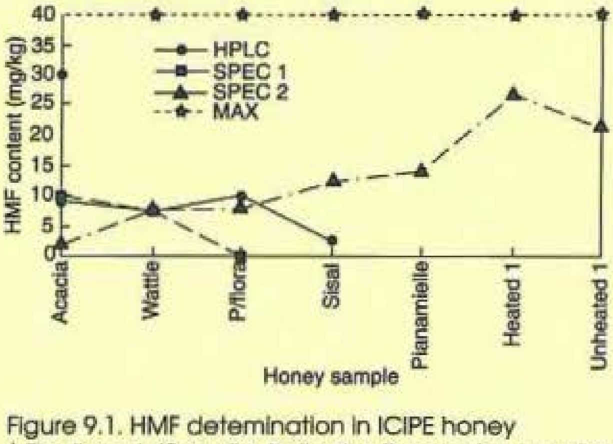


Figure 9.1. HMF detemination in ICIPE honey
+ The line at 40 mg/kg indicates the maximum value of HMF acceptable in a table honey sample.

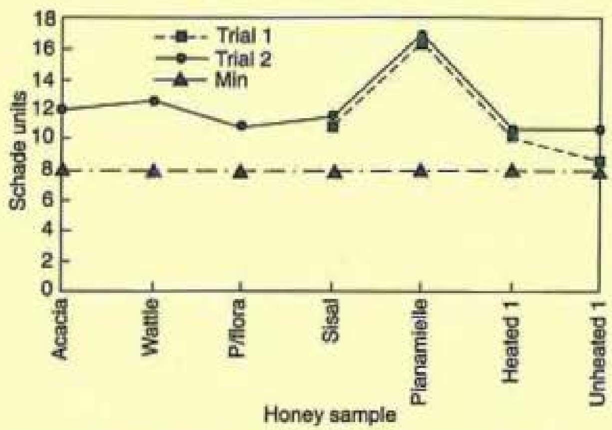


Figure 9.2. Diastase determination in ICIPE honey
+The line at 8 Schade units represents the minimum diastase activity allowed in any table honey sample.

10. REGIONAL NETWORKING

Kenya

Several field sites have been established in both sericulture and apiculture areas in the country. Three sites have been developed for domesticated silkworm farming and two for wild silk utilisation and conservation to revive the sericulture industry. In addition, sericulture officials from the Ministry of Agriculture were trained together with NGOs and farmers on sericulture activities. There are four fully established apiaries in different areas in Kenya where ICIPE staff carry out training and demonstration to beekeepers on modern technology in beekeeping. At least 25 NGOs have been trained in beekeeping.

Uganda

Introduction of the Langstroth hives in Hoima and Kibale by ICIPE has resulted in the invitation of beekeepers and farmers' groups to visit ICIPE for a one-day training programme especially designed for them. The IFAD Coordinator, Simon Mugaya of Hoima, and Mrs Teddy from the DEC, Kibale District are assisting in this regard. The postharvest technology for silkworm cocoons is being established at NARO with the assistance of the Commissioner of Entomology and Mr Muller of the Sericulture Development Project of EU. The improvement of beekeeping, harvesting and marketing of Ugandan honey has been developed in collaboration with Mr Clive Drew, Coordinator of IDEA (USAID) project and Mr Ramsey, the President of the Honey Beekeeping Association. However, the unreliability in their production capacity is the major constraint in establishing of fixed market outlets for them.

Tanzania

ICIPE has initiated apiculture/sericulture farming in collaboration with the Arumeru Beekeepers Society (ABESO) in Arusha, Tanzania. This is an association of four main groups; Sakila, Maji ya Chai, Mutengano and Lake Tatu. About 50 Langstroth hives were distributed to these groups and ICIPE has set 2.7 ha of mulberry plantation at ABESO for silkworm farming. The first cocoon production is expected in August 1998, after completion of the model farmhouse.

Ethiopia

ICIPE has initiated a mulberry plantation in 6 ha in the BioVillage area. The government has allocated 20 ha of land for sericulture and apiculture operation where a model rearing house is being constructed. Langstroth hives (100) were distributed among the farmers groups in Gurage, Bales Valley, Tigrai and Sodo area. The report on honey production is awaited.

Eritrea

The RAM farm in Tigrai has modern hives developed by a private beekeeper. ICIPE has demonstrated the queen rearing techniques to the local beekeepers who were trained in colony multiplication.

Zambia

ICIPE has developed a project proposal to IFAD for the development project (Development of the Zambia Forest Project) in three Districts of Solwezi, Kasempa and Mwinilunga of the Northwestern Province. The main traditional honey-producing figures given do not tally with the actual production of honey in Zambia. We are developing ways and means to obtain the actual production figures to connect beekeepers with the market.

Zimbambwe

Honey Processor (Pvt) Ltd., owned by Mr C.J. Coleman, a private beekeeper in Mazowe, is collaborating with ICIPE in pollination ecology.

Output

Publications

Kioko E. N., Raina S. K. and Mueke J. M. Conservation of the wild silkmoths for economic incentives to rural communities of the Kakamega forest in Kenya. *International Journal of Wild Silkmoth & Silk* Vol.2. (In press).

Kioko E.N., Raina S.K. and Mueke J. M. Chorion structure and egg size of the African silkmoth, *Argema mimosae* and *Gonometa* sp. (Lepidoptera: Bombycoidea in Kenya. *Kenyattta University Science Journal*. (In press).

Conferences

1. Participated in IFAD Expo.
2. Various lectures were delivered by the project head and staff in China, USA, African countries, Australia, Germany, etc.
3. Visited Uganda and Zambia to develop project in beekeeping and sericulture.
4. First International Workshop on Commercial Insects held on 18 to 21 August, 1997.

Capacity building

The capacity of indigenous smallscale open market sectors developed.

Short term training for farmers, NGOs, Government officials.

Farmers' training courses held on-site.

Long term training in sericulture and apiculture.

On-farm trials and testing of apiculture and sericulture technologies are currently being conducted in Uganda, Tanzania, Kenya, Ethiopia and Eritrea. About 3500 farmers, individuals from NGOs and governmental agencies received training at ICIPE and at their respective field sites to learn commercial insects utilisation techniques. ICIPE will act as an intermediary between the farmer and trader to assist the beekeepers and silkworm rearers in the marketing of commercial insect products. Thus, through IFAD's support, the farmers will benefit economically through the use of procedures designed at ICIPE to conserve and protect a fragile and eroding environment.

Local traders, tool makers, school children trained in sericulture and apiculture practices.

PhD students

Esther Kioko. Biodiversity of wild silkmoths (Lepidoptera) and their potential for silk production in East Africa. Kenyatta University, Kenya. PhD research in progress.

Shi Wei. Breeding and genetic selection of the African honeybees *Apis mellifera* and *scutellata*. Swedish Univ. of Agric. Sciences. PhD research in progress.

Betty Nyagode. Identification of the attractants of the brown ear tick, *Rhipicephalus appendiculatus* found in cow washes. Egerton Univ., Kenya. Phd Research in progress.

Donna Dakuou. Haemocytic response in the desert locust *Schistocerca gregaria* (Forskal) (Orthoptera Acrididae) infected by the protozoa *Malamoeba locustae* (King and Taylor) (Protozoa: Amoebidae). Abidjan Univ., Ghana. PhD awarded, 1995.

Ahmed Salih. Transovarial transmission and reproductive parameters in the desert locust, *Schistocerca gregaria* (Orthoptera: Acrididae) infected with protozoan, *Malamoeba locustae*. University of Khartoum, Sudan. PhD research in progress.

Kenneth Kambona. Physiological aspects and biocontrol of *Beauveria bassiana* (Deuteromycetes: Fungi Imperfecti) on the desert locust, *Schistocerca gregaria* (Orthoptera: Acrididae). Moi University, Kenya PhD awarded in 1996.

Eucharia Kenya. Mechanisms for selective toxicity of newly isolated strains of *Bacillus thuringiensis* (*Bt*) (Berliner). Rivers State Univ. of Science and Technology Nigeria. PhD awarded, 1995.

Project proposals submitted and funding

IFAD: Commercial Insects Phase I Jan. 1996– Dec. 1998 1.3 million.

IFAD: Commercial insects Phase II Jan. 1999–Dec. 2001 2.2 million.

FAO: TCP grant for 12 African countries (in the pipeline) Jan. 1999–2003.

IFAD: Regional project for N. Africa 1999–2001 US$ 800000.

UNDP: Farmers Trickle-Up Programme US$ 60,000 (distributed).

Impact

Economic impact

It is expected that about 400 farmers/beekeepers will be selected for participation in beekeeping trials and validation efforts to increase the number of modern beehives by the year 2000; each beekeeper will keep a minimum of 5 hives in each country. This will increase the yield of honey by 50 metric tonnes (at the medium average of 25 kg per hive/year). The beeswax production is averaged at 1 kg per 60 kg of honey and an increase of 1000 kg is expected. With the growing interest among the farmers and beekeepers generated by proper training at ICIPE, an increase in the gross national product is expected in subsequent years. Thus beekeeping will prove to be a multiple source of income for rural population and subsistence farmers, without competing with agriculture, because it does not require heavy investment or large land holdings and is well suited for women and children.

In sericulture, about 200 farm families will be selected for participation in the first year of the trial from each country. An area of 200 hectares is expected to come under mulberry cultivation. It is expected to have a green cocoon production of about 108 tonnes which will generate approximately 12 tonnes of raw silk. The value of the silk at the rate of US$ 35 will be US$ 420,000 which gives each farmer an additional income of US$ 2100 per year. The expenditure incurred by farmers for fertiliser and other costs should not exceed more than 30%. This gives a net benefit to each farmer of US$ 1470 per annum.

Honey has great medicinal and health value. The wax has commercial and industrial value, especially in the cosmetic and candle industries. Sale of colonies by queen rearing is another source of income. Production of other hive products such as royal jelly, bee venom, propolis and pollen are in high demand by pharmaceutical companies and can further increase the sources of income. The bee-brood has a very high protein value and can be used in the pickle industry or as a fish feed. During nectar and pollen gathering, the honey bees effect pollination and improve the quality and quantity of crop produce. This benefit is derived by a community rather than only by the beekeeper.

Similarly, silk farming has many benefits, such as in the silk cloth itself, mulberry leaves as animal feed; the pupae after reeling can be used as fish or chicken feed. The pupal oil can also be extracted for making soap or cosmetics and the mulberry fruits for making jam. The silkworm faeces are a good source of Vitamin B_2.

Promotion of cottage industries in Africa

Apiculture/sericulture will be undertaken as a rural family venture without significantly interfering with normal farming activities. They will provide an additional source of protein food, while simultaneously introducing rural industrialisation and trade, by creating a demand for locally manufactured equipment. Both apiculture and sericulture can therefore be used in the development of appropriate industrial technologies in the rural sector and the creation of off-farm rural employment. Moreover, they can ensure the long-term preservation of honey bees and silkmoth species in Africa, while providing economic benefits to the local communities. Because of the wide agroecological zones in which the mulberry and other wild host plants thrive, both apiculture and sericulture have potential as income-generating activities for the semi-arid regions.

Environmental impact

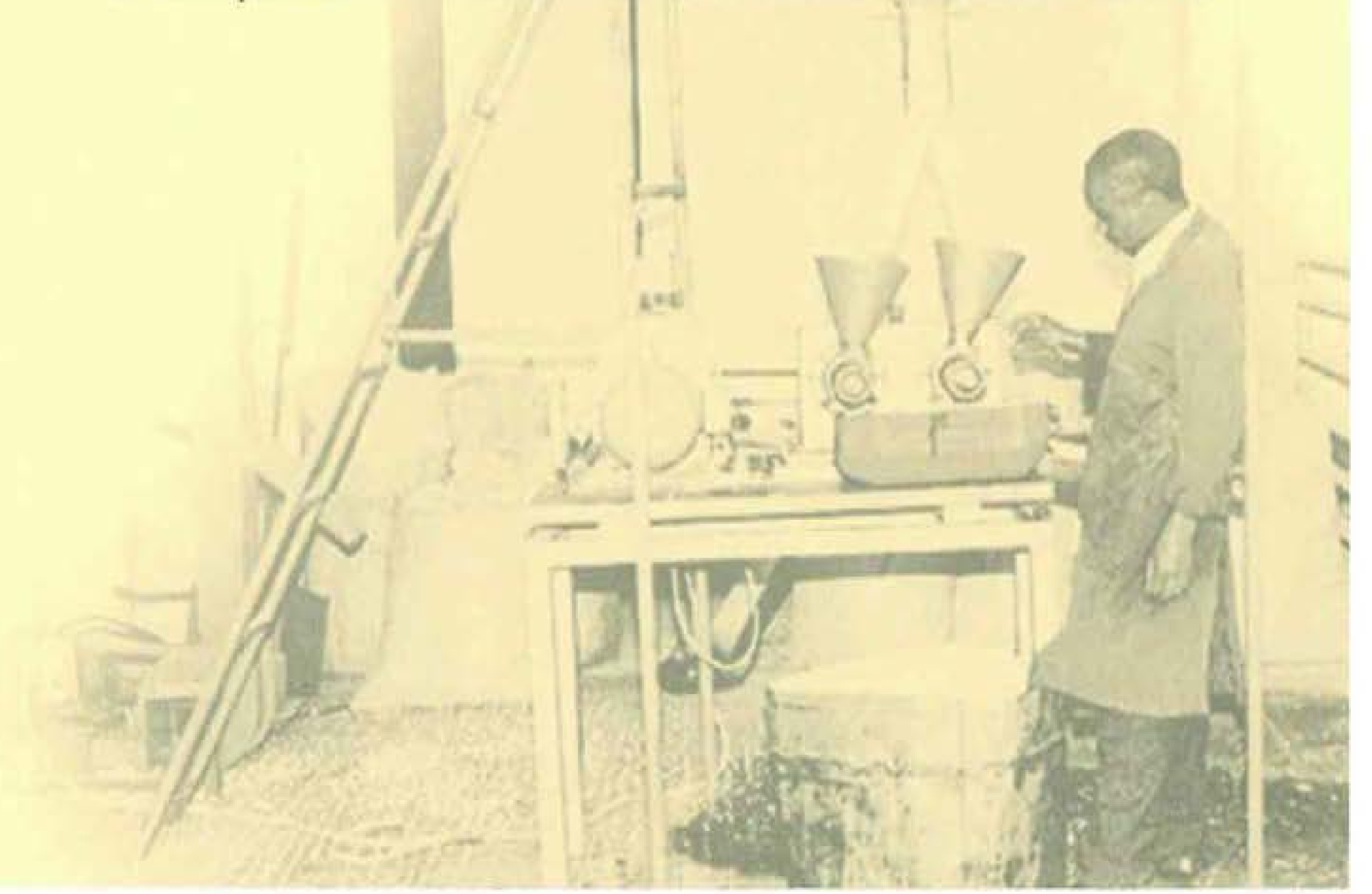
The project trials will be conducted among all networking partners in Africa. This will not only provide food and income, but will also enhance the productivity of horticultural and other field crops by honey bee pollinating activities; this will ultimately strengthen Africa's national food security systems. This will advance understanding of ecosystem composition, structure and function, which provides baseline data for environmental monitoring. This knowledge can then be used to link basic and applied apiculture and sericulture research and sustainable land use and development, for the conservation of forest biological diversity in Africa.

ICIPE's strategic role in South-South cooperation

The need for developing countries to rely on their own resources and efforts to revitalise development applies not only at the national level, but at the South-South level. There is also a clear need to reduce the costly dependence on institutions in the North. By expanding the flow of finance, trade, technology and skills within the South, for instance through stronger links which take advantage of complementary assets, South-South cooperation can fortify the development of all countries. ICIPE has set up a specialised, research-cum-training programme on honey bees and silkmoths to offer able scientists from developing countries in Africa and Asia, the opportunity to work in the South for the South.

CONTENTS

Directorate of International Cooperation and Capacity Building



I. Directorate of International Cooperation and Capacity Building

Background, approach and objectives

The mission of the Directorate of International Cooperation and Capacity Building (DIC-CB) is to contribute to the attainment of the International Centre of Insect Physiology and Ecology's (ICIPE's) goals through competent and innovative development and management of stakeholders' relations, resource mobilisation and capacity building programmes. This mission is guided by four major considerations:

- ICIPE's competitive advantage in arthropod science and its application;
- The comparative strength of our national and international partners;
- The changing needs of our clientele;
- Global trends in research funding and attendant competitive pressures in resource mobilisation.

The Directorate is divided into three departments dealing with:

(i) Regional and Global Cooperation (including fund-raising);
(ii) Project Development and Donor Liaison; and
(iii) Capacity Building.

1. REGIONAL AND GLOBAL COOPERATION

Participants: *R. A. Odingo (1995, 1996) Head of International Cooperation, M. T. Futa (Head, 1997), J. R. Kapkirwok, L. W. Gacheru*

1.1 MEMORANDA OF UNDERSTANDING

The Memorandum of Understanding or Agreement (MoU/A) is the main formal instrument that ICIPE uses to define and provide the framework of cooperation with partners. ICIPE currently has such formal agreements with more than 80 institutions worldwide, in addition to many informal collaborative arrangements with other institutions worldwide. Since the beginning of 1997, the following memoranda of understanding/agreements have been signed or are being negotiated:

1. The Kenyan Medical Research Institute (KEMRI)—*on malaria vectors research and capacity building (signed).*
2. The Ethiopian states of Oromia and Tigrai, and the Ethiopian Science and Technology Commission (ESTC)—*on tsetse control, capacity building and insect-related income generating activities (signed).*
3. Asian Vegetable Research and Development Council (AVRDC)—*on pest management in vegetables (signed).*
4. Research Cooperation Technologies, a US-based firm—*on disclosure, evaluation and commercialisation of technologies (signed).*
5. SAROC LTD, a Kenyan-based agro-chemical firm—*on the processing and marketing of neem products (signed).*
6. Universities of Zimbabwe, Malawi, Zambia, Ghana and Assiut in Egypt, and International Centre for Research in Agroforestry (ICRAF)—*on capacity building through ARPPIS (signed).*
7. Chinese Academy of Agricultural Sciences (CAAS)—*on pest management research and capacity building (signed).*
8. International Centre for Scientific Culture, World Laboratory—*on the establishment of a World Laboratory Centre in Insect Science Research and Training (signed).*
9. Kenya Wildlife Services (KWS), Ministry of Environment and Natural Resources of Kenya (MENR) and Kenya National Environment Secretariat (KNES)—*on bioprospecting (being negotiated).*
10. World Health Organisation/FAO/UNEP/UNCHS—*on the designation of ICIPE as one of Collaborating Centres for Environmental Management for Vector Control (being negotiated).*
11. Government Plant Protection Division in Tanzania (Zanzibar), *Uganda, Ethiopia, Eritrea, Malawi, Zimbabwe, Somalia and Mozambique—on control agents. This will be done as part of the implementation of the activities of Phase two of the project 'Biological Control of Cereal Stem Borers...' funded by the Netherlands Government (being negotiated).*
12. Indian Council for Agricultural Research (ICAR)—*on arthropod-related agricultural research, development and training especially in plant protection (being negotiated).*

13. CIAT—*on the management of whiteflies within the framework of the Inter CG Centre IPM (System-wide) Initiative (being negotiated).*
14. Papua New Guinea—*on arthropod-related research and plant protection (being negotiated).*
15. The Flemish Organisation for International Cooperation (VVOB)—*on secondment of personnel to ICIPE (being negotiated).*
16. ORSTOM—*on collaboration in pest and vector research, development in Kenya (being negotiated).*
17. Honey Care International—*on Apiculture/Sericulture development in Kenya (being negotiated)*
18. Institute for Agricultural Research (IAR), Ethiopia—*on classical biological control of stemborers (being negotiated).*

UNESCO and FAO are processing the upgrading of their relationship with ICIPE to consultative status, or category 'A' which is the highest status. We are awaiting a formal communication on ICIPE's new status with UNESCO and FAO.

Plans are also underway to initiate formal collaborative agreements with institutions in Latin America. During a visit to Mexico by the ICIPE Director General and the Deputy Director General, several institutions linked to the Ministry of Agriculture (plant and animal health divisions), expressed interest in collaborating with ICIPE. Among areas of possible collaboration include improved management of fruit flies, coffee berry borer, ticks, locusts and honey bees.

1.2 INTER-CENTRE (SYSTEM-WIDE) IPM INITIATIVE

ICIPE and AVRDC are partners in the Inter-CG Centre IPM (System-wide) Initiative. Among the first eight themes identified for eco-regional IPM initiatives ICIPE's Director General is leading a task force on functional agro-biodiversity and IPM. A planning workshop convened by ICIPE in October 1996 was later followed by a meeting of the Steering Committee in June 1997 in Nairobi, with the objective of developing a project for submission to the IPM-Working Group based at IITA. Because of the number of groups involved and the interactive nature of the process, proposal development has proceeded rather slowly.

Under the system-wide white fly IPM, ICIPE has signed an agreement with CIAT in which ICIPE, with funding from DANIDA, will co-ordinate a sub-theme on white fly problems in vegetable-based cropping systems in eastern and southern Africa. Other system-wide IPM initiatives where ICIPE will be involved include: Systemwide IPM on cereal stemborers (led by CIMMYT); systemwide IPM theme on legume pests (led by ICRISAT); and Systemwide IPM theme on agroforestry systems (led by ICRAF).

As unrestricted core funding has become more and more difficult to obtain, we increasingly see cooperation in research and training as a tool for leveraging additional funding. In this regard, ICIPE will continue to be guided by strategic considerations in its international cooperation policy.

1.3 STRATEGY FOR FUND-RAISING

ICIPE has developed a strategy for fund raising which is intended to mobilise resources for its approved 5-Year Plan. Currently, the gap between what is available and what is needed for operations is about $6 million. The primary focus of this strategy is to bridge this gap. The main elements of the strategy are the following:

(i) enlargement of the group of core donors of ICIPE;
(ii) increasing the portfolios of restricted project funding through proposals that are better conceived and written, and which are relevant to the needs of the intended beneficiaries;
(iii) developing a sensitive systems for identifying project ideas that are in vogue with donors and better mechanisms for tracking project proposals that are submitted to donors;
(iv) developing closer links with national agricultural research and extension systems as a means of accessing bilateral funds;
(v) exploring the possibility of generating income through direct investment, or through commercialisation arrangements for ICIPE's R&D products.

This strategy is currently being tested through a variety of means, including sensitisation missions to potential donor countries. So far, 10 countries have been visited in western, eastern and southern Africa. At least seven of these countries (Senegal, Côté d'Ivoire, Burkina Faso, Mali, Malawi, Swaziland and Uganda) have accepted in principle to make core contribution to ICIPE, but find the proposed level of their contribution too high given their current financial difficulties. ICIPE is renegotiating the issue with them.

2. PROJECT DEVELOPMENT AND DONOR LIAISON

2.1 THE BIOVILLAGE INITIATIVE

Our research and training activities in Ethiopia continue to expand following the signing of research cooperation agreements with the Ethiopian states of Oromia and Tigrai, and the Ethiopian Science and Technology Commission (ESTC). The agreements have greatly facilitated the joint implementation of the planned tsetse 'control' campaign by ICIPE, ESTC and IAEA in the Southern Rift Valley region of Ethiopia. The campaign initially focused on tsetse control through trapping, supplemented by a new technique called 'lethal insect technique' (LIT). Further consultations with the community and the regional governments led to the conclusion that a holistic and integrated rural development approach was required. Consequently, the Biovillage Initiative was conceived.

The Biovillage Initiative is a holistic way of looking at the issues of food security, health and environment in Africa. It is designed to strengthen community participation in identifying and addressing integrated rural development problems. A model BioVillage will consist of traditional, but insect-proof, tukuls (rural dwellings). The Initiative has received enthusiastic community and government support. The Austrian Development Cooperation has demonstrated support by funding a component of the initiative, i.e, tsetse control, through lethal insect technique in addressing these vital and inter-linked issues simultaneously. The BioVillage may finally provide the long-sought, but so far elusive, model for sustainable development, including assurance of food security in Africa.

The Austrian Development Cooperation (ADC) has assumed a leading role in supporting the BioVillage Initiative.

2.2 THE AFRICAN FRUIT FLY INITIATIVE

ICIPE has put together a concept paper—the *African Fruit Fly Initiative*—which aims at promoting quality fruit growing in East Africa through control of the fruit fly, *Ceratitis capitata*. The final complete proposal is ready and has been submitted to a consortium of donors for funding.

The African Fruit Fly Initiative has attracted interest and support among community groups in Kenya and in Africa in general even the Ministry of Agriculture of Kenya. In this regard an agreement is being prepared between OAU/STRC and ICIPE for the implementation of the proposal. In addition, 14 institutions from America and Europe have indicated support and interest to collaborate in the Initiative. IFAD funded the initial preparatory work with US$ 100,000, and FAO have accepted to help organise the donors meeting to be held later in September in Rome under the auspices of IFAD.

2.3 THE ICIPE TECHNOPARK INITIATIVE

The Directorate of International Cooperation and Capacity Building is involved in the planning for the establishment of a pioneer science park—the *ICIPE Technopark*—to be based in Nairobi which should bring a number of benefits to scientists, industrialists and local people throughout Africa. The conceptual framework for such a park had been developed and discussed with a cross-section of potential partners in industry, government, universities and the donor community. The key ministries of Research and Science, Industry, as well as the Treasury of the host government, Kenya, including universities have also expressed intention to participate in the Technopark. In a recent seminar organised jointly by the Export Processing Zones Authority of Kenya and ICIPE, there was unanimous support for the establishment of the Technopark.

The Technopark is envisaged to be developed gradually within a period of 10 years. It will initially develop ICIPE products, but will also encourage other interested parties. Among ICIPE products considered good candidates for the Technopark include organic pesticides such as Dudustop® from *Bacillus thuringiensis*; bioactive limonoid products from the neem tree; fungi-based biopesticides; the NZI trap; plant-based insect repellents, especially from *Ocimum* spp., honeybee and silkworm-products, vaccines and diagnostic kits.

The ICIPE Charter empowers the organisation to undertake investments as long as the returns are ploughed back into R&D activities.

The report on capacity building follows.

See the following report (II) for Capacity Building.

II. Capacity Building

Capacity building is one of the most active programmes of ICIPE, through which substantial achievements have been made in the past two decades. The programme aims to enhance the capabilities of developing countries in the tropics and subtopics, particularly in Africa, for research and training in insect science to promote the development and utilisation of sustainable arthropod management technologies. Apart from providing a mechanism by which ICIPE disseminates its research findings to the consumers, the programme makes a major contribution to ICIPE's research through the activities of postgraduate students and postdoctoral scientists training at the Centre. In financial terms, the programme constitutes more than 30% of ICIPE's annual budget. The thrust of ICIPE's capacity building strategy is directed toward three major areas of activity:

- training of African nationals for leadership in insect science and to enhance interactive technology generation and adaptation;
- enhancement of national capacities for technology diffusion, adoption and utilisation; and
- facilitation of dissemination and exchange of information.

Participants: *V. O. Musewe (Head of Capacity Building), V. K. Manene (1995, 1996), R. Runo (1995)*

Donors: *Netherlands Ministry of Foreign Affairs, German Academic Exchange Service (DAAD), GTZ Horticulture Project, IFAD, Rockefeller Foundation, ICRAF, Gatsby Charitable Trust, European Union, FAO/TDR*

Collaborators: *• ARPPIS participating universities—Pretoria, Ibadan, Malawi, Moi, Assiut, Zimbabwe, Nnamdi Azikiwe, Khartoum, Enugu State, Ghana, Kenyatta, Rivers State, Ogun State, Alemaya, Addis Ababa, Nairobi, Cape Coast, Gezira, Zambia, Egerton • Association of African Universities (AAU) • Third World Academy of Sciences (TWAS) • International Agricultural Research Centres—ICRAF, ILRI, IITA • National research organisations in African countries signatory to ICIPE Charter • Universities in developed countries—Pennsylvania, Michigan State, Swedish University of Agricultural Sciences, Newcastle-upon-Tyne, Kiel, Hannover, Constance, Zena • Kenya Polytechnic • Institutes of technology*

A. POSTGRADUATE TRAINING PROGRAMMES

1. THE AFRICAN REGIONAL POSTGRADUATE PROGRAMME IN INSECT SCIENCE (ARPPIS)

The African Regional Postgraduate Programme in Insect Science (ARPPIS) celebrated its thirteenth anniversary in 1997, having been launched as a collaborative training programme in 1983. The prime objective of the programme is to train arthropod scientists and pest management specialists in Africa. As at 31 December 1997, 18 selected African universities were collaborating with the ICIPE in ARPPIS, many of them having registered ARPPIS scholars in their PhD training programmes.

ARPPIS releases between seven and ten PhD graduates to the national research and educational systems every year; the graduates continue to expand the network of ARPPIS-trained arthropod scientists. This network of ARPPIS graduates promotes South-South cooperation among research organisations and universities throughout the continent.

The ARPPIS PhD programme is based at ICIPE, where students undergo three years of research training. The ICIPE provides a thesis project, research facilities and supervision, and a training fellowship, to support students' maintenance, university fees and research costs. The full ARPPIS scholarship amounts to US$ 30,000 per student per year. The students are registered at any of the Participating Universities, whose responsibility it is to provide additional research supervision and ensure the research meets international academic standards, and to examine the students and award them with degrees.

Each PhD class is composed of an average of seven students. The programme has, at any time, between 20 and 40 students at various stages of their theses work at ICIPE. A total of 131 scholars have been enrolled in the programme (Table 1.1). The major

Table 1.1. Country distribution of postgraduate students enrolled in ARPPIS PhD Programme (1983–1997 Classes)

Country	# Students	Country	# Students
Benin	1	Namibia	1
Burkina Faso	1	Nigeria	13
Cameroon	1	Rwanda	2
Chad	2	Senegal	2
D.R. Congo	4	Sierra Leone	3
Egypt	3	Somalia	2
Ethiopia	9	South Africa	1
Ghana	3	Sudan	15
Kenya	40	Tanzania	7
Malagasy	1	Uganda	10
Malawi	2	Zambia	5
Mali	1	Zimbabwe	1
Mozambique	1		
Total enrollment (1983–1997)			131+

+The total includes 11 students whose training programmes were discontinued for academic reasons or natural causes.

activities of the ARPPIS PhD programme between 1995 and 1997 are reported.

1.1 THE PHD TRAINING PROGRAMME

1.1.1 *ARPPIS students awarded PhD degrees at registering universities*

A total of 26 ARPPIS doctoral students were awarded degrees by their registering universities during the period. This brings the total number of PhDs graduated through the programme to 91 since 1983 when the programme started. Table 1.2 shows the particulars of the students graduated from 1995 to 1997.

1.1.2 *Scholars completing their doctoral programmes and submitting theses*

Twenty-nine scholars of the 1992–1994 classes formally completed their 3-year training programmes during the period, under sponsorship by various donors (Table 1.3); the 1994 class having formally concluded training on 28 February 1997. All the candidates required extension of their training fellowships for various durations, ranging from a few months to one year. Most of the scholars of the 1994 class completed their studies, submitted draft theses, and left ICIPE within 1997.

1.1.3 *Fifteen new students joined ARPPIS in 1995–1997*

Fifteen students from various African countries enrolled in the ARPPIS doctoral programme and were trained during the review period. Ten of these students belong to the 1995 and 1996 classes which made excellent progress on their research projects. The other five students joined the programme at various times of 1997; their joining times were staggered to coincide with availability of funded projects for their theses research. Each newly admitted student immediately embarked on the development of a research proposal with the help of a prospective supervisor, and in consultation with a supervisor from the preferred registering university. The biodata of the new scholars admitted in 1997 are given in Table 1.4, while the more detailed training information on all the students is given in Table 1.5.

1.1.4 *Collaboration with participating universities*

The programme continued to receive support from participating universities, both in research coaching and general programme management. A total of 15 visits by students to their registering universities were made to enable them present seminars and interact with faculty members. In the same period, 23 visits to ICIPE were undertaken by university professors to supervise their students. A revised memorandum of understanding for universities collaborating with ICIPE was signed by 18 universities by the end of 1997. The revised list of ARPPIS participating universities is shown in Table 1.6. The ARPPIS Academic Board, which is constituted of members of ICIPE's ARPPIS Secretariat and representatives of participating universities, met at the University of Ghana, Legon, Accra on 9–10 December 1997.

1.2 THE ARPPIS MASTERS PROGRAMME

The ARPPIS Sub-Regional Masters Programme received a major boost when the Academic Board resolved last December to rekindle the establishment of a fourth Sub-Regional Centre to cater for French-speaking African countries. This idea had been shelved in 1995 when it was decided to allow time for those centres already operating to mature and register some success. A host university for the Fourth Centre has yet to be identified in consultation with relevant universities.

Excellent progress has been made by the three operating ARPPIS Sub-Regional Masters Centres. The Centre for Southern Africa based at the University of Zimbabwe is the oldest of the three, having admitted its first class in 1992 and continues to admit every alternate year. The third class of four students started in March 1997; to date, the Centre has admitted 15 students. The Centre for West Africa, hosted by the University of Ghana at Legon admitted its first class in 1994 and continues to admit every year. The 1997/98 class of seven students joined the programme in September 1997; to date, the Centre has admitted 28 Masters students.

The Centre for Eastern and North-Eastern Africa, hosted by Addis Ababa University, admitted its first class in September 1997, but classes could not start until February 1998. Five students were admitted but only four from Ethiopia, Sudan, Uganda and Tanzania were granted scholarships. The Centre will be admitting students annually. Training scholarships for the Masters Centres are secured jointly by ICIPE and the host Universities, but some students are self-sponsored. ICIPE also assists the Centres with departmental support in the form of training equipment and sponsorship to ARPPIS Academic Board meetings.

2. DISSERTATION RESEARCH INTERNSHIP PROGRAMME (DRIP)

The Dissertation Research Internship Programme (DRIP) continued to provide training opportunities outside of the ARPPIS programme, for students from any part of the world. Through this programme, postgraduate students at PhD or MSc levels who are registered at any accredited university in the world and have completed the course work requirements of the registering universities, are enrolled for thesis research at the ICIPE. The students receive scholarship support (personal expenses and university fees) from their sponsors, while ICIPE provides them with a research project, facilities and research supervision up to thesis preparation. Depending on the sponsor and nature of project, ICIPE may not charge training fees under this programme. Also, where the thesis project is part of ICIPE's ongoing research activities, all research costs are met by ICIPE.

A unique feature of this programme is its flexibility with respect to subject matter of student projects; the programme caters for social science students who would otherwise not fit in the ARPPIS programme, so long as their studies have some relevance to ICIPE's research objectives. Also, the programme is gaining popularity as a base for research training in tropical arthropod science for students enrolled at universities in the developed countries.

Training under DRIP, which picked up dramatically in 1996 with nine students enrolled on the programme, continued to show promise as a viable complement to the ARPPIS programme. In 1997, eleven new students were enrolled, with four of them receiving partial scholarships from ICIPE in addition to research project financing. In the past three years, a total of fifteen Masters and nine doctoral students have been enrolled on the programme (Table 2.1).

B. PROFESSIONAL DEVELOPMENT PROGRAMMES

Three professional development schemes enable ICIPE to attract both young and established scientists and professors from developing and developed countries to contribute to ICIPE's research. These include the postdoctoral fellowship programme, the visiting scientist scheme and the research associateship scheme. Table 3.1 shows the list of beneficiaries during the period 1995–1997.

3. POSTDOCTORAL FELLOWSHIP PROGRAMME

Postdoctoral fellows are fresh doctoral graduates normally employed as regular staff of specific research projects. It is a practice of ICIPE to retain a modest number of senior scientists as core staff and provide them with adequate support from young and enthusiastic scientists. The numbers of postdoctoral fellows in service at any time is determined by the availability of research projects that require their services. The past two years (1996/97) were lean years for ICIPE in terms of funded research projects. The Centre had only four postdoctoral scientists among the research staff.

4. VISITING SCIENTISTS SCHEME

Seven visiting scientists worked at ICIPE (Table 4.1) for various durations during the period. Professor Shigemi Yagi continued his studies on the intra- and inter-specific signals modulating behavioural and phase changes in locusts, and the ecological conditions inducing such transformations. He is also pursuing studies to identify new uses of commercial insects and insect pests such as locusts and grasshoppers as human food, to increase their value for rural communities in Africa. Professor Yagi is from the Japan International Agricultural Research Centre (JIRCAS). He was attached to the Behavioural Biology and Chemical Ecology Department, and collaborated with Professor Hassanali. Dr Satoshi Hiroyoshi, from the Institute of Life Sciences, Nagoya Women's University, was attached to the Behavioural Biology and Chemical Ecology Department, where she collaborated with Professors Hassanali and Yagi on studies on the system of sperm supply in grasshoppers. Dr Hiroyoshi's visit was supported by the Japan Society for the Promotion of Science (JSPS). Dr Peter G. Markham from the John Innes Centre, UK, was at ICIPE for a brief period in November 1997, during which time he conducted a workshop on DNA techniques from 24–28 November 1997.

4.1 RESEARCH ASSOCIATESHIP SCHEME

The Centre was unable to host visiting research associates under the Third World Academy of Sciences (TWAS) associateship scheme due to financial constraints. Also, the Centre could not accommodate any associates under the John Pringle Scheme of the Royal Society. However, two research associates, Drs Arop Leek Deng and Yousif O.H. Assad, both Sudanese, worked at ICIPE in the early part of 1997. They were ARPPIS graduates retained in their host departments and assigned to complete additional studies related to their PhD research projects.

C. NON-DEGREE TRAINING PROGRAMMES

5. SHORT COURSES FOR SPECIALISTS

5.1. RESEARCH METHODOLOGY COURSES FOR NARS SCIENTISTS

In collaboration with the John Innes Centre, UK, a workshop on DNA Techniques was conducted at ICIPE from 24–28 November 1997. The course was coordinated by Dr Peter Markham and sponsored by the Rockefeller Foundation and the ISAAA AfriCentre. Participants included five scientists from ICIPE and six from Kenya Agricultural Research Institute (KARI). Resource persons included Ellie Osir, Mohamed Ali Bob, Stephen Obuya and James Kabii, all of ICIPE and Gina Banks and Darren Martin of the John Innes Centre.

5.2 TRAINING OF PEST/VECTOR MANAGEMENT PRACTITIONERS

Two national training courses on tsetse biology, trapping techniques and management of banana pests were conducted for Somali and Kenya nationals, respectively. A total of 31 participants were trained through these courses. One international and two national group training courses were held at ICIPE in 1997. An international course on tsetse management and control was held at Duduville and Kenya Coast from 1–30 November 1997. The course was the second to be conducted under the auspices of the European Union Tsetse Project. Twelve participants from Kenya, Ethiopia and Uganda were trained. Resource persons from ICIPE were assisted by a scientist from CIRDES, Burkina Faso.

6. CONSUMER AWARENESS TRAINING

ICIPE ensures that the intended end-users of technology are made aware of plans and results of research and development projects so as to enlist their participation. Community involvement is secured through formal awareness courses, demonstrations and open days. More than 4000 farmers have benefited from pest management technology extension activities of the Centre. In 1997, awareness training was offered to farmers in the areas of commercial insect production, neem as a natural pesticide and general IPM technologies. A course on the validation and dissemination of IPM technologies for banana weevil was offered to 60 farmers of Nyarongi Division of Homa Bay District, Kenya, on 8th December 1997. The ICIPE/DANIDA neem project offered several courses to extension workers from various parts of Africa, while the ICIPE/IFAD commercial insects project trained farmers on cottage level bee keeping and silk production.

Details of these activities are covered under the relevant project reports.

Table 6.1 gives a summary of workshops, practitioner training courses and farmers training seminars undertaken from 1995 to 1997, in which 381 NARS scientists and technologists from 28 developing and a few developed countries, and more than 1500 farmers from eastern African countries participated. To date, ICIPE has trained a total of 925 insect pest and vector management practitioners and scientists from developing and developed countries and thousands of farmers.

7. FIELD ATTACHMENT FOR TECHNICAL AND UNDERGRADUATE STUDENTS

The ICIPE provided practical laboratory training to 21 university undergraduates from Africa and abroad, and 85 trainees from technical training colleges and government ministries. Field attachment trainees are admitted on a competitive basis and at no fee, for a minimum duration of three months. Each trainee works on a well designed training programme developed by an assigned supervisor. Performance evaluation is undertaken jointly by the supervisor and an evaluator from the sponsoring institution. Between 1995 and 1997 a total of 229 university and polytechnic students were given practical laboratory/field training under this programme (Table 7.1).

Table 1.2. List of ARPPIS PhD recipients during the period 1995–1997

Name	Sex	Nationality	Class	Title of thesis	Registering university	Date of examination/ award
Dr B. J. Adgeh	M	Ethiopian	1991	Effects and use of some *Ocimum* plant species and their essential oils on some storage insect pests	University of Nairobi, Kenya	November 1995
Dr E. U. Kenya	F	Nigerian	1990	The mode of action of some isolates of *Bacillus thuringiensis*	Rivers State University, Nigeria	June 1995
Dr S. G. Mwangi	M	Kenyan	1991	Inheritance and linkage studies using isoenzymes and morphological characters in arid-resistant cowpea cultivars	University of Nairobi, Kenya	December 1995
Dr S. W. Kimani	F	Kenyan	1991	Morphological and biochemical systematics of the *Cotesia* parasitoid complex (Hym. Braconidae)	University of Nairobi, Kenya	November 1995
Dr Y.O.H. Assad	M	Sudanese	1992	The role of host plants in maturation of the desert locust *Schistocerca gregaria* (Forskal) (Orthoptera: Acrididae)	University of Gezira, Sudan	October 1995
Dr A. L. Deng	M	Sudanese	1992	Studies on the factors that influence phase dynamics of the desert locust *Schistocerca gregaria*	University of Khartoum, Sudan	October 1995
Dr M. A. Mohammed	M	Sudanese	1991	Interaction between *Bacillus thuringiensis* (Berliner) enhancing agents and sorghum genotypes for control of the spotted stemborer, *Chilo partellus*	University of Gezira, Sudan	October 1995
Dr G. Tikubet	M	Ethiopian	1985	Tsetse ecology and trypanosomiasis challenge in southern Ethiopia	University of Sierra Leone	October 1996
Dr H. Oranga	M	Kenyan	1988	Modelling productivity of indigenous zebu cattle (*Bos indicus*) under the natural field conditions on Rusinga Island, Kenya	Moi University, Kenya	November 1996
Dr B. A. Rapuoda	F	Kenyan	1988	Ecological and behavioural studies of mosquitoes in Mwea Tebere Irrigation Scheme, Kirinyaga District, Kenya with special reference to *Anopheles arabiensis* (Diptera: Culicidae)	Kenyatta University, Kenya	October 1996
Dr K. Kambona	M	Kenyan	1990	Biocontrol potential of the fungus *Beauveria bassiana* (Balsamo) against the desert locust, *Schistocerca gregaria* (Forskal)	Moi University, Kenya	November 1996
Dr D. O. Ogoyi	M	Kenyan	1990	Changes in lipophorin structure and function during phase transition in *Schistocerca gregaria* (Forskal) (Orthoptera: Acrididae)	University of Nairobi, Kenya	November 1996
Dr S. I. Kamara	M	Sierra Leonian	1991	Effect of host semiochemicals on the behaviour of *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae)	University of Sierra Leone	April 1996

Continued next page

Table 1.2 .Continued

Name	Sex	Nationality	Class	Title of thesis	Registering university	Date of examination/ award
Dr S. Bengaly	M	Malian	1992	Studies on cellular and humoral immune responses of *Amblyomma variegatum* and *Rhipicephalus appendiculatus* to infection by pathogens and parasitoids	University of Ghana, Accra	June 1996
Dr M. Nabasirye	F	Ugandan	1992	Statistical inferences on pest resistance indices: Implications for selection in crop plants	Makerere University, Uganda	September 1996
Dr J. J. Randriamanoro	M	Madag-ascan	1993	Behavioural and physiological responses of the maize stalkborer *Busseola fusca* Fuller (Lepidoptera: Noctuidae) to selected cultivated and wild host plants	Rivers State University of Science & Technology, Nigeria	July 1996
Dr H. A. F. Mohammed	M	Egyptian	1992	Comparison of two isolated populations of the desert locust *Schistocerca gregaria gregaria* Forskal and *Schistocerca gregaria flaviventris* Burmeister with particular reference to pheromone communication system (Orthoptera: Acrididae)	Ain Shams University, Egypt	December 1996
Dr F. Masaninga	M	Zambian	1992	Adaptation of *Trypanosoma congolese* types to different hosts and transmission by *Glossina* species	University of Zambia, Lusaka	October 1997
Dr A. Ngi-Song	F	Camer-oonian	1992	Chemical ecology of host finding behaviour in *Cotesia flavipes* (Cameron) and *Cotesia sesamiae* (Cameron)	University of Ghana, Accra	March 1997
Dr T. T. Epidi	M	Nigerian	1992	Mechanisims of resistance in selected sorghum genotypes to the spotted stemborer, *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae)	Rivers State University, Nigeria	March 1997
Dr K. Dossa	M	Beninois	1990	Studies on acquisition of tick resistance against *Amblyomma variegatum* in cattle and on the effects of parasitism (trypanosomiasis and babesiosis) on tick resistance	University of Ghana, Accra	March 1997
Dr C.J. Mutinda	M	Kenyan	1992	Genetic variability and responses to selection for *Chilo partellus* (Swinhoe) resistance in a maize (*Zea mays* L.) population	University of Nairobi, Kenya	December 1997
Dr E.O. Omolo	M	Kenyan	1992	Cloning and sequence analysis of the genes that encase the delta endotoxin of novel *Bacillus thuringiensis* strains, effective against tsetse flies (*Glossina morsitans morsitans*) and armyworms (*Spodoptera exempta*)	University of Nairobi, Kenya	December 1997
Dr E.K. Kinyua	M	Kenyan	1992	Effect of host blood and its digestive products on trypanosome differentiation in tsetse fly *Glossina morsitans*	University of Nairobi, Kenya	December 1997
Dr A.I. Tawfic	M	Egyptian	1992	Interaction between pheromones and hormones in phase dynamics of the desert locust *Schistocerca gregaria* (Forskal)	Assiut University, Egypt	January 1997
Dr S.F. Kutua	M	Congolese	1991	Behavioral responses of *Rhipicephalus appendiculatus* Neuman 1901 to host and non-host semiochemicals	Kenyatta University, Kenya	November 1997 (posthumous)

Table 1.3. Training information on the ARPPIS PhD scholars who completed the PhD programme in 1995, 1996 and 1997

Name & country	Sponsor	Thesis research title	Host dept/ supervisors	University supervisors	Registering university
Mr J. M. Mwesigwa (Ugandan, 1992–95)	BMZ	Interaction effects of banana weevil *Cosmopolites sordidus* Germar and nematodes in bananas	Dr K.V. S. Reddy Dr A. Odulaja	Dr M. Ogenga-Latigo	Makerere University, Uganda
Mr J. A. Sumani (Zambian, 1992–95)	DSO	Biology of the banana weevil on rhizomes or different banana varieties and types and also mechanisims of resistance	Dr K.V. S. Reddy Prof. A. Hassanali Dr I. Ndiege	Dr K.J. Mbata	University of Zambia, Lusaka
Mr C.J.H. Mutinda (Kenyan, 1992–95)	UNDP/ DAAD	Genetic variability and responses to selection for *Chilo partellus* (Swinhoe) resistance in a maize (*Zea mays* L.) population	Prof. K.N. Saxena Dr A. Odulaja	Dr S.O. Ajala	University of Nairobi, Kenya
Mr H. Tekie (Ethiopian, 1992–95)	DSO	Biological effects of neem seed derivatives on the management of maize stalk borer *Busseola fusca* (Fuller) in pest management	Dr R.C. Saxena Prof. K.N. Saxena	Dr A. Gebre-Amlak	University of Addis Ababa, Ethiopia
Mr S. Bengaly (Malian, 1992–95)	DSO	Cellular and humoral immune responses of the tropical bont-legged tick *Amblyomma variegatum* F. and brown ear tick *Rhipicephalus appendiculatus* (Ixodidae: Acari) to pathogens	Dr G.P. Kaaya Dr S. Essuman	Prof. R.J. Agbede	Ahmadu Bello University, Nigeria
Mr F. Masaninga (Zambian, 1992–95)	EU	Adaptation of *Trypanosoma congolese* types to different hosts and transmission by *Glossina* species	Dr S. Mihok Dr L.H. Otieno	Dr K.J. Mbata	University of Zambia, Lusaka
Mr I. S.T. Jalloh (S/Leonean, 1992–95)	DAAD	Pheromone and plant odour perception in *Busseola fusca*	Dr S. Lux Dr W. Lwande Dr S. Waladde	Dr B.A. Okwakpam	Rivers State U of S&T, Nigeria
Mr Y. O.H. Assad (Sudanese, 1992–95)	ICIPE	The role of host plants in maturation of the desert locust *Schistocerca gregaria* (Forskal) (Orthoptera: Acrididae)	Prof. A. Hassanali Prof. S. El Bashir Dr H. Mahamat Dr B. Torto	Prof. Nabil H.H. Bashir	University of Gezira, Sudan
Mr A. L. Deng (Sudanese, 1992–95	IFAD	Studies on the factors that influence phase dynamics of the desert locust *Schistocerca gregaria* (Forskal)	Dr B. Torto Prof. A. Hassanali Dr H. Mahamat Dr D. O.-Ofori	Dr El Tahir Ali Prof. El Imam El Khidir	University of Khartoum, Sudan
Mr M. A. Mohamed (Sudanese, 1992–95)	DAAD	Influence of additives and ultra violet protectants on *Bacillus thuringiensis* for control of *Chilo partellus* infesting some sorghum cultivars	Dr M. Odindo Dr M. Makayoto Dr A.E.M. Nour	Dr El Ameen El Toum	University of Gezira, Sudan

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Table 1.3. Continued

Name & country	Sponsor	Thesis research title	Host dept/ supervisors	University supervisors	Registering university
Mr B. Kaoneka (Tanzanian, 1992–95)	DSO	Acaricidal properties of active principles from *Commiphora swynertonni* Burtt. and one Meliaceae species against the brown ear tick *Rhipicephalus appendiculatus* Neuman	Prof. A. Hassanali Dr B. Torto	Dr S.M. Rajab	Moi University, Kenya
Mrs M. Nabasirye (Ugandan, 1992–95)	DSO	Statistical inference on pest resistance indices	Dr A. Odulaja Dr S. Nokoe	Dr S.O. Ajala	Makerere University, Uganda
Mr E. K. Nguu (Kenyan, 1992–95)	DAAD	Effect of host blood and its digestive products on trypanosome differentiation in tsetse fly *Glossina morsitans*	Dr E.O. Osir Dr M.O. Imbuga	Prof. N.K. Olembo Prof. D. Makawiti	University of Nairobi, Kenya
Mr T. T. Epidi (Nigerian, 1992–95)	DAAD	Mechanisims of resistance in selected sorghum genotypes to the spotted stemborer, *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae)	Prof. K. N. Saxena Dr A. M. Nour Dr W. Lwande	Dr B. A. Okwakpam	Rivers State University of S & T, Nigeria
Mr A. I. Tawfik (Egyptian, 1992–95)	IFAD	Interaction between pheromones and hormones in phase dynamics of the desert locust *Schistocerca gregaria* (Forskal)	Dr E. O. Osir Prof. A. Hassanali	Prof. S. H. Ismail	Assiut University, Egypt
Mr M. H. Abakar (Chadian, 1993–96)	DSO	Isolation of *Glossina* trypanolysis/trypanoglutinin and assessment of their use in the interruption of trypanosome differentiation	Dr E. O. Osir Dr M.O. Imbuga	Prof. H. Morgan	University of Sierra Leone, Fourah Bay
Mr H.A.F. Mohamed (Egyptian, 1993–96)	IFAD	Comparison of two isolated populations of the desert locust *Schistocerca gregaria gregaria* (Forskal) and *Schistocerca gregaria flaviventris* Burmeister with particular reference to pheromone communication system (Orthoptera: Acrididae)	Prof. A. Hassanali Dr E. O. Osir	Prof. A.H. Kaschef	Ain Shams University, Egypt
Mr K. M. Kiarie (Kenyan, 1993–96)	UNDP	The potential of neem derivatives for the management of maize pests with special reference to *Sitophilus zeamais* (Motsch) (Coleoptera:Curculionidae)	Dr R.C. Saxena Dr K.V.S. Reddy Dr S. Sithanantham	Prof. J.M. Mueke Dr E.W. Kairo	Kenyatta University, Kenya
Mr A. Niassy (Senegalese, 1993–96)	IFAD	Studies on some factors mediating the interaction between *Schistocerca gregaria* (Forskal) and *Locusta migratoria migratorioides* (Reich & Fairmaire) in relation to phase polymorphism	Dr B. Torto Prof. A. Hassanali Dr D. O.-Ofori	Prof. S. El Bashir	University of Ghana, Legon
Mr J.J. Randriamanoro (Madagascan, 1993–96)	DAAD	Behavioural and physiological responses of the maize stalkborer, *Busseola fusca* Fuller (Lepidoptera: Noctuidae) to selected cultivated and wild host plants	Dr Z. R. Khan Prof. K. N. Saxena Dr S. O. Ajala	Dr B. A. Okwakpam	Rivers State University of S&T, Nigeria

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Table 1.3. Continued

Name & country	Sponsor	Thesis research title	Host dept/ supervisors	University supervisors	Registering university
Mrs E. Sebitosi (Ugandan, 1993–96)	DSO	The physiology of the tick, *Rhipicephalus appendiculatus* in relation to the transmission of *Theileria parva*	Dr G. P. Kaaya Dr T. Musoke Dr A. Young	Prof. R. I.S. Agbede	Ahmadu Bello University, Zaria, Nigeria
Mr A. I. Tawfik (Egyptian, 1993–96)	IFAD	Interaction between pheromones and hormones in phase dynamics of the desert locust, *Schistocerca gregaria* (Forskal)	Dr E. Osir Prof. A. Hassanali	Prof S.H. Ismail	Assiut University, Egypt
Mr G. M. Zimba (Malawian, 1994 -97)	DAAD/ ICIPE	Synthesis of a lectin-trypsin complex and its role in *Trypanosoma brucei* differentiation in the tsetse fly, *Glossina* sp.	Dr E. Osir Dr M. Imbuga	Dr T. Ngwira	University of Malawi
Mrs Z. Njogu (Kenyan , 1994–97)	DAAD/ EU	Role of the monitor lizard *Varamis niloticus* in trypanosome epidemiology	Dr S. Mihok Dr M. M. Ahmed Dr N. Massamba	Dr E. Kokwaro	Kenyatta University, Kenya
Mr F. A. Demas (Namibian , 1994–97)	DAAD/ ICIPE	Mechanisms of location of *Amblyomma variegatum* and other ticks by the parasitoid, *Ixodiphagus hookeri*	Dr E. Mwangi Prof. A. Hassanali	Dr E. Kunjeku Mrs Mabveni	University of Zimbabwe
Miss V. C. Ofomata (Nigerian, 1994–97)	DAAD/ Dutch- (WAU)	Investigations into the mechanisms of displacement of *Chilo orichalcocilielius* Strand by *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) on the Kenya Coast	Dr W. Overholt Dr S. Lux	Prof. R. I. Egwuatu	Nnamdi Azikiwe University, Nigeria
Mr M. N. S. Sallam (Egyptian, 1994–97)	DAAD/ Dutch (WAU)	Comparative evaluation of *Cotesia flavipes* and *Cotesia sesamiae* (Hymenoptera: Braconidae) for the management of *Chilo partellus* (Lepidoptera: Pyralidae) in Kenya	Dr W. Overholt	Dr E. Kairu	Kenyatta University, Kenya
Ms S. Akinyi (Kenyan, 1994–97)	EU	Reproductive behaviour of *Glossina fuscipes fuscipes* (Diptera: in *Glossina fuscipes fuscipes* Glossinidae)	Dr R. K. Saini Dr J. Zdarek Dr D. Denlinger	Dr N. O. Oguge	Kenyatta University, Kenya
Mr J.B. Muhigwa (Zairean, 1994–97)	DAAD/ EU	Behavioural responsiveness of *Glossina fuscipes* Newstead (1910) to visual cues and host odours, with particular reference to the lizard	Dr R. K. Saini Dr M. Mohamed	Dr M. El Bashir	University of Khartoum, Sudan

Table 1.4. Biodata of new students admitted to ARPPIS in 1997

Name	Age	Nationality	Qualifications	Employment status
Mr Sileshi G. Weldesemayat	33	Ethiopian	BSc Biology (Hons), Addis, 1987 MSc Crop Prot. 1994, Alemaya Thesis: Management of the sorghum shootfly *A. soccata* Rondani (Diptera: Muscidae) in the Eastern Hararghe region	Lecturer and Head of Biology Section, Alemaya University (on study leave)
Mr Vincent O. Oduol	33	Kenyan	BSc Biochem./Chem. Upper 2nd class, Nairobi, 1989 MSc Biochem.,Nairobi, 1993 Thesis: Temporal synthesis of cuticle proteins during larval development of tsetse fly (*Glossina morsitans morsitans*)	Tutorial Fellow, Dept of Biochemistry, University of Nairobi
Mr Abera T. Haile	32	Ethiopian	BSc Plant Sciences (Distinction), Alemaya University, 1986 MSc /DIC Applied Entomology, London University, 1992 Thesis: Studies on the toxicity of *Bacillus thuringiensis*, a neem extract and teflibenzuron against larvae *of Spodoptera littoralis* Boisduval (Lepidoptera:Noctuidae)	Senior Agricultural Expert, Ministry of Agriculture, Ethiopia
Mr Serigne T. Kandji	27	Senegalese	Bac serie C, Lycee Malick Sy de Theis Ingenieur agronome specialisation en production vegetale: Ecole Nationale Superieure d'Agriculture, Mention Bien Thesis: Use of neem (*Azadirachta indica* A. Juss) products to protect seeds from *Caryedon* (*Coleoptera bruchidae*) attack	Recent graduate, unemployed
Ms Samira A. Mohamed	34	Sudanese	BSc (1st class) Agric. Sciences University of Gezira, 1985 MSc (Crop Protection), Wageningen Agric.University Thesis: Biological control of whitefly (*Bemisia tabaci*) by *Incarsia formosa*	Research Officer ARC, Ministry of Agriculture

Table 1.5. Training information on ARPPIS students of 1995–1997 classes, currently in training at ICIPE

Name & country	Class	Sponsor	Thesis research title	ICIPE host dept and supervisors	University supervisors	Registering university/year of registration
Mrs R.O. Maranga (Kenyan)	1995	DAAD/ICIPE	Innovative control methods for *Amblyomma variegatum* (Fabricius, 1894)	MBBD Dr G. P. Kaaya Prof. A. Hassanali	Prof. J. M. Mueke	Jomo Kenyatta University of Agr & Technology, Ruiru, Kenya (October 1996)
Ms M. A. Groepe (South African)	1995	DAAD/ Univ. Pretoria	Effect of synthetic pyrethroid cattle dips on non-target beneficial dung insects	Zoology, Univ. of Pretoria Prof. A. Hassanali	Prof. C. Scholtz	University of Pretoria, RSA (January 1995)
Mr J. P. Mbugi (Kenyan)	1995	DAAD/ Gatsby	Movement of stemborers, *Busseola fusca* Fuller (Lepidoptera: Noctidae) and *Chilo partellus* Swinhoe (Lepidoptera: Pyralidae) moths between wild and cultivated habitats	BBCED Dr Z. R. Khan Dr W. A. Overholt	Prof. J. M. Mueke	Kenyatta University,Nairobi, Kenya (September 1996)
Mr A.G. Malual (Sudanese)	1995	DAAD/IFAD	The effect of plant density on gregarisation of desert locust, *Schistocera gregaria* (Forskal)	BBCED Prof. A. Hassanali Dr B. Torto	Dr E. E. Ali	University of Khartoum, Sudan (September 1995)
Mr S. Ekesi (Nigerian)	1995	DAAD/ICIPE	Variability of pathogenic activity of entomogenous fungi (Hyphomycetes) towards the legume flower thrips, *Megalurothrips sjostedti* (Trybom) (Thysanoptera: Thripidae) and their potential for biological control	MBBD Dr N. K. Maniania Dr K. Ampong-Nyarko Dr B. Lohr (GTZ)	Dr I. Onu	Ahmadu Bello University, Zaria, Nigeria (October 1995)
Mrs E. N. Kioko (Kenyan)	1996	IFAD	Biodiversity of wild silkmoths (Lepidoptera) and their potential for silk production in East Africa	Dr S. K. Raina Dr S. Essuman	Prof. J. M. Mueke Dr E. D. Kokwaro	Kenyatta University Nairobi, Kenya (November 1996)
Mrs J. M. Songa (Kenyan)	1996	R/Foundation	Temporal dynamics, economic importance and management of stemborers in maize production systems of eastern Kenya	Dr W. A. Overholt	Prof. J. M. Mueke Prof. R.S.S. Okelo	Kenyatta University Nairobi, Kenya (November 1996)
Mrs E. A. Misiani (Kenyan)	1996	DAAD/ KARI-ODA	The role of arthropod vectors in the transmission of lumpy skin disease in cattle	Dr S. Mihok Dr C. Gichabe (KARI)	Prof. R. S. S. Orago	Kenyatta University Nairobi, Kenya (March 1997)
Ms D. S. Pacho (Mozambican)	1996	DAAD/GTZ	Biology of tomato leafminers in Kenya	Dr S. Sithanantham Dr A. M.Varela Dr B. Lohr	Prof. J. Scholtz	University of Pretoria, RSA (July 1997)

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Table 1.5. Continued

Name & country	Class	Sponsor	Thesis research title	ICIPE host dept and supervisors	University supervisors	Registering university/year of registration
Mr N. K. Gikonyo (Kenyan)	1996	DAAD/EU	Semiochemical basis of nonpreference in some wild animals by the *Glossina morsitans* group of tsetse	Prof. A. Hassanali Dr P. Njagi Dr R.K. Saini	Prof. P. Gitu Prof. J. Midiwo	University of Nairobi, Kenya (September 1997)
Mr S. G. Weldessemayat (Ethiopian)	1997 wef 15 July	DAAD/ ICRAF	Insect pests of *Sesbania sesban*, with a focus on *Mesoplatys* beetle as a potential pest in improved fallow technology in southern Africa	PEESD Dr S. Sithanantham Dr Meko Rao (ICRAF) Dr J. A. Maghembe (ICRAF)	Prof. C. Ogol	Kenyatta University, Kenya
Mr V. O. Oduol (Kenyan)	1997 wef 1st June	Rockefeller Foundation/ DAAD	Research study on "Genetic biodiversity in banana weevil" *Cosmopolites sordidus*	MBBD Dr Osir Dr Cliff Gould (IITA)	Dr F. Mula	University of Nairobi, Kenya
Mr A. T. Haile (Ethiopian)	1997 wef 27 Sept	DAAD/ICIPE	Potential of egg parasitoid in control of pest Lepidoptera on export vegetable crop in Africa	PEESD Dr S. Sithanantham	Prof. C. Ogol	Kenyatta University, Kenya
Mr S. T. Kandji (Senegalese)	1997 wef 17 Jan 1998	DAAD/ICRAF	Studies on the role of agroforestry practices on the biodiversity of sub-dwelling nematodes: Case of improved fallows in western Kenya	PEESD Dr S. Miller Dr L.M. Rogo	Prof. C. Ogol	Kenyatta University, Kenya
Ms S. A. Mohamed (Sudanese)	1997 wef 13 Feb 1998	DAAD/USDA	Biological control of fruit flies with particular attention to fruit fly parasitoids	BBCED Dr S. Lux Dr W. Overholt	Dr E. M. Eltoum Dr R. M. Khafagi	University of Gezira, Sudan

Table 1.6. Updated list of ARPPIS Participating Universities and their representatives in the ARPPIS Academic Board

Name of university	Date of signing	Signatory and title	Representative and department
University of Pretoria, RSA	2 Feb 1996	Prof. P. Smit Vice Chancellor	Prof. C. Scholtz Department of Zoology
University of Ibadan, Nigeria	22 Feb 1996	Prof. O. A. Ojengbede Vice Chancellor	Prof. J. A. Odebiyi Crop Protection
University of Malawi	1 Apr 1996	Prof. B. B. Chimphamba Vice Chancellor	Dr V. W. Saka Bunda College of Agr.
Moi University, Kenya	9 Apr 1996	Prof. J. Irina Vice Chancellor	Prof Ole Karei Chief Academic Officer
Assiut University, Egypt	11 May 1996	Prof. Dr M. R. Mohmoud President	Dr S. H. Ismail Zoology Department
University of Zimbabwe	13 May 1996	Prof F. W. G. Hill Ag Vice Chancellor	Dr B. N. Dube Biological Sciences
Nnamdi Azikiwe University, Nigeria	13 Jun 1996	Prof. F. A. Nwako Vice Chancellor	Prof. R. I. Egwatu Applied Entomology
University of Khartoum, Sudan	15 Jun 1996	Prof. H. M. El Hadi Vice Chancellor	Prof I. El Khidir Crop Protection
Enugu State University, Nigeria	28 Jun 1996	Prof. J. O. Onah Vice Chancellor	Dr E. D. M. Umeh Biotech and Pest Mgt Centre
University of Ghana	13 Aug 1996	Prof. G. Benneh Vice Chancellor	Prof. J. N. Ayertey Crop Science
Kenyatta University, Kenya	6 Sep 1996	Prof. G. S. Eshiwani Vice Chancellor	Dr E. W. Kairu Zoology Department
Rivers State University of S & T, Nigeria	30 Sep 1996	Prof. A. I. Ahiazu Vice Chancellor	Dr B. A. Okwakpam Biological Sciences
Ogun State University, Nigeria	19 Nov 1996	Prof. O. Y. Oyeneye Vice Chancellor	Dr V. A. Awoderu Biological Sciences
Alemaya University of Agr., Ethiopia	7 May 1997	Dr Desta Hamito President	Dr Mengistu Hulluku Academic Vice President
University of Nairobi, Kenya	5 Jun 1997	Prof. F. J. Gichaga Vice Chancellor	Prof. W. Ogana Faculty of Science
University of Cape Coast Ghana	6 Jun 1997	Prof. S. K. Adjengpong Vice Chancellor	Dr M. Botchey Zoology Department
University of Gezira, Sudan	10 Jul 1997	Dr M. A. Magzoub Vice Chancellor	Dr M. Zeinelabdin Crop Protection
University of Zambia	22 Jul 1997	Prof. A.A. Siwela Vice Chancellor	Prof .A. A. Siwela VC's Office/ Dir Res &GS
Dschang University, Cameroon	25 Mar 1998	Prof. M. Echuents Rector	Dr I. Prah Entomology Dept.
Addis Ababa University, Ethiopia	15 Apr 1998	Dr M. Asenafi President	Dr M. Fetene Dept of Biology

Table 2.1. Training information on DRIP scholars in training between 1995–1997

Name & country	Title of thesis project	Registering university	Degree	Host department/ supervisor	Duration	Sponsor
Ms A.L. Sumba (Kenyan)	Mechanical transmission of *Trypanosoma evansi* and *Trypanosoma congolense* by African *Stomoxys* flies	University of Nairobi, Kenya	MSc	PEES Dr Steve Mihok	1 January–31 December 1995	EU project
Mr Fred A. Amimo (Kenyan)	Ecology of *Phlebotomine* flies in Marigat, Kenya	Kenyatta University, Kenya	MSc	BRU Dr Adedapo Odulaja	1 April–30 September 1995	ICIPE/Self
Ms C. M. Janssen (American)	History, organisational development and management of science in Africa	University of Pennsylvania, USA	PhD	Prof F. Kiros Dr V.O. Musewe	Attachment intended for 2 years from 1 Sep 1995 but student changed the subject after a few months and moved to Uganda	National Science Foundation, USA
Mr M. H. Mohamud (Somali)	Suitability of different wild gramineous plants for the survival and development of the stemborer *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae)	Kenyatta University, Kenya	MSc	BBD and AED Drs Z.R. Khan and W. A. Overhalt	1 Year 1 April 1995–31 March 1996	Gatsby and WAU projects
Mr F. N. Baliraine (Kenyan)	Studies on tick population genetics	University of Nairobi, Kenya	MSc	MBBD Dr E. Osir	1 Year 4 Nov 1996– 4 Nov 1997	MBBD
Mr C. G. Manyara (Kenyan)	Assessing the impact of the tsetse fly on land use and human welfare: A case study of Lambwe Valley, Kenya	Michigan State University, USA	PhD	Social Sciences, MPFS/ Dr Lako	9 Months 1 Nov 1996–31 July 1996	Rockefeller Foundation
Mrs H. L. Kutima (Kenyan)	Biochemical interactions between trypanosomes and haematophagous insects other than *Glossina*	Jomo Kenyatta, Univ. of Agr. & Technol. Kenya	PhD	MBBD	2 Years Dr E. Osir	JKUAT Jan 96 -Jan 98
Mr L. M. Gitonga (Kenyan)	Biotechnology of thrips in French bean growing systems	Jomo Kenyatta, Univ. of Agr. & Technol. Kenya	PhD	AED, GTZ Project	3 Years July 96– Jan 99 Dr Overholt	DAAD
Mrs Shi Wei (Chinese)	Breeding and genetic selection of the African honey bees, *Apis mellifera* and *cutellata*	Swedish University of Agricultural Sciences	PhD	Commercial Insects	3 Years Apr. 96–99	IFAD

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Table 2.1. Continued

Name & country	Title of thesis project	Registering university	Degree	Host department/ Supervisor	Duration	Sponsor
Mr N. J. Hutter (British)	Insect-plant interaction	University of New-castle-upon-Tyne	MSc	BBD, MPFS Dr Z. Khan	4 Months 1May–30 Aug 1996	University of New-castle-upon-Tyne
Ms S. Michalik (German)	Integrated pest management for French beans	University of Hannover, Germany	PhD	GTZ IPM Hort. Project: Dr B. Lohr	2 years from January 1996	GTZ and University of Hannover
Mr G. Kolsch (German)	Anaerobic respiration of submerged insects	University of Kiel, Germany	PhD	BBCED Dr S. Lux	3.5 months 10 October– 18 November 1996	University of Kiel
Mr M. K. Tsanuo (Kenyan)	Studies on *Striga hermonthica* seed germination stimulants/inhibitors exuded by the roots of selected fodder legumes	Jomo Kenyatta, Univ. of Agri. & Technoll.	PhD	BBCED Prof. A. Hassanali Dr Z. R. Khan Prof. J. Picket (RES, UK)	3 years 1 April 1997– 31 March 1999	DAAD/JKUAT/ ICIPE-Gatsby
Mr S. M. Githahi (Kenyan)	Pollution and food-chain bioaccumulation of some organochlorinated and organophosphorus insecticides in Lake Naivasha, Kenya	Moi University, Kenya	MSc	BBCED Dr W. Lwande Prof. Mwakio Tole	9 months 1 November 1997– 31 July 1998	Moi University/ ICIPE
Mr T. N. Njuguna (Kenyan)	Whitefly ecology	Kenyatta University, Kenya	MSc	AEESD Dr S. Sithanantham	2 years 1 November 1997– 31 August 1999	ICIPE/USAID Exp. Veg. Prog/Self
Mr J. K. Kangethe (Kenyan)	Isolation of antigens from the bont-legged tick, *Amblyoma variegatum*, and an assessment of their vaccine potential	University of Nairobi, Kenya	MSc	MBBD Dr S. Essuman	1 year 1 September 1997– 31 August 1998	Univ. of Nairobi/ ICIPE
Mr Z. O. Ouma (Kenyan)	Genetic variability in diamondback moth populations among vegetable crops in Kenya	University of Nairobi, Kenya	MSc	AEESD Dr E. Osir	1 year 1 September 1997– 31 August 1998	Univ. of Nairobi/ ICIPE

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Table 2.1. Continued

Name & country	Title of thesis project	Registering university	Degree	Host department/ Supervisor	Duration	Sponsor
Mr Z. N. Otieno-Ayayo (Kenyan)	Effects of biological pesticides *Azadirachta indica* and *Bacillus thuringiensis* on diversity and abundance of some ecologically important non-target arthropods occurring in French beans and okra in western Kenya	Moi University, Kenya	MSc	AEESD Dr S. Sithanantham Dr R.C Saxena Dr J. B. Okeyo-Owuor	9 months 1 August 1997–31 March 1998	Moi Univ./ICIPE
Mr H. I. Boge (Kenyan)	Chemical analysis on the gut microflora of soil feeding termites	University of Constance, Germany	PhD	BBCED Dr W. Lwande Dr L. Rogo Dr Brune	3 years April 1997–March 2000	DAAD/Univ. of Constance
Mr Marco Brese (German)	Lethal insect technique	University of Zena, Germany	MSc	BBCD Dr H. Mahamat	1 year 1 October 1997–30 September 1998	Self/ICIPE
Mr C. M. Mboya (Kenyan)	Ecology of major pests of cucurbits and yield losses	Kenyatta University, Kenya	MSc	PEESD Dr S. Sithanantham	2 years 1 September 1997–31 August 1999	ICIPE/USAID Veg. Proj/Self
Mr S. M. Kagunda (Kenyan)	Pests of Asian vegetables, Nguruman	Kenyatta University, Kenya	MSc	PEESD Dr S. Sithanantham	2 years 1 September 1997–31 August 1999	ICIPE/USAID Veg. Proj/Self
Mr J. M. Baya (Kenyan)	Entomopathogenic viruses and control of vegetable caterpillars	Kenyatta University, Kenya	MSc	PEESD Dr C. Kariuki (KARI) Dr S. Sithanantham	2 years 1 September 1997–31 August 1999	ICIPE/USAID Veg. Proj/Self
Ms R. K.Gathu (Kenyan)	Use of neem formulation for pest control on export vegetable	Kenyatta University, Kenya	MSc	PEESD Dr S. Sithanantham	2 years 1 September 1997–31 August 1999	ICIPE/USAID Veg. Proj/Self

Table 3.1. Beneficiaries of ICIPE's Professional Development Schemes in 1995–1997

Name	Department/Programme	Duration	Position	Sponsor
Dr Rosalind M.W. Vundla	Molecular Biology and Biochemistry Dept	1 March 1977–31 December 1995	Postdoctoral Fellow	ICIPE Core
Dr Manoj M. Rai	Behavioural and Chemical Ecology Dept/ Commercial Insects Project	11 March 1991–30 June 1997	Postdoctoral Fellow	ICIPE/IFAD
Dr Adele Josee Ngi-Song	Population Ecology and Ecosystem Sciences / ICIPE-WAU Project	16 April 1995–30 June 1996	Postdoctoral Fellow	ICIPE/WAU
Dr Susan Wangari Kimani - Njogu	Population Ecology and Ecosystem Sciences/ ICIPE-WAU Project	1 July 1995–30 June 1996	Postdoctoral Fellow	ICIPE/WAU
Dr Joseph Mworia Maitima	Social Sciences Dept/Rockefeller Foundation Project	6 September 1995–30 June 1997	Postdoctoral Fellow	Rockefeller Foundation
Dr Melaku Girma	Behavioural and Chemical Ecology Dept	18 September 1995–30 June 1997	Postdoctoral Fellow	ICIPE/EU
Ms Maria Janetta Bonhof	Population Ecology and Ecosystem Sciences / ICIPE-WAU Project	1 June 1995–31 May 1997	Research Associate	WAU Project
Mr Arop Leek Deng	Behavioural and Chemical Ecology Dept/ Locust Project	1 August 1995–31 March 1996	Research Associate	IFAD Locust
Mr Yousif Osman Hussein Assad	Behavioural and Chemical Ecoolgy Dept/ Locust Project	15 September 1995–31 March 1996	Research Associate	IFAD Locust
Dr William Allan Overholt	Population Ecology and Ecosystem Sciences / ICIPE-WAU Project	25 May 1991 —	Visiting Scientist	WAU Project
Dr Muhinda Mugunga	Behavioural and Chemical Ecology Dept/ Sandfly Project/Mosquito Project	1 January 1995–30 June 1997	Visiting Scientist	Hebrew Project
Dr S.A. Lux	Behavioural and Chemical Ecology Dept	30 September 1991–30 June 1997	Visiting Scientist	ICIPE Core
Dr Eiko Khan	Behavioural and Chemical Ecology Dept	25 May 1995–24 March 1996	Visiting Scientist	JSPS
Dr Paul Nduati Ndegwa	Population Ecology and Ecosystem Science		Postdoctoral Fellow	ICIPE/EU
Prof. Shigemi Yagi	Behavioural and Chemical Ecology Dept/ Locust Project	November 1994–November 1997	Visiting Scientist	JIRCAS
Dr Satoshi Hiroyoshi	Behavioural and Chemical Ecology Dept	May 1996–February 1997	Visiting Scientist	JSPS
Dr Peter G. Markham	Molecular Biology and Biotechnology Dept	November 1997	Visiting Scientist	Rockefeller Fdn., UK ISAAA AfriCentre

Table 6.1. List of research methodology workshops, practitioner training courses and consumer awareness training activities conducted from 1995–1997

Name of workshop/course	Sponsor	Course date and venue	No. of participants	Countries represented
International Group Training Course on Tsetse Management, Monitoring and Control	European Union	1–30 Nov 1995 ICIPE, Kenya	15	Kenya, Ethiopia, Chad, Uganda, Zimbabwe, Tanzania and South Africa
International Group Training Course on Classical Biological Control of Gramineous Stemborers in Africa	Netherlands, through ICIPE/WAU project	15–27 Oct 1995 ICIPE, Kenya	22	Tanzania, Sudan, Kenya, Uganda, Zambia, Malawi, Mozambique, Ethiopia, Zimbabwe, and Botswana
International Course on Plant Protection for the IAC Alumni from Africa "Extension for IPM"	International Agricultural Centre, Netherlands	3–16 Dec 1995 ICIPE, Kenya	19	Ethiopia, Kenya, Sudan, Tanzania, and Uganda
International Locust/Grasshopper Biological Control Training Course	USAID/AELGA/ICIPE	1–6 Oct 1995 ICIPE, Kenya	18	Kenya, Ethiopia, Uganda, Tanzania, Egypt, Yemen, Somalia, Eritrea and Sudan
Components Essential for Ecologically Sound Pest and Vector Management Systems	DSO	19 Feb–8 Mar 1996 Niamey, Niger	18	Benin, Burkina Faso, Chad, Guinea-Bissau, Guinea, Gambia, Ivory Coast, Mali, Mauritania, Niger and Senegal
Neem Training Workshop	FINIDA	23 Jun–6 Jul 1996 ICIPE, Kenya	43	Ethiopia, Kenya, Malawi, Tanzania, Uganda and Zambia
National Group Training Course on Basic Tsetse Biology and Trapping Technologies (Somalia)	ICRC	14–28 Jul 1996 ICIPE, Kenya	8	Somalia
National Group Training Course on Integrated Management of Crop Pests (Tanzania)	GTZ	13 Oct–27 Nov 1996 ICIPE, Kenya	20	Tanzania
Neem Training Workshop	FINIDA	17–27 Nov 1996 ICIPE, Kenya	37	Ethiopia, Kenya, Tanzania, Uganda and Zambia
National Farmers Course on Community-Based Tsetse Control (Kenya)	EU	Various dates, 1996 Nguruman, Kenya	300 farmers	Kenya
National Farmers Course on Community-Based Tsetse Control (Ethiopia)	EU	Various—May, Aug and Sep 1996 Gurage Zone, Ethiopia	235	Ethiopia

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Table 6.1. Continued

Name of workshop/course	Sponsor	Course date and venue	No. of participants	Countries represented
National Course on Community-Based Tsetse Control for Field Technicians and Veterinarians (Ethiopia)	EU	August 1996 Southern Region, Ethiopia	45	Ethiopia
National Group Training Course on Basic Tsetse Biology and Trapping Technologies	ICRC	20 Apr–5 May 1997	9	Somalia
Training Course on the Management of Banana Pests	BMZ	5–9 May 1997 Kisii, Kenya	22	Kenya
KARI/ICIPE DNA Techniques Workshop	Rockefeller Foundation and ISAAA AfriCentre	24–28 Nov 1997 ICIPE, Nairobi	11 scientists	Kenya, Ghana, Sudan
International Group Training Course on Tsetse Management, Monitoring and Control	European Union	5 Nov–5 Dec 1997	12	Kenya, Uganda, Tanzania, Ethiopia
Training Course on the Management of Banana Weevil	BMZ	8 Dec 1997 ICIPE Kuja River Field Site, Kenya	60 farmers	Kenya
First International Workshop on Commercial Insects	IFAD	18–21 Aug 1997	43 scientists	Kenya,Uganda, China, India, Australia, United Kingdom, Zimbabwe, Switzerland, Sweden, Egypt, Japan, Zambia Tanzania, Ethiopia
Training Course in Silk Farming and Honey-Bee Keeping	IFAD	Various (7 Fridays 1997)	1200 farmers	Kenya, Uganda, Tanzania
Neem Awareness Training Workshops	FINIDA/UNEP	2 courses at various times	39	Eritrea, Ethiopia, Kenya, Malawi, Tanzania, Uganda, Zambia

Table 7.1. Summary of beneficiaries of ICIPE's Field Attachment Scheme (1995–1997)

Area of training	No. of males	No. of females	Total
Administration and finance	2	5	7
Animal (arthropods and lab. rodents) rearing technology	7	5	12
Arthropod biosystematics	0	1	1
Behavioural and chemical ecology	8	6	14
Biostatistics and data management	5	1	6
Catering and hotel management	7	42	49
General agriculture	8	4	12
Information science and computer applications	16	9	25
Medical laboratory technology	1	0	1
Molecular biology and biotechnology	38	20	58
Physical plant maintenance & engineering	17	1	18
Population ecology and ecosystem sciences	8	8	16
Science editing and publishing	4	2	6
Social science in pest and vector management	2	2	4
Total enrollment (1995-97)	123	106	229

III. Public Relations

Background, approach and objectives

The Public Relations (PR) office serves as a liaison between ICIPE and the general public. The office has promoted the image of ICIPE by disseminating information to local and international media and to regional, subregional and national organisations.

The PR office also produces the popular monthly newsletter, *ICIPE Update*, which informs all staff, Members of Governing Council and donors on key Developments and upcoming events at ICIPE.

Participating staff: *R. P. Ortega, R. Onyango*

1. SPECIAL EVENTS

The past two years have been eventful in many respects for ICIPE. ICIPE celebrated its 25th Anniversary in 1995 and the PR's office coordinated all the commemorative activities. These included release of special commemorative postage stamps and flag raising by several donors and charter signatories at the headquarters.

A well attended NGO Day was held at ICIPE in October 1995 with the theme 'Utilisation of ICIPE Technologies and Rural Resources for Poverty Alleviation and Improvement of Rural Health in Africa'. Thirty-four international and national organisations took part.

The launching of ICIPE's *Vision and Strategic Framework towards 2020* was coordinated by the PR office. The event was attended by heads of diplomatic missions, donor representatives, national and international organisations and private sector entrepreneurs.

The handing over of ICIPE's trapping technology to the local community in Nguruman, Kenya took place on 6th September 1996. Prof. George Saitoti, the Vice President represented the Kenya Government at this event which symbolises one of the final steps in technology transfer and the Centre's research efforts to develop tsetse control methods that are environmentally benign, affordable and sustainable.

2. MEDIA

During the past three years, ICIPE has featured in a series of broadcasts on Radio France Science Corporation, AGFAX Radio and Press services run by the UK-based WREN-media. The broadcasts and publications were distributed to all major radio stations of Anglophone RFI, Deutsche Welle and Swiss Radio. The articles were also distributed to daily newspapers in Africa and to international publications. ICIPE's tsetse and horticulture research activities were featured on ORF Austrian TV and RFI (Radio France International).

Media coverage of ICIPE's activities was also boosted when a Swiss film crew led by Andreas Schriber, filmed several of ICIPE's research and development activities, with particular emphasis on Dr Herren's role in undertaking research on selected insects and the application of this knowledge to the development of friendly management technologies for pests and vectors. This special 30-minute TV programme 'Miracles Take A Little Longer' was televised by Swiss TV with an audience of nearly 0.5 million people.

3. CONFERENCES, WORKSHOPS AND EXHIBITIONS

Throughout 1995, 1996 and 1997 the PR's office was involved in the organisation of various conferences, workshops and exhibitions (Tables 1–3).

ICIPE staff were kept abreast of the latest developments in insect science through seminars by invited speakers and centre scientists.

4. VISITORS

The PR's office also coordinated all visitor services and many distinguished international and national guests visited ICIPE during these years.

ICIPE has also become a popular visiting place for students of all age groups and many farmers.

LIST OF ICIPE GUEST SEMINARS AND VIDEO SHOWS

Table 1. ICIPE guest seminars for 1995

	Name and address of speaker	Topic	Date
1.	Dr J.W. Smith Jr Dept of Entomology, Biological Cont. Facility, Texas A & M University College Station, Texas,USA	Creating novel host-natural enemy unions: A strategy for biological control of indigenous pests	19 April 1995
2.	Dr Wiedenman As above	Foraging strategies of parasites of lepidopteran stemborers	21 April 1995
3.	Dr S. Halevy Dept of Pharmaceutical Chemistry The University of Jerusalem P O Box 12065, Jerusalem, Israel	Algal inheritance of parasitic Protozoa	15 May 1995
4.	Dr Paul Eggleston Liverpool School of Tropical Medicine Pembroke Place, Liverpool, UK	Progress in mosquito molecular genetics	5 July 1995
5.	Mr Samuel Ochieng (ICIPE Technical staff on study leave)	A topic in behavioural biology/chemical ecology	16 August 1995
6.	Dr Karin Horn FAO World Acaricide Resistance Reference Centre, Berlin, Germany	Presentation of World Acaricide Resistance Reference Centre (WARRC) and its activities	24 August 1995
7.	Mr Amer I. Tawfiq ARPPIS Scholar, ICIPE	Interaction between pheromones and hormones in phase dynamics of the desert locust, *Schistocerca gregaria* (Forskal)	6 September 1995
8.	Dr Adrian Linacre Forensic Science Unit Strathclyde University, Scotland	DNA profiling in forensic science	14 September 1995
9.	Mr Yousif O.H. Assad ARPPIS Scholar, ICIPE	Effects of some inter- and intra-specific signals (kairomones and pheromones) on the maturation of the desert locust *S. gregaria* (Forskal) (Orthoptera: Acrididae)	21 September 1995
10.	Mr Arop Leek Deng ARPPIS Scholar, ICIPE	Studies on some factors that influence phase dynamics of the desert locust, *Schistocerca gregaria* (Forskal) (Orthoptera: Acrididae)	28 September 1995
11.	Dr Ralf Schaab Oberfield 30,D-65205 Wiesbaden Germany	Economics of biological control of the cassava mealybug *P. manihoti* (Mat., Ferr.) (Hom.,Pseudococcidae) in Africa	30 October 1995
12.	Dr Bruce McPheron Dept of Entomology Penn. State University, USA	Genetic markers in the medfly: Implications for the study of New and Old World Populations	31 October 1995
13.	Dr Steve Sheppard US Department of Agriculture Beltsville, MD, USA	Intraspecific taxonomy of the honey bee, *Apis mellifera*	1 November 1995
14.	Dr Stefan A. Escher Dept of Genetics, Umea University Sweden	Evolution of the dec-1 eggshell locus in *Drosophila*: Restriction site mapping and sequence comparison in the *melanogaster* species subgroup	15 November 1995
15.	Mr Hatem A.F. Mohamed ARPPIS Scholar, ICIPE	Morphometric and molecular comparisons of two isolated populations of the desert locust, *Schistocerca gregaria*	28 November 1995
16.	Dr Miranda V. Heusden Dept of Biochemistry University of Arizona Tucson (AZ) USA	Lipoproteins in insect haemolymph and their possible role in parasite development	29 November 1995

Table 2. List of seminars for 1996 at ICIPE

	Name and address of speaker	Topic	Date
1.	Prof. Yasuo Chinzei, Department of Medical Zoology, School of Medicine, Mie University, Tsu, 514, Japan	Regulation of gene expression by juvenile hormone: Control mechanism of gene switching in a haemolymph protein, cyanoprotein of a Hemiptera insect	17 January 1996
2.	Dr David Gisselquist Officer in Charge of the World Bank Field Office Lilongwe, Malawi	Technology transfer, competition and trade liberalisation for low risk pest management	2 February 1996
3.	Dr David Jones Export Sales Manager VG-Organic, UK	The new VG-platform II mass spectrometer	2 February 1996
4.	Ms Mary Anne Groepe ARPPIS Scholar, ICIPE	The effect of environmental factors on the spatial and temporal variability of *Glossina pallidipes* Austen, at Nguruman, southwest Kenya	20 February 1996
5.	Prof. John F. Beaver Fulbright Scholar, Sunny College at Buffalo, Department of Educational Communications & Tech. Kenyatta University, Nairobi, Kenya	Presenting: Not simply reading or talking: Using the powers of desktop presenting	27 February 1996
6.	Mrs Rosebella O. Maranga ARPPIS Scholar, ICIPE	Innovative control methods for *Amblyomma variegatum* (Fabricius 1794) using entomopathogenic fungi *Beauveria bassiana, Metarhizium anisopliae* and anti-tick botanicals in traps baited with aggregation -attachment pheromone	5 March 1996
7.	Dr Hal Wilson Department of Entomology Ohio State University, USA	Noctuids on corn in the Great Lakes Region	6 March 1996
8.	Mr Sunday Ekesi ARRPIS Scholar, Pathology & Microbiology Department, ICIPE	Variability of pathogenic activity of entomogenous fungi towards the legume flower thrips, *Megalarothrips sjostedti*, and their potential for biological control	20 March 1996
9.	Dr Scot O'Neil Department of Epidemiology and Public Health Yale University, USA	Cytoplasmic incompatibility and genetic manipulation of insect populations	18 March 1996
10.	Prof. Ahmed Hassanali Interim DDG, ICIPE	Towards a conceptual model of gregarisation of the desert locust	26 March 1996
11.	Dr A. Odulaja, Head, Biomathematics Unit, ICIPE	Analysis of entomological data: Some common pitfalls	16 April 1996
12.	Dr Cole Dodge Director, Resource Mobilisation, UNEP, Nairobi	Resource mobilisation	23 April 1996
13.	Dr Walter I. Knausenberger, Environmental Analyst, USAID, Washington,USA	-	10 May 1996
14.	Mr Jean-B. Muhigwa ARPPIS Scholar, ICIPE	Visual and olfactory cues of *Glossina fuscipes fuscipes*	2 July 1996
15.	Dr Tovi Lehmam Department of Health & Human Services, Centres for Disease Control (CDC) and Prevention,Atlanta, USA	Genetic structure of populations of *Anopheles gambiae* ss	30 July 1996
16.	Dr N. S. Talekar Entomologist, AVRDC,Taiwan	Biological control-based IPM of diamondback moth in Southeast Asia	6 August 1996

Continued next page

Table 2. Continued

Name and address of speaker	Topic	Date
17. Dr Paula S. J. Martin Emory University, Atlanta, Georgia, USA	Rapid bioassessment of water quality using aquatic macro-invertebrate communities	13 August 1996
19. Dr Arthur Ratnakaran Project Leader, Biotechonology of Pest Management, Canadian Forest Service, Ontario, Canada	Mode of action of RH-5992, a non steroid ecdysone analog	2 September 1996
20. Dr S. Sithanatham, Ag. Head, Plant Pests Management, ICIPE	Status of IPM in agricultural projects in Africa	10 September 1996
21. Dr Lucie Rogo Consultant, Biodiveristy Project, ICIPE	The biodiversity project at ICIPE	15 October 1996
22. Dr Suresh Raina, Head of Commercial Insects Research, ICIPE	Queen rearing and variations in *Apis mellifera* races	22 October 1996
23. Dr Apreh Nuamah Ghana	Farmer participation in IPM implementation	23 October 1996
24. Prof. Abdu Latif Faculty of Veterinary Science University of Khartoum, Sudan	Tick and tick-borne disease control in Zimbabwe	24 October 1996
25. Dr Robert S. Copeland ICIPE	Insect macrophotography under natural field conditions	5 November 1996
26. Dr Bill Hominick, Director, CAB International Institute of Parasitology, UK	Entomopathogenic nematodes—more questions than answers	6 November 1996
27. Dr Tracy Johnson Visiting Scientist,Fullbright Scholar, North Carolina State University, USA	Ecology of insect resistant transgenic crops: A North American perspective	9 November 1996
28. Dr H. Kakinohana Okinawa Prefectural Agricultural Exp. Station, Japan	The successful eradication of the melon fly by means of sterile insect technique in Okinawa	26 November 1996
29. Dr Guiyun Yan Department of Animal Health and Biomedical Sciences, University of Wisconsin, Madison, USA	Molecular analysis of fitness and populations genetic structure of yellow fever mosquitoes	27 November 1996
30. Video Show	World Food Prize presentation 'Miracles take a little longer'	28 November 1996
31. Dr Hiroshi Shinbo National Institute of Sericulture and Entomological Science, Ministry of Agriculture, Forestry and Fisheries, Japan	Development of artificial diets for the silkworm and topics which are currently in progress in the sericulture laboratory	3 December 1996

Table 3. List of ICIPE Seminars for 1997

	Name and address of speaker	Topic	Date
1.	Dr Mudiumbula T. Futa African Development Bank Abidjan, Côte d'Ivoire	Global research agenda and its implications for an effective collaborative partnership	11 February 1997
2.	Dr S. K. Raina Head of Commercial Insects Project, ICIPE	Commercial insects rearing in African economy	4 March 1997
3.	Dr Gisbert Zimmermann Federal Biological Research Centre for Agriculture and Forestry, Institute for Biological Control Darmstadt, Germany	Entomopathogenic fungi from the lab to the field	6 March 1997
4.	Dr George T. Lako Social Sciences Department, ICIPE	Highlights of socioeconomic research activities in Nguruman	11 March 1997
5.	Dr Mohamed Ali Bob ICIPE	Species/biotypes characterisation of whiteflies (Homoptera: Aleyrodidae): Preliminary study on the use of molecular markers	18 March 1997
6.	Dr Susan Kimani-Njogu ICIPE	Biosystematics unit at ICIPE	25 March 1997
7.	Dr Hassane Mahamat ICIPE	Sexual attraction in the desert locust	1 April 1997
8.	Dr Maurice Odindo ICIPE	Tsetse rearing at ICIPE	8 April 1997
9.	Dr Andreas Brune Faculty of Biology, University of Konstanz, Germany	Microecology of the termite gut	14 April 1997
10.	Dr D. Mbungu Head, Biology Department Baraton University, Eldoret, Kenya	Peptide modulation of insect neuromuscular transmission	15 April 1997
11.	Dr Akke van der Zijpp	Management of research at ICIPE: A challenge	21 April 1997
12.	Dr Prabhakara V. Choudary	Insects: Novel bioreactors for the new millennium	21 April 1997
13.	Dr Richard Hall	Biocontrol studies in the Caribbean—Too little but not too late	22 April 1997
14.	Dr Steve Mihok ICIPE	Visual perception in biting flies	6 May 1997
15.	Dr Peter Njagi ICIPE	Further insights into the complexity of the oviposition aggregation semiochemicals of the desert locust, *Schistocerca gregaria*	13 May 1997
16.	Dr Bart Knols Ifakara Institute, Tanzania	The current status of semiochemical research of malaria vectors and the future challenges in this field	14 May 1997
17.	Mr Jason Kapkirwok ICIPE	Order and disorder in nature	3 June 1997
18.	Dr Suliman Essuman ICIPE	Making arthropod vaccines	17 June 1997
19.	Dr Madoka Nakai Tokyo University of Agriculture and Tech., Tokyo, Japan	Interactions between entomopathogenic viruses and endoparasitoid *Ascogaster reticulatus* in the smaller tea tortrix	1 July 1997

Continued next page

Table 3. Continued

Name and address of speaker	Topic	Date
20. Dr Satoshi Nakamura JIRCAS, Tsukuba, Japan	Ovipositional strategy of the parasitoid fly, *Exorista japonica*	7 July 1997
21. Prof. John H. Law Former GC Member and Regents Professor, University of Arizona Tucson, USA	The Centre for Insect Science in Tucson —What we do and how we do it	15 July 1997
22. Dr Ochieng-Odero ICIPE	Living beyond the signoid curve (ICIPE Science Park)	21 July 1997
23. Dr Johann Baumgärtner ICIPE	Analysis of populations' dynamics for management purposes	5 August 1997
24. Prof. David L. Denlinger Visiting Scientist Ohio State University, USA	Tsetse parturition and other fly tales	11 August 1997
25. Mr Sallaam Mohamed ARRPIS Scholar	Order in nature (Commentary on previous talk by Mr J. Kapkirwok entitled "Order and disorder in nature")	12 August 1997
26. Dr Koiji Kawashima Director, Crop Protection and Postharvest Technology Division, JIRCAS, Japan	Prevention of aflatoxin contamination of Thai maize by plastic film bag	19 August 1997
27. Dr Ne N. Massamba ICIPE	*Leishmania* parasites: Identification and characterisation	26 August 1997
28. Dr Adele J. Ngi-Song ICIPE	Intraspecific diversity in parasitoids: Implication for biocontrol	2 September 1997
29. Dr Gabriel Neve Unite d'ecologie et de Biogeographie Universite Catholique de Louvain, Belgium	Spatial structure of butterfly populations: Methods, results and management applications	8 September 1997
30. Dr S. K. Raina ICIPE	What's new in silkworm/honey bee research in ICIPE?	9 September 1997
31. Dr Robert Copeland ICIPE	Phytotelmata: Cryptic aquatic habitats and their insect fauna	16 September 1997
32. Dr Melodie McGeoch University of Pretoria Rep. of South Africa	Edge effects on the holly leafminer in a suburban woodland	23 September 1997
33. Dr John Githure ICIPE	ICIPE/KEMRI Mosquito Collaborative Project	7 October 1997
34. Dr Peter Luthi Federal Institute of Technology Zurich, Switzerland	*Bacillus thuringiensis*	8 October 1997
35. Dr Yunlong Xia ICIPE	Insect informatics	14 October 1997
36. Dr Hassane Mahamat ICIPE	Improved insect rearing at ICIPE	21 October 1997
37. Dr Brent Swallow Agricultural Economist ILRI, Nairobi, Kenya	Impacts on trypanosomosis on African agriculture	12 November 1997
38. Dr Baldwyn Torto ICIPE	Desert locust semiochemicals Research: Recent advances	18 November 1997
39. Dr Vitalis O. Musewe ICIPE	Postgraduate training in ICIPE	25 November 1997
40. Dr Yunlong Xia ICIPE	How to make multi-media presentation using MS Power Point and LCD Projector	2 December 1997
41. Dr Gerry Killeen Department of Tropical Medicine Tulane University New Orleans, USA	Screening recombinant antibodies for biological activity against mosquitoes	2 December 1997

IV. The ICIPE Technopark—Forging Partnerships between Research and Industry

Participating scientists: *M. Makayoto, M.A. Okech, M. T. Futa, W. A. Overholt, S. Mihok, S.K. Raina, A. Hassanali, E.O. Osir, S. Essuman, N.N. Massamba, N.K. Maniania, R.C. Saxena, J.P.R. Ochieng'-Odero (Project leader)*

Financial information: *GTZ, UNEP, Government of Finland, IFAD*

Collaborators: *• The Export Processing Zones (EPZ) Authority • Jomo Kenyatta University of Agriculture and Technology (JKUAT) • Egerton University • Kenya Industrial Research and Development Institute (KIRDI) • Hebrew University • GAC Products Limited, Finland • SAROC Ltd, Kenya*

Background, approach and objectives

ICIPE has initiated pilot scale production of a number of its R&D products since 1995, especially those emanating from biotechnology. This development is taking place within the framework of a science park initiative known as the ICIPE Technopark. The pioneer park is developing as a high-tech biotechnology industry, aiming to capture a number of niche markets by its wide range of products and services. ICIPE works closely with a number of interested collaborators to provide a number of high-tech biotechnology-related services at the park. Interested entrepreneurs are invited to identify promising products and develop upscaling protocols.

ICIPE is developing the Technopark based on the following eight promising environmentally friendly pest management products:

- Fungus-based biopesticides (*Beauveria/ Metarhizium*) with excellent activity against locusts, grasshoppers, cereal stemborers, termites, thrips and ticks.
- *Bacillus thuringiensis* (*Bt*)-based biopesticides with activity against cereal stemborers and mosquitoes. Dudustop[R], which is active against filthflies, has had considerable market survey studies undertaken.
- Bioactive botanical products from the neem tree for control of cereal stemborers, storage pests, termites, ticks and nematodes. Neem is also a popular medicinal plant and can be used in the treatment of a number of health disorders, in soaps and cosmetics.
- Traps: R&D efforts at ICIPE have resulted in production of specific arthropod targeting traps which are environmentally friendly. The NZI trap for instance is a simple, safe and economic trap for biting flies. It is active against tsetse flies, houseflies and stable flies.
- Pheromone attractants, and behaviour modifiers: A number of pheromone traps have been developed and tested by ICIPE and a number of R&D institutions in Africa. Examples for potential use include the adult and anti-gregarising pheromone of desert locusts and other pheromones of tsetse and stemborers.
- Bio-based repellents: There is sufficient knowledge about a number of plants producing bioactive compounds with strong repellent or antifeedant activity against some insect species (such as mosquito) and ticks.
- Apiculture and sericulture products and technology: Commercial use of insects in sericulture and apiculture have a great potential as income-generating opportunities for small holders, particularly in the rural areas of Africa. Bee venom, royal jelly, propolis and eco-honey are some of the high value products. Silk fibre from domestic and wild silkmoths is in high demand on the world market.
- Products from bioprospecting: Essential vitamins, amino acids, pigments, enzymes and pharmaceuticals are some high value products that may be prospected from insects.

ICIPE will also be providing specialised high-tech services that fall into two major categories:

(i) Informatics—Information-related products such as management information and indicator systems, specialised databases and knowledge-packs about African insects.

(ii) Analytical services and diagnostic kits—ICIPE is well equipped with the personnel and equipment to undertake a number of analytical services. These range from chemical analysis and synthesis, biotechnology services based on the use of techniques such as ELISA for ingested meal analysis, to electron microscopy services using both the scanning (Joel T33OA) and transmission (Phillips CM 12) microscopes.

Work in progress

1. *BT*-BASED PRODUCTS

1.1 *BT*-BASED CONTROL AGENTS

ICIPE has developed a number of *Bt*-based biopesticides for use against mosquitoes, stemborers and wax moth. Dudustop[R] is a *Bt* formulation used to control filthflies. It has been used to treat toilets and rubbish heaps in densely populated settlements such as refugee camps and slums in Kenya and Ethiopia. Through the Technopark initiative, ICIPE is currently negotiating with private and international organisations to scale-up production. *Bt kurstaki* is being produced in limited quantities for control of *Chilo partellus* as further studies on indigenous *Bt* isolates against selected tropical insect pests are being carried out. *Bt aizawai* from the ICIPE microbial bank have been screened against the greater wax moth, *Galleria mellonella* which is an endemic pest of honeybee colonies with most promising results.

1.1.1 Bt *for control of mosquitoes*

As a result of collaboration between ICIPE and the Hebrew University of Jerusalem, more persistent clones of *Bacillus sphaericus (Bsp)* incorporating the toxic protein from *Bt israelensis* has been developed. The clones have shown strong activity against three mosquito species, *Aedes aegypti, Culex quinquefasciatus* and *Anopheles gambiae*. The main objective of this work was to develop more persistent and improved larvicidal activity of cloned materials of *Bacillus sphaericus* by transferring material coding for one or more of the several *Bacillus thuringiensis israelensis (Bti)*. The ICIPE carried out both bioassay and persistence of nine clones of *Bsp* and *Bti* materials prepared in Israel on *Aedes aegypti, Culex quinquefasciatus* and *Anopheles gambiae*.

The final results based on at least four experiments proved that the nine clones were more toxic to *Ae. aegypti* with an LD_{50} range of 0.36–1.01 mg/ml as compared to original *Bsp* with an LD_{50} 46.18 mg/ml. The *Bti* still remains the most toxic with an LD_{50} of 0.017 mg/ml. The toxicity of the nine clones, *Bsp* and *Bti* to both *Cu. quinquefasciatus* and *An. gambiae* was comparable with LD_{50} range of 0.0010–0.0096 mg/ml. It is very clear that the clones are active against the three mosquito species, except that they seem to deteriorate on storage due to proteolytic reaction. Growth media need further investigation for eventual mass production.

1.1.2 Bt *for control of stemborers*

The biotechnology laboratory has produced more than 125 litres of *Bt kurstaki* for control of *Chilo partellus* in collaboration with Social Sciences Department. The material has been transported for distribution to the farmers at the Coast. It is important to emphasise that the fermentation facility presently used is a big constraint to production. Meanwhile, further studies on more indigenous *Bt* isolates against selected tropical insect pests are being carried out. From these studies, three selected isolates (ISO1, ISO2, ISO3) proved more toxic to the three species with LD_{50} range of 1.98–6.012 mg/ml for *C. partellus*, 1.57–1.64 mg/ml for *E. saccharina* and 9.98–24.83 mg/ml for *S. calamistis*. ICIPE is consulting with a number of organisations and companies to scale-up the fermentation facility. Notable ones are SAROC Ltd, UNIDO, UNHCR and Sumitomo Ltd of Japan.

1.1.3 *Production of Dudustop*[R] *for control of filthflies*

The production of Dudustop[R] continues to be done in a small laboratory fermenter (15L) and available shaker incubators. A locally based pesticide company, SAROC Ltd, has fabricated a 1000-litre fermenter and final touches on sterilisation are being put in place. The ICIPE biotechnology laboratory will provide the inoculum to the plant. The UNIDO and UNHCR are also in contact for pilot scale production. ICIPE has provided the Lutheran World Federation (LWF) and International Committee of the Red Cross (ICRC) with 200 and 150 litres of Dudustop[R] respectively, locally produced for control of filthflies. The requirement for Dudustop[R] for 1996 by UNHCR was about 2000 litres. A private company Oy GAC Ab from Finland has produced 500 litres and this was distributed to UNHCR by ICIPE as per the current agreement. It is hoped that SAROC will undertake to produce the material locally when the plant is ready.

1.1.4 Bt *for the biocontrol of greater wax moth,* Galleria mellonella

The massive infestation of combs by the greater wax moth, *Galleria mellonella* in Kenya is of great concern to both the farmer and National Bee Keeping Division of the Ministry of Agriculture, Livestock Development and Marketing, Nairobi. Bee keeping and honey production capacity has been minimal due to losses because of damage caused to honey combs by the greater wax moth. The major objective of the work is to develop a *Bt*-based biopesticide for the control of the greater wax moth for enhanced honey production.

Four *Bt* isolates, *Bt aizawai, M44-2, 50* and *ICIPE-T* from ICIPE microbial bank have been screened against the wax moth. *Bt aizawai* was found to be more active against the wax moth and was chosen for further development work. The LD_{50} bioassay results based on milled combs for second and third instar larvae after 5 days are 25.05 mg/ml and 41.55 mg/ml, respectively. On artificial diet, the LD_{50} for second instar after 3 and 4 days are 632.46 mg/ml, and 106.57 mg/ml, respectively and for third instar the LD_{50} after 3 and 4 days are 24,231.54 mg/ml and 1461.89 mg/ml, respectively.

The bioassay on eggs and first instar give maximum protection, since no emergence or development of subsequent stages are noticed, even in concentrations below 20 mg/ml. From the LD_{50} analysis, it would thus be appropriate to target the second instar as the latest stage for control. Simulated laboratory field trials with combs using second and third instar of wax moth larvae is in progress.

The *Bt aizawai* broth from the fermentation facility with different concentrations has been used. The results so far indicate that concentration of between 3–5 % of the fermentation broth gives between 80–100% protection after 5–7 days, particularly in the case of second instar larvae. Largescale field application in some areas in Kenya with heavy infestation of wax moth will be carried out with the National Bee Keeping Division of the Ministry of Agriculture, Livestock Development and Marketing. Simulated laboratory field trials will be extended to real field situations for development of an appropriate delivering system and application strategy.

2. NEEM PRODUCTS

2.1 NEEM PRODUCTION: AWARENESS BUILDING AND FACILITATING THE USE OF NEEM AS A SOURCE OF NATURAL PESTICIDES AND OTHER USEFUL PRODUCTS IN SUB-SAHARAN AFRICA

See report on neem under Plant Health section for details on background, funding, collaboration, publications and impact.

As a result of increased awareness, collection of neem seed in remote areas of Wajir, Garissa, Lamu, Malindi and Mombasa has become a part-time income-generating activity. From scratch, neem seed collection has increased to about 20 tonnes per season in Kenya. Also in Tanzania, the value of neem seed is being recognised. Some of the women's groups in Tanzania are now producing mosquito repellent candles made with a mixture of wax and neem oil.

At the ICIPE Field Station, Mbita Point, a simple process of preparing aflatoxin-free neem oil and cake has been developed. Washing of seed, followed by bleaching with 1% sodium hypochloride and drying to 10–12% moisture content, yields high quality seed for processing as well as for propagation purposes, as viability is markedly prolonged. This sterilised seed is in great demand and is being sent as far as South Africa, Mozambique, Eritrea, Ethiopia and other countries in Africa, and Jamaica and Panama outside of Africa.

2.2 NEEM-BASED PRODUCTS

Since 1995, ICIPE has collaborated with GTZ and SAROC Ltd on the development of neem-based insecticides, with the aim of producing simple standardised pesticides, which can be marketed at competitive prices. Over 20 tonnes of seeds have been purchased from the East African region and have been used at ICIPE to develop two promising formulations, neem cake powder with 0.5% azadirachtin, and water miscible oil with 0.03% azadirachtin. These products have now been approved for use by the Pest Control Products Board (PCPB) of Kenya.

(See the report on a neem-based smallscale industry under Report IX in the Plant Health section).

Output

Publications

Promotional and public awareness publications on the Technopark were produced. These included brochures and newpaper articles titled as follows:

- *The ICIPE Technopark: Research-Industry Interface*
- *The ICIPE Technopark for Commercialising Research Outputs*

Conferences

(i) ICIPE in conjunction with the Export Processing Zone of Kenya (EPZ) co-sponsored a one-day national seminar on 24 September 1997. Over 110 participants drawn from industry, national R&D institutions, relevant government policy departments, representatives of the public universities and the financial sector, overwhelmingly agreed on the need to establish the Technopark.

(ii) Conference organised by Bergen High-Technology Centre, Ltd (HIB) in Norway on Development of Science Parks, September 28–29 1997.

Proposals

A proposal entitled 'The Establishment of a Model Science Park in Africa: A Proposal for the ICIPE Technopark' was prepared and submitted to a number of development banks and donors.

Impact

Though not yet operational, tremendous interest has been generated from entrepreneurs and farmers at large.

CONTENTS

Disciplinary Departments

I. Population Ecology and Ecosystem Science Department

Background, approach and objectives

The Population Ecology and Ecosystem Science Department was established in 1997 to coordinate research and implementation work on the levels of populations, communities and ecosystems.

The systems analysis approach is used. It recognises the hierarchical organisation of nature and considers populations as the basic units of communities and ecosystems, and typically uses mathematical models to represent their spatio-temporal dynamics and interactions. For this purpose, simulation models are developed.

The following are concepts being reviewed and evaluated with international partners, discussed in Department meetings and used in research activities as well as in project proposal preparation:

1. the temporal dynamics of single species populations
2. the spatial dynamics of single species populations
3. population interactions
4. multi-species population interactions
5. ecosystem processes
6. information dissemination

Participating scientists: *J. Baumgärtner (Department Head), Y. Xia (Insect Informatics Section Leader) and others, as per staff lists.*

Donors: *ICIPE Core Funds, USAID (Insect Informatics)*

Main collaborators: *• ENEA, La Spezia, Italy • University of Parma, Italy • University of California, Berkeley, USA*

(Note that most of the activities of Department members are reported under project reports).

II. Behavioural and Chemical Ecology Department

Background, approach and objectives

The Department hosts scientists with expertise in behavioural ecology, ethology, sensory physiology, analytical chemistry, chemical ecology and natural products chemistry. Its primary role is to undertake research on semiochemical and other signals that mediate ecological interactions and to exploit these for the development of monitoring tools and control tactics for target pests. In this respect, its activities form part of the research programmes of most megaprojects. The department's contribution to these is reflected in the respective sections of the megaprojects.

In addition, the Department has undertaken exploratory work on a variety of anti-insect natural products from local plants, including antifeedants, repellents, acaricides and insecticidal compounds. The work was undertaken in collaboration with local and overseas universities.

Work in progress

1. ANTI-INSECT BOTANICALS

1.1 EVALUATION OF THE SHRUB, *OCIMUM SUAVE* (WILLD) AS A SOURCE OF REPELLENTS, TOXICANTS AND PROTECTANTS IN STORAGE AGAINST THREE STORED PRODUCT INSECT PESTS

Participating scientists: *A.J. Bekele, D. Obeng-Ofori, A. Hassanali*

As part of investigations to understand the scientific basis for the use of leaves and seeds of *Ocimum* spp. (Labiatae). in traditional grain protection, a study was carried out to establish the bioactivity of products derived from the leaves of *Ocimum suave* against three major stored product insect pests. The bioactivity of materials from the leaves and succulent stems of *O. suave* was tested against *Sitophilus zeamais* (Mots), *Rhyzopertha dominica* (Fab.) and *Sitotroga cerealella* (Oliv.) in maize and sorghum. *Ocimum suave* applied as dry or ground leaves was not toxic to *S. zeamais*, but as an essential oil extract was highly toxic to the weevil. Higher dosages of ground leaves and essential oil extract induced 100% mortality in *R. dominica*. *Sitotroga cerealella* was most susceptible to *O. suave* since all the plant materials bioassayed evoked higher mortalities in the moth. The materials also caused significant reduction in progeny produced by the insects. All the plant materials were highly repellent to *S. zeamais*, with ground leaves evoking the highest repellent action. There was, however, considerable variation in the repellency of the materials against *R. dominica* and *S. cerealella*. Ground leaves and essential oil extract provided the greatest protection of maize and sorghum against attack by the insects.

The protection of grains against insect damage provided by materials derived from *O. suave* suggests that there may be an objective basis for their use in traditional methods for grain protection. The results of this study demonstrate a possible scientific rationale for the incorporation of these products into grain protection practices of certain communities in eastern Africa. There is thus the need for more thorough investigations into such practices to facilitate their improvement and adoption for the control of stored product insect pests, especially in rural communities. For example, some of the materials could be developed into powdered dusts or appropriate fumigants for use in traditional storage of grains.

1.2 PRODUCTS FROM THE LEAVES OF *OCIMUM KILIMANDSCHARICUM* (LABIATAE) AS POSTHARVEST GRAIN PROTECTANTS AGAINST INFESTATION BY THREE MAJOR STORED PRODUCT INSECT PESTS

Participating scientists: *B. Jembere, D. Obeng-Ofori, A. Hassanali*

Ocimum kilimandscharicum (Labiatae) is a perennial woody shrub that is common in the upland areas of eastern Africa. It has been widely used traditionally for the treatment of serious colds and coughs, abdominal pains, measles and mild diarrhoea in children. The leaves are also used as grain protectants in traditional storage in East Africa. The efficacy of products from the leaves of *O. kilimandscharicum* as grain protectants against *S. zeamais*, *R. dominica* and *S. cerealella* was evaluated.

The bioactivity of materials from the leaves of *Ocimum kilimandscharicum* was tested against *S. zeamais* Motschulsky (Coleoptera: Curculionidae), *Rhyzopertha dominica* (Fabricius) (Coleoptera: Bostrichidae) and *S. cerealella* (Olivier) (Lepidoptera: Gelechiidae) in maize and sorghum grains in the laboratory. Exposure of adults of the three insect species to dried ground leaves and essential oil extract of *O. kilimandscharicum* induced 100% mortality after 48 h. Fresh and dried whole leaves were not toxic to *S. zeamais* or *R. dominica*. Grains treated with dried ground leaves and essential oil extract caused significant reductions in the number of progeny and survival rate of all three pest species tested. There was no adult survival or progeny production in grains treated separately with each of the two materials at doses of 25.0 g (dried ground leaves) and 0.3 g (essential oil) per 250 g of grain, respectively.

Unlike *R. dominica* and *S. cerealella*, grains treated with fresh leaves enhanced the feeding activity of *S. zeamais*. Ground leaves and the essential oil, however, protected the grains against feeding by all three species, resulting in lower weight loss and number of damaged seeds compared with untreated grains. All the plant materials were repellent to *S. zeamais* with the essential oil extract applied at 0.3 g/250 g of grain evoking the highest repellent action. There was, however, considerable variation in the repellency of the materials against *R. dominica* and *S. cerealella*.

As in the case of *O. suave*, there may be an objective basis for the use of materials derived from *O. kilimandscharicum* in traditional methods of grain protection, and a possible scientific rationale for this in rural communities. Some of the materials could be developed into powdered dusts or appropriate fumigants for use in traditional storage of grains by local communities.

The chemical identity of the components from the leaves of *O. kilimandscharicum* is of special interest. We believe that the identification of the active compounds and a study of their mode of action, currently in progress, will contribute to their use in grain protection.

1.3 EVALUATION OF *OCIMUM KENYENSE* (AYOBANGIRA) AS A SOURCE OF REPELLENTS, TOXICANTS AND STORAGE PROTECTANTS AGAINST THREE MAJOR STORED PRODUCT PESTS

Participating scientists: *B. Jembere, D. Obeng-Ofori, A. Hassanali*

Ocimum kenyense (Ayobangira) (Labiatae) is a 10–30 cm-tall aromatic shrub which grows extensively in the uplands of Kenya and northern Tanzania, particularly in the wet, seasonally water-logged soil. It is a rhizomatous herb with ascending stems and subsessile ovate to elliptic slender leaves. The leaves have traditionally been used in East Africa as insect repellents, particularly against mosquitoes. Local farmers also commonly mix stored foodstuffs with dry leaves of *Ocimum* spp. for protection against insect infestation.

The bioactivity of materials derived from the leaves and succulent stems of *Ocimum kenyense* against *S. zeamais*, *R. dominica* and *S. cerealella* was assessed in maize and sorghum grains in the laboratory. *Ocimum kenyense* applied as dry or ground leaves was not toxic to *S. zeamais* and *R. dominica*. The highest dosage of essential oil killed only 35% of the weevils, but induced 96% mortality in the borer after 96 h. *Sitotroga cerealella* was most susceptible to *O. kenyense*, and all the plant materials bioassayed evoked higher mortalities in the moth. Grains treated with 30 g of ground leaves and 750 mg of essential oil killed all the moths after 24 h. Similarly, dry and ground leaves had no effect on progeny production by *S. zeamais*, but grains treated with essential oil extract significantly reduced the number of progeny produced by the weevil.

All levels of dry leaves, ground leaves and essential oil extract of *O. kenyense* caused significant reduction in progeny produced by *R. dominica* and *S. cerealella*. There was no progeny produced by both species in grains treated with the highest dosages of 30 g of ground leaves and 750 mg of essential oil extract.

All the plant materials were highly repellent to *S. zeamais*, with the highest dosages of ground leaves and essential oil evoking the highest repellent action. The materials, however, showed only moderate repellency to *R. dominica* and rather low repellency to the moth. Ground leaves and essential oil extract provided the greatest protection of maize and sorghum against feeding by *R. dominica* and *S. cerealella*, with no observable feeding damage to grains treated with the highest dosages of both materials.

As in the case of *O. suave* and *O. kilimandscharicum*, the results of this study indicate good potential for the use of *O. kenyense* as repellent and toxicant agents in stored pest management systems. They also demonstrate a possible scientific rationale for the incorporation of the leaves and seed of *Ocimum* species into grain protection practices of certain communities in Eastern Africa. Botanical toxicants are broad-spectrum in pest control, and many are easy to apply and can be produced by farmers and smallscale industries, and are therefore potentially less expensive. There is thus the need for more thorough investigation of such practices to facilitate their improvement and adoption for the control of storage insect pests, especially in rural communities.

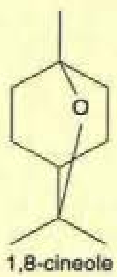
The chemical identity of the components from the leaves of *O. kenyense* is of special interest. The use of plant materials in pest control could become important supplements to imported synthetic pesticides. Botanical pesticides thus represent an important potential for integrated pest management (IPM) programmes in developing countries as they are cheap and based on local materials. However, natural products should be selective, environmentally safe and harmless to mammals, man and beneficial arthropods. It is also essential that appropriate technology transfer systems are developed to promote direct on-farm preparation of traditional pesticides for those resource-poor farmers who have no access to commercial pesticides or who cannot afford them.

1.4 BIOLOGICAL ACTIVITY OF 1,8-CINEOLE, A MAJOR COMPONENT OF THE ESSENTIAL OIL OF *OCIMUM KENYENSE* (AYOBANGIRA) AGAINST STORED PRODUCT BEETLES

Participating scientists: *D. Obeng-Ofori, B. Jembere, A. Hassanali*

Collaborators: *Institute for Stored Product Protection, Germany*

1,8-cineole (Figure 1.1) is known to be a major component of the essential oil of *O. kenyense*. Laboratory bioassays were carried out to evaluate the repellency, toxicity and protectant potential of 1,8-cineole against the grain weevils, *Sitophilus granarius* (Linnaeus), *S. zeamais* (Motschulsky) (Curculionidae), the red flour beetle, *Tribolium castaneum* (Herbst) (Tenebrionidae) and the larger grain borer, *Prostephanus truncatus* (Horn) (Bostrichidae).



1,8-cineole

Figure 1.1. 1,8 cineole, a major component of the essential oil of *Ocimum kenyense*

1,8-cineole applied topically or impregnated on filter paper, and mixed on whole wheat and maize grains, was highly toxic to all the four beetle species. Beetle mortality was dose-dependent, with the highest dose of 10 μl/insect evoking 100% mortalities in the beetles after 24 h exposure. 1,8-cineole was more toxic in grain than on filter paper since the lowest dosage of 0.5 μl/kg controlled all beetles exposed. There was, however, a highly significant loss of toxicity after only 24 h following treatment, irrespective of dosage applied. Development of eggs and immature stages within grain kernels and progeny emergence were completely inhibited in treated grain. 1,8-cineole evoked strong repellent action against *S. granarius* and *S. zeamais*, but was moderately repellent to *T. castaneum* and *P. truncatus*.

The results obtained suggest good potential for the use of 1,8 cineole preparations as repellent and toxic agents against several stored product beetle pests. The precise mode of action of 1,8-cineole is of special interest. Future work would focus on its mode of penetration into insect cuticle and grain, metabolic targets in the insect body and its effects on beneficial arthropods and other mammals fed on treated materials.

1.5 PLANT OILS AS GRAIN PROTECTANTS AGAINST INFESTATIONS OF THE BEETLES, *CRYPTOLESTES PUSILLUS* AND *RHYZOPERTHA DOMINICA* IN STORED GRAIN

Participating scientist: *D. Obeng-Ofori*

The use of plant oils in the control of storage insect pests is an ancient practice and is particularly appropriate in smallscale storage systems. In recent years, increasing attention has been given to the control of storage pests in grain depots by the use of oils, including vegetable essential and mineral oils. Plant oils (cottonseed, soybean, corn, groundnut and palm) at different dosages were evaluated in the laboratory for their ability to suppress the populations of *Cryptolestes pusillus* and *Rhyzopertha dominica* in maize and sorghum.

Exposure of adults of these beetle species to grains treated with 10 ml/kg of the different oils induced 100% mortality within 24 h. A dose of 5 ml/kg of each oil significantly decreased the progeny produced by *R. dominica*. Complete protection was achieved on grains treated with 10 ml/kg. These oils also repelled the adults of both species. Percentage weight loss caused by *R. dominica* in grains treated with 5 ml and 10 ml/kg levels were significantly lower than in untreated grains. Oil treatment did not affect the germination of, or water absorption by, maize and sorghum grain, compared with untreated grains.

This work and several other studies clearly showed that many plant oils of different origins and composition are effective as grain protectants against infestation by major stored product insect pests. The choice of a particular oil to use will depend on its availability in different localities. It is unlikely that plant oils alone would solve the problem of stored product pests. They may, however, appear to be quite useful in integrated pest management strategies when combined with other derivatives of plants, such as neem and *Ocimum* spp.

1.6 THE ESSENTIAL OIL OF *CLEOME MONOPHYLLA* AND ITS CONSTITUENTS AS TICK (*RHIPICEPHALUS APPENDICULATUS*) AND MAIZE WEEVIL (*SITOPHILUS ZEAMAIS*) REPELLENTS

Participating scientists: *W. Lwande, M. Ndungu, A. Hassanali*

Assistant: *L. Moreka*

Collaborators: *Kenyatta University, Kenya*

Cleome monophylla (Family: Capparidaceae) is a shrub whose leaves are used as a vegetable in West Africa; the young leaves, shoot and inflorescence are used as a pot-herb. In the East Indies, the plant has been used as an anthelmintic. The plant is readily available and if endowed with anti-pest properties, could find use in pest management among rural communities. The repellency of the essential oil of *C. monophylla* and constituents identified from its oil were evaluated against the livestock tick, *Rhipicephalus appendiculatus* and the maize weevil, *S. zeamais*.

In a tick climbing-repellency bioassay, the oil of *C. monophylla* exhibited repellency which, at the highest dose, was comparable to that of the commercial arthropod repellent *N, N*-diethyl toluamide (DEET). In a Y-tube olfactometer bioassay, *C. monophylla* oil showed higher or comparable repellency against *S. zeamais* relative to DEET at all the doses tested. Fourteen compounds were identified in the *C. monophylla* oil by GC, GC-MS and coinjection with authentic samples. Terpenolene was found to occur in largest quantity (14%) followed by 1-α-terpeneol (10%), pentacosane (9%), (α + β)-humulene (8%), phytol (5%) and 2-dodecanone (4%). The most highly repellent components against *R. appendiculatus* and *S. zeamais* were 1-α-terpeneol and 2-dodecanone. The overall pattern of repellency activity of the *C. monophylla* constituents with respect to the two arthropods was, however, different.

The repellent action of *C. monophylla* oil is caused by an additive effect of the compositionally significant components with different levels of repellency. Moreover, the general pattern of repellency of the components suggest that the structural requirements of repellent action are different in *R. appendiculatus* and *S. zeamais*. The implication of this in practice is that the blend as a whole rather than specific constituents, might constitute an agent with a sufficiently broad spectrum of activity for use as a general purpose arthropod repellent. The possibility of using the oil for such a purpose is currently being explored.

1.7 REPELLENCY AND ACARICIDAL PROPERTIES OF *OCIMUM SUAVE* AGAINST THE BROWN EAR TICK, *RHIPICEPHALUS APPENDICULATUS*

Participating scientists: *E. Mwangi, A. Hassanali, S. Essuman*

Assistants: *E. Nyandat, L. Moreka, M. Kimondo*

Ocimum suave Willd (Labiatae) is a shrub which is common in the upland forest areas of eastern Africa and has been used in folk medicine for stomachache, cough and influenza, and traditionally as a perfume, a mosquito repellent and grain protectant. The insect repellent property of *O. suave* oil has been confirmed previously. The oil obtained by hydrodistillation of the leaves was evaluated against different stages of the brown ear tick, *R. appendiculatus*, using *in vitro* and *in vivo* bioassays, and its effectiveness in protecting cattle in the field against the tick tested.

The oil was found to repel and kill all stages of *R. appendiculatus*. In an *in vitro* bioassay on the larvae, the LC_{50} of the oil in liquid paraffin was 0.024%. A 10% solution was found to kill all immatures and more than 70% of the adults feeding on rabbits. Rabbits were protected for 5 days against attaching larvae using a 10% solution. Preliminary experiments undertaken with cattle kept in the field suggested that the oil may have potential in tick control, and a role in integrated tick management.

Production of the repellent acaricide could be achieved by harvesting the plant which grows in the wild, or alternatively, by cultivating it on a large scale by farmers and supplying to a steam distillery where it could then be appropriately formulated before distribution.

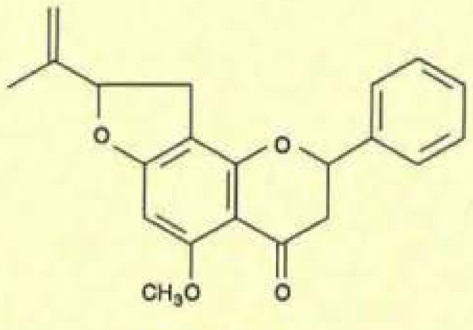
1.8 IDENTIFICATION OF THREE NEW FLAVONOIDS FROM THE ROOT OF *TEPHROSIA EMOROIDES* AND THEIR ANTIFEEDANT ACTIVITY AGAINST THE LARVAE OF THE SPOTTED STEMBORER, *CHILO PARTELLUS* SWINHOE

Participating scientists: *W. Lwande, A.K. Machocho, A. Hassanali*

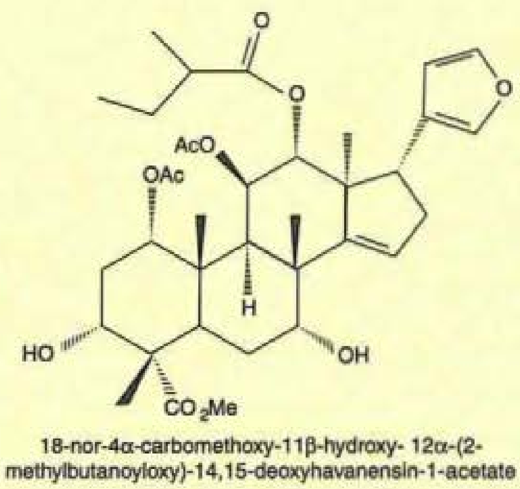
Assistant: *L.V.C. Moreka*

Collaborators: *Kenyatta University, Kenya*

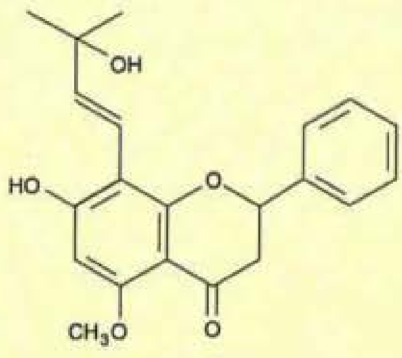
Tephrosia emoroides A. Rich (Leguminosae, subf. Papilionoidae), a woody perennial herb, is one of over 300 species of the large genus *Tephrosia* Pers. that are distributed in the tropical and subtropical regions of the world. Extracts from a range of *Tephrosia* spp. have been widely used as insecticides. *Tephrosia emoroides* is well-distributed in Kenya, where the Pokot people use concoctions of its roots as a remedy for



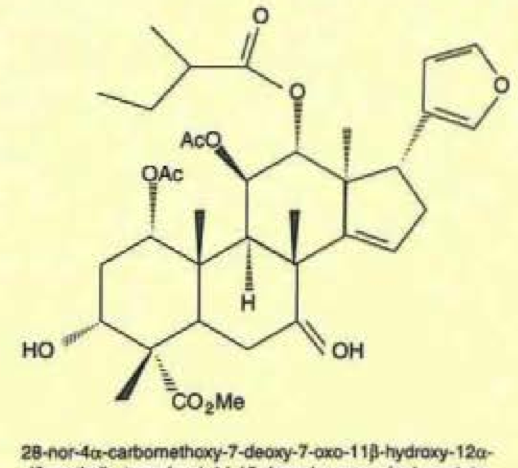
Emoroidenone



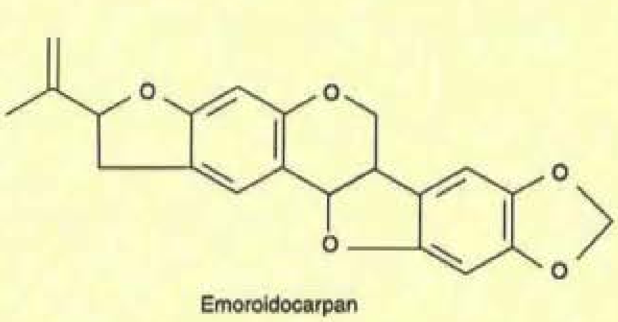
18-nor-4α-carbomethoxy-11β-hydroxy- 12α-(2-methylbutanoyloxy)-14,15-deoxyhavanensin-1-acetate



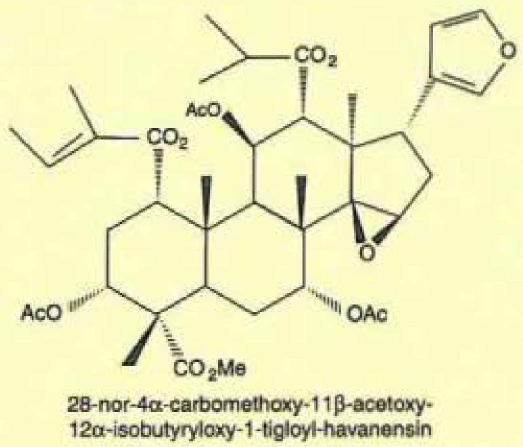
Emoroidone



28-nor-4α-carbomethoxy-7-deoxy-7-oxo-11β-hydroxy-12α-(2-methylbutanoyloxy)-14,15-deoxyhavanensin-1-acetate



Emoroidocarpan



28-nor-4α-carbomethoxy-11β-acetoxy-12α-isobutyryloxy-1-tigloyl-havanensin

Figure 1.2. Novel compounds identified from the root of *Tephrosia emoroides*

cough, while the roots are also chewed for the same purpose.

Three new and two previously known flavonoids were isolated and identified from the roots of *T. emoroides* A. Rich. The new flavonoids included the flavanone 4″, 5″-dihydro-5-methoxy-5″ isopropenylfurano-[2″,3″:7,8]-flavanone, the flavone 7-hydroxy-5-methoxy-8-(3″-hydroxy)-isopent-1-eneflavone and the pterocarpan 4′, 5′-dihydro-5′-isopropenyl-8, 9-methylenedioxyfurano-[2′,3′:2,3]-pterocarpan. The three new compounds were named emoroidenone, emoroidone and emoroidocarpan, respectively (Figure 1.2). The previously known flavonoids that were isolated were the flavanone, 5-methoxyisolonchocarpin and the flavene, hildegardtene.

The flavonoids were tested for antifeedant activity against the larvae of *Chilo partellus* Swinhoe using the maize leaf disc bioassay. The flavanone emoroidenone showed strong feeding deterrent activity against *C. partellus* larvae with a mean percentage deterrence of 66.1% at a dose of 100 μg/disc. The other flavonoids showed little or no feeding deterrent activity against *C. partellus* larvae.

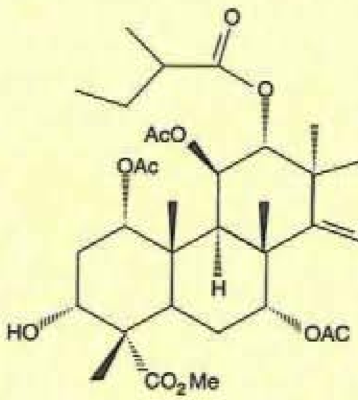
1.9 LIMONOIDS FROM THE PLANT *TURRAEA FLORIBUNDA*

Participating scientists: *B. Torto, A. Hassanali,*

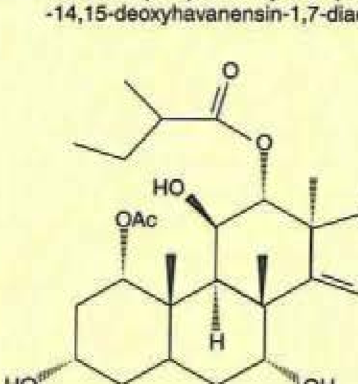
Assistant: *E. Nyandat*

Collaborators: *University of Maine, Orono, USA*

Many plants of the family Meliaceae such as neem (*Azadirachta indica*) and others have been of interest as they have been found to contain anti-insect pest and medicinal natural products. The biological activity in these plants has been attributed mainly to a class of compounds called limonoids. In continuing studies of limonoids in this family of plants, the chemistry of *Turraea floribunda* (Meliaceae) was explored. *Turraea floribunda* is a shrub distributed throughout East Africa. In traditional medicine, the bark is used as an emetic, and both the root and the bark are used as a purgative.



28-nor-4α-carbomethoxy-11β-acetoxy-12α-(2-methylbutanoyloxy) -14,15-deoxyhavanensin-1,7-diacetate



28-nor-4α-carbomethoxy-11β-hydroxy-12α-(2-methylbutanoyloxy) -14,15-deoxyhavanensin-1-acetate

Figure 1.3. Novel compounds identified from the rootbark of *Turraea floribunda*

Chemical studies of extracts of the root bark of *T. floribunda* yielded four new limonoids of the havanensin class: 28-nor-4α-carbomethoxy-11β-acetoxy-12α-(2-methylbutanoyloxy-14,15-deoxyhavanensin-1,7-diacetate; 28-nor-4α-carbomethoxy-11β-hydroxy-12α-(2-methylbutanoyloxy)-14,15-deoxyhavanensin-1-acetate; 18-nor-4α-carbomethoxy-11β-acetoxy-12α-(2-methylbutonoyloxy)-14,15-deoxyhavanensin-1-acetate; and 28-nor-4α-carbomethoxy-7-deoxy-7-oxo-11β-acetoxy-12α-(2-methylbutanoyloxy)-14,15-deoxyhavanensin-1-acetate (Figure 1.3). The structures were determined by spectroscopic methods. The structure for the first of these compounds was also confirmed by X-ray diffraction methods.

Further fractionation of the methanolic extract of the root bark of *T. floribunda* was undertaken and the resulting fractions examined further. A novel limonoid of the havanensin class with six ester functions was isolated from the root bark and characterised by spectroscopic methods as 11β-acetoxy-3,7-diacetyl-4α-carbomethoxy-12α-isobutyryloxy-28-nor-1-tigloyl-havanensin. The identified compounds will be evaluated for bioactivity against several insect pest species.

Output

Publications

Bekele A.J., Obeng-Ofori D. and Hassanali A. (1996) Evaluation of *Ocimum suave* (Willd) as a source of repellents, toxicants and protectants in storage against three stored product insect pests. *International Journal of Pest Management* 42(2), 139–142.

Bekele A.J., Obeng-Ofori D. and Hassanali A. (1997) Evaluation of *Ocimum kenyense* (Ayobangira) as source of repellents, toxicants and protectants in storage against three major stored product insect pests. *Journal of Applied Entomology* 121, 169–173.

Jembere B., Obeng-Ofori D., Hassanali A. and Nyamasyo G.N.N. (1995) Products derived from the leaves of *Ocimum kilimandscharicum* (Labiatae) as post-harvest grain protectants against the infestation of three major stored product insect pests. *Bulletin of Entomological Research* 85, 361–367.

Leitao S.G., Kaplan M.A.C., Monache F.D., Nyandat E. and Rwekika E. F. (1995) Antifeedant activity of two phenylpropanoid glucosides from *Aegiphila obducta* against *Chilo partellus* larvae. *Insect Science and Its Application* 16 (3/4), 375–378.

Machocho A.K.., Lwande W., Jondiko J.I., Moreka L.V. C. and Hassanali A. (1995) The new flavonoids from the roots of *Tephrosia emoroides* and their antifeedant activity against the larvae of the spotted stalk borer *Chilo partellus* Swinhoe. *International Journal of Pharmacognosy* 33(3), 222–227.

Mwangi E.N., Essuman S., Kaaya G.P., Nyandat E., Munyinyi D. and Kimondo M.G. (1995) Repellence of tick *Rhipicephalus appendiculatus* by the grass *Melinis* *minutiflora*. *Tropical Animal Health and Production* 27, 211–216.

Mwangi E.N., Hassanali A., Essuman S., Nyandat E., Moreka L. and Kimondo M. (1995) Repellent and acaricidal properties of *Ocimum suave* against *Rhipicephalus appendiculatus* ticks. *Experimental & Applied Acarology* 19, 11–18.

Ndungu M., Lwande W., Hassanali A., Moreka L. and Chabbra S.C. (1995) *Cleome monophylla* essential oil and its constituents as tick (*Rhipicephalus appendiculatus*) and maize weevil (*Sitophilus zeamais*) repellents. *Entomologia Experimentalis et Applicata* 76, 217–222.

Obeng-Ofori D. (1995) Plant oils as grain protectants against infestations of *Cryptolestes pusillus* and *Rhyzopertha dominica* in stored grain. *Entomologia Experimentalis et Applicata* 77, 133–139.

Obeng-Ofori D., Reichmuth CH., Bekele J. and Hassanali A. (1997) Biological activity of 1,8-cineole, a major component of essential oil of *Ocimum kenyense* (Ayobangira) against stored product beetles. *Journal of Applied Entomology* 121, 237–243.

Torto B., Bentley M.D., Cole B.J.W., Hassanali A., Huang F.-Y., Gelbaum L. and Vanderveer D.G. (1995) Limonoids from *Turraea floribunda*. *Phytochemistry* 40 (1), 239–243.

Torto B., Hassanali A., Nyandat E. and Bentley M.D. (1996) A limonoid from *Turraea floribunda*. *Phytochemistry* 42 (4), 1235–1237.

Conferences attended

Torto B. 6th International Chemistry Conference in Africa, Accra, Ghana, July 31 to August 4, 1995. 'New limonoids from *Turrea floribunda*'

Capacity building

The following students supervised by members of the Department in exploratory areas of research completed their graduate training:

J.A. Bekele PhD (ARPPIS) (1995) Effects and use of some *Ocimum* plant species and their essential oils on some storage insect pests.

F.K.N. Sika PhD (ARPPIS) (1996) Behavioral responses of *Rhipicephalus appendiculatus* Neumann 1901 (Acari: Ixodidae) to host and non-host semiochemicals.

S. I. Kamara PhD (ARPPIS) (1995) Effect of host semiochemicals on behaviour of *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae).

T.T. Epidi PhD (ARPPIS) (1995) Mechanism of resistance in some sorghum genotypes to the spotted stem borer *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae).

E. Rwekika PhD (ARPPIS) (1995) Feeding allelochemicals for the banana weevil, *Cosmopolites sordidus* Germar.

P. U. Richard PhD (ARPPIS) (1995) The reproductive biology, behaviour and pheromones of the banana weevil, *Cosmopolites sordidus* Germar (Coleoptera: Curculionidae).

F. Nyongesa (MSc) (1996) University of Nairobi. *Rhipicephalus appendiculatus* attractants from cattle.

S.M. Kimani (MSc) (1996) University of Nairobi. Airborne volatiles of *C. partellus* cultivated and wild host and non-host plants.

I. L. Kwatenge (MSc) (1996) University of Nairobi. Airborne volatiles of maize and sorghum.

B. Nyagode (MSc) (1997) Egerton University. *Rhipicephalus appendiculatus* attractants from cattle.

Impact

The major impact of the Department's exploratory work was in capacity building through training of African students in new areas related to arthropod science. In addition, exploratory work in tick chemical ecology and the use of plants as protectants against stored pests has opened up future promising areas of Megaproject research.

III. Molecular Biology and Biotechnology Department

Background, approach and objectives

The Molecular Biology and Biotechnology Department conducts goal-oriented research in areas of molecular sciences and biotechnology pertinent to the goals of ICIPE's megaprojects. The Department is committed to the development of cutting edge technologies that span the different major research areas. From a disciplinary standpoint, MBBD is organised into two closely interacting sections, namely, molecular bioscience (MB) and applied microbiology (AM). In the MB section, research focuses on arthropod population genetics, parasite–vector relationships and molecular taxonomy. The AM section deals with the development of fungi, bacteria, nematodes and viruses for the control of various target pests and vectors. In addition to these research activities, the department offers services in both light and electron microscopy. An ELISA-based system for identifying blood meals in arthropods has been developed and will soon be offered to other researchers in the region. Plans for the development of a germplasm centre at ICIPE have been finalised. This centre will act as a repository for various arthropod pathogens isolated at ICIPE. This activity will be undertaken in collaboration with USAID / ARS Soil and Nutrition Lab, the International Mycology Institute (UK) and Ministere des Resources Naturelles (Canada).

Due to funding constraints, capacity is currently lacking in certain key areas such as formulation. In addition, several research areas have either been dropped or scaled-down. For example, work on development of an anti-tick vaccine has been discontinued until substantial funding is mobilised. It is also planned that future research in this area will be conducted in close collaboration with ILRI and other international partners such as CSIRO (Australia), ID-DLO (Netherlands) and University of Victoria (Canada).

Collaboration: *• Kenya Agricultural Research Institute (KARI) and Sokoine University (Tanzania) on the use of neem for tick control, and tick population genetics • Kenya Trypanosomiasis Research Institute (KETRI) on bloodmeal identification in arthropods and the use of fungi for tsetse control • National Agricultural Research Organisation (NARO, Uganda), Makerere University (Uganda) and IITA on the use of fungi for termites and thrips control • Centre for Bioelectrostatics (UK) and University of Florida on novel formulation of fungal-based biopesticides • Virginia Tech. (USA) and IIBC on formulation, delivery and production systems and commercialisation of biopesticides, especially fungi • Kenya Medical Research Institute (KEMRI, Kenya) • Centres for Disease Control (CDC, USA)• New York State University, (SUNY, Buffalo, USA) and University of Pavia (Italy) on development of molecular markers for studying arthropod populations • Yale University (USA) and Joint FAO/IAEA on tsetse-trypanosome interactions •Kimron Veterinary Institute (Israel) on evaluation of the potential of nematodes for tick control.*

Work in progress

The research undertaken by the department falls within a number of clearly defined themes. Much of this work is reported under the respective programme areas. An overview of each thematic area is given below:

1. MICROBIAL CONTROL OF ARTHROPODS

The activities under this theme include prospecting for new pathogens, evaluation of efficacy and production, formulation and development of delivery systems. In the case of fungi (*Metarhizium anisopliae* and *Beauveria bassiana*), emphasis is on thrips, ticks, locusts and grasshoppers. A number of local isolates of *Bacillus thuringiensis* (*Bt*), have shown activity against stemborers (*Chilo partellus*, *Busseola fusca* and *Sesamia calamistis*). Molecular characterisation of two isolates (active against adult *Glossina* spp. and *C. partellus*) has been carried out. A project on the use of nematodes against ticks is being undertaken in collaboration with Kimron Veterinary Institute, Israel.

1.1 CHARACTERISATION OF THE δ-ENDOTOXIN OF A *BACILLUS THURINGIENSIS* ISOLATE ACTIVE AGAINST TSETSE, *GLOSSINA MORSITANS*, AND A STEMBORER, *CHILO PARTELLUS*

Background, approach and objectives

Bacillus thuringiensis (*Bt*) is a gram-positive bacterium pathogenic to a wide variety of insect species. It is characterised by its ability to synthesise a parasporal proteinaceous crystalline inclusion (consisting of δ-endotoxins) during sporulation. Upon ingestion by a susceptible insect host, the crystal δ-endotoxin is processed and the resulting toxin interacts with cells of the insect midgut epithelium via high affinity binding sites, disrupting the cell membrane integrity, and thus leading to insect death.

The use of *Bt* in pest control is, however, limited, mainly due to its selectivity and moderate efficacy. Moreover, resistance to *Bt* has now become a reality. In order to make the use of *Bt* more effective, it is essential to understand the molecular basis of the insecticidal properties of these toxins and consequently, their selective toxicity. For instance, it is now accepted that the widespread use of transgenic plants creates a situation in which the pest is continuously exposed to selection pressure, leading to intense selection for resistance. Hence, the ability to regulate the expression of toxin in transgenic plants would be invaluable. To date, much work has been reported on the use of *Bt* as a pesticide, but there is still very little information on the molecular basis for the insecticidal properties of the toxins. Research must therefore focus on the characterisation of the toxins and their receptors, which could lead to an improvement in both selectivity and efficacy. Moreover, the understanding of structure-function relationships between the toxin and the insect may lead to novel strategies of dealing with the problem of resistance development. As part of ongoing research in our laboratory, we report on the physico-chemical properties of a local isolate of *Bt* that has biological activity against the tsetse *Glossina morsitans morsitans*, and the stemborer *Chilo partellus*.

The objective was to carry out physical chemical characterisation of the δ-endotoxin from a *Bt* isolate active against tsetse and *C. partellus*.

Participating scientists: *E. O. Osir, W. R. M. Vundla*

Assistant: *C. Agufa*

Donor: *USAID and ICIPE Core Funds*

Work in progress

1.1.1 *Characterisation of the δ-endotoxin*

Nutrient broth was inoculated with 1% (v/v) starter culture (220 rpm, 28°C, 24 h) and incubated in a shaker incubator (220 rpm, 28°C, 72 h). The δ-endotoxin crystals were harvested from the 72-h culture by centrifugation (1100 x *g*, 10 min., 4°C). The crystals that settled at the bottom of the tube were washed several times with distilled water by centrifugation. The purified δ-endotoxin crystals were solubilised in 50 mM Na_2CO_3.$NaHCO_3$ buffer (pH 9.5) containing 10 mM dithiothreitol (DTT) and the suspension centrifuged. The resulting supernatant fraction was treated with either commercial bovine trypsin or chymotrypsin.

In another study, the protoxin (M_r ~64,000), the trypsin-toxin (M_r ~62,000) and the chymotrypsin-toxin (M_r ~60,000) were each subjected to gel permeation chromatography on a Superose 12 column attached to a Fast Protein Liquid Chromatography system. Fractions from this column were assayed for trypsin activity using 2 mM α-N-benzoyl-DL-arginine-*p*-nitroanilide HCl (BApNA) as substrate. The solubilised samples were stained for carbohydrates using periodic acid Schiff stain or flourescein isothiocyanate conjugated-concanavalin A (FITC-Con A) using standard protocols.

In a separate experiment, samples were separated by electrophoresis and then stained for trypsin-like activity using benzoyl-arginine-naphthylamide (BANA). The *N*-terminal amino acid was determined by automated Edman degradation using an Applied BioSystems protein/peptide sequencer. The amino acid derivatives (phenylthiohydantoin-amino acids, PTH-AA) were analysed by HPLC using a C-18 PTH reversed-phase column.

Under the culture conditions used, complete lysis of the bacterial cells occurred after 72 h and most of the released crystals settled at the bottom of the flask. Separation of the crystals from the spores and cell debris was achieved by low speed centrifugation. Analysis of these crystals by denaturing gel electrophoresis revealed that the major component of the crystal δ-endotoxin was a protein of M_r ~120,000. Upon solubilisation under alkaline pH and reducing conditions, the crystal yielded a protoxin of M_r ~64,000. This value is similar to that of other *Bt kurstaki* protoxins. Activation of the protoxin with bovine trypsin resulted in a shift in the molecular weight to a toxin of M_r ~62,000, while treatment with bovine chymotrypsin gave a toxin of M_r ~60,000. Staining with periodic acid Schiff reagent showed that the endotoxin was glycosylated. The carbohydrate moiety was found to be of the high mannose type as shown by staining with fluorescein isothiocyanate conjugated to concanavalin A. However, it is possible that O-glycosyl residues may also be present. Although other toxins have also been shown to be glycosylated, the function of these residues is not known. Following gel permeation chromatography on a Superose 12 column, the protoxin resolved into 6 main protein peaks, two of which had trypsin-like activity. Intracrystalline proteinases have been shown in other *Bt kurstaki* isolates. Although the exact nature of the proteinases is not known, they may be involved in crystal solubilisation and/or activation.

For bioassays involving *Chilo partellus*, the artificial diet maintained at 45°C was placed in petri-dishes. δ-endotoxin preparations were added to and thoroughly mixed with the slurry to give the required concentrations (25, 50, 100, 150 or 200 µg/ml). The diet was allowed to solidify at room temperature and 10 fourth instar *C. partellus* larvae, previously starved for 24 h, introduced into each Petri dish. Mortalities were scored at fixed time intervals for up to 72 h.

Teneral female *G. m. morsitans* were starved for 24 h. Each protoxin preparation was added to fresh rabbit blood to give the required concentration (25, 50, 100, 150 or 200 µg/ml). For bioassays of the sub-unit peaks from gel permeation chromatography, each protein preparation was added to rabbit blood to give a final concentration of 100 µg/ml. The tsetse were allowed to feed on the blood through an artificial membrane. Mortalities were scored at fixed intervals for up to 48 h, for the protoxin assays, and 56 h for the bioassays involving chromatographic fractions.

Third instar *Aedes aegypti* larvae were transferred into glass tubes containing distilled water (20 ml) and the protoxin preparation added to the water to give a final concentration of ~50 µg/ml. Larval mortality in each tube was recorded at fixed intervals for up to 48 h. The same experiment was repeated using a suspension of crystals in water. In this case, the concentration (based on dry weight) was ~500 µg/ml.

The endotoxin caused mortalities in *G. m. morsitans* (LC_{50} of 42.4 µg/ml) and fourth instar *C. partellus* larvae (LC_{50} of 53.8 µg/ml). The δ-endotoxin had no effect on third instar *Aedes aegypti* larvae. This finding correlates well with previous observations that antibodies against this isolate cross-react with the protoxin from a *C. partellus* isolate but not with *Bt israelensis* protoxin. The finding that this isolate causes mortality in tsetse is of interest although it is not clear how it might be used practically. However, it is possible that an appropriate formulation of the isolate can be applied onto the surface of cattle so that tsetse would pick it up with their blood meals. Indeed, *Bt* var. *thuringiensis* applied to sheep has been shown to provide protection against *Lucilia cuprina* for several weeks. *(See also report on* Bt *manufacture under the Technopark section).*

2. CONTROL OF ARTHROPODS USING A COMBINATION OF MICROBIAL AGENTS AND SEMIOCHEMICALS

The objective is to use semiochemicals to attract arthropods to a specific place where they can be contaminated with pathogens. The contaminated arthropods can also act as vehicles for disseminating the pathogens. A project on the use of *Metarhizium anisopliae* against ticks in combination with an attraction-aggregation-attachment-pheromone (AAAP) is being undertaken by a PhD student. A kairomone-baited tsetse trap is being tested for use in combination with a contaminating device containing fungi.

3. ARTHROPOD POPULATION GENETICS

The objective is to develop molecular tools for use in studying population structures of arthropods. Regardless of the methods selected for the management of arthropods, it is critical that there should be a detailed understanding of genetic diversity that may exist among different populations. A clear understanding of such diversity has several levels of application: (i) The extrapolation of research results, for example, how relevant a study conducted in West Africa would be to the East or South African situation, (ii) Awareness of how much diversity exists among local populations within and between geographical regions can help both in the interpretation of studies on pest/ vector biology and better understanding of population dynamics, habitat characteristics and dispersal patterns, (iii) The interaction between pests/ vectors and their natural enemies. For example, differences in behaviour may influence the efficacy of parasitoids. Research under this theme is focused on mosquitoes, banana weevil, ticks and honey bees.

4. MOLECULAR TAXONOMY

The objective is to develop and use molecular tools (e.g. DNA probes and specific primers) for characterisation of species (sub-species and biotypes). This activity provides an opportunity for collaboration with the Biodiversity Megaproject and NARES.

5. PARASITE–VECTOR RELATIONSHIPS

The objective here is to study the molecular mechanisms involved in the interactions between parasites and their arthropod vectors. Current work is on the factors in tsetse that influence development of trypanosomes. A blood meal-induced molecule that plays an important role in the differentiation of bloodstream trypanosomes into procyclic (midgut) forms has been isolated and characterised. Another high molecular weight protein (trypanolysin) that lyses bloodstream trypanosomes has also been identified. Research on its isolation and characterisation is underway. A PhD student working on this project is funded by WHO (TDR).

6. VECTOR–HOST RELATIONSHIPS

6.1 BLOOD MEAL IDENTIFICATION IN TSETSE FLIES

Background, approach and objectives

Identification of blood meals in arthropods is an important aspect of the epidemiology of vector-borne diseases. For example, tsetse flies prefer to feed on certain animal host species. This host preference determines, among other factors, whether an individual fly species is an efficient vector of human or animal trypanosomiasis. Knowledge of the preferred hosts is also important for the detection of the relevant animal reservoirs. In addition, the search for kairomones for specific fly species can be greatly facilitated by knowing the preferred hosts of the fly species in question. In general, blood meal identification can contribute towards the development of effective control strategies.

The objective is to analyse animal host preferences of the major tsetse fly species in Africa. The service will be offered at cost to tsetse scientists in Africa.

Participating scientist: *E. O. Osir*

Assistant: *J. Kabii*

Donor: *ICIPE Core Funds, EU*

Collaborators: *• Kenya Trypanosomiasis Research Institute (KETRI) • Kenya Wildlife Service (KWS) • University of Nairobi, Kenya • National Resources Institute (NRI) • University of Greenwich, UK • Ol Jogi Ranch (Nanyuki, Kenya)*

Work in progress

Midguts of blood-fed tsetse flies were removed from the abdomens and smeared on filter paper (Whatman No. 1 paper), impregnated with 0.1% sodium azide. These were air-dried and then stored in a desiccator containing silica gel and transported (preferably at 4° C). The filters were stored at -20°C on arrival at the laboratory. Using a clean pair of scissors, the blood-meal smears were cut out of the paper disc and eluted overnight at 4°C in 500 µl of 0.15 M phosphate buffered saline (PBS). The eluted test blood meals were coated on the wells of microtiter plates at dilutions of 1:200 in 0.05 M carbonate-bicarbonate buffer, pH 9.6. Control blood meals were also coated for every antibody conjugate tested. All the coated wells had 100 µl of antigen. The plates were incubated (overnight, at room temperature), and wells washed three times using 0.15 M PBS containing 0.5% Tween 80. Specific horseradish peroxide-conjugated antibodies were added to the wells at dilutions previously determined by Checker Board titrations and incubated for 1 h at 37°C. The wells were washed up to five times, and a substrate (hydrogen peroxide and ABTS) added and incubated for 1 h at room temperature. The absorbances were measured at 405 nm using a Titertek Plus MS 212 Plate reader. The values obtained were compared with those of the positive controls.

The following conjugates have been tested against homologous and several heterologous blood meal samples and their specificities assessed as follows:

(a) Specific conjugates (18 out of 31 conjugates): baboon, buffalo, camel, crocodile, giraffe, goat, Grants' gazelle, human, lion, monitor lizard, pig, ostrich, sheep, warthog, water buck, wildebeest, Thomson's gazelle and elephant.
(b) Non-specific conjugates: bovine, donkey, eland, impala and zebra.
(c) Not calibrated: bushbuck, bush pig, dik dik, hippo, kongoni, kudu, oryx and rhino.

Future work will include: (i) Completion of blood meal and conjugate dilution calibrations for group (c) animals using blood samples from Athi River and Ol Jogi Game Ranches and Kenya Wildlife Service (KWS). (ii) Improvement of antibody specificity for group (b) animals by production of antisera in rabbits using the method of Staak (1981) and preparation of new and more specific conjugates. (iii) Expansion of the range of conjugates available to include: Canidae (dogs), other felines (cheetah, leopard and domestic cat), chimpanzee, bongo, topi, reed buck, nyala, hartebeest and other tsetse hosts.

Output

Publications

Dossa S. C., Essuman S. and Kaaya G. P. Characterization of *Amblyomma variegatum* saliva and salivary gland antigens inducing anti-tick immunity in Boran cattle. *International Journal of Acarology* 24 (In press).

Dossa S. C., Kaaya G. P., Essuman S., Odulaja A. and Assoku R. G. K. (1996) Acquisition of resistance of the tick *Amblyomma variegatum* in Boran cattle, *Bos indicus* and the effects of *Trypanosoma congolense* and *Babesia bigemina* on host resistance. *Veterinary Parasitology* 62, 317–330.

Ekesi S., Maniania N. K., Onu I. and Löhr B. Pathogenicity of entomopathogenic fungi (Hyphomycetes) to the legume flower thrips, *Megalurothrips sjostedti* (Trybom) (Thysanoptera: Thripidae). *Journal of Applied Entomology* (In press).

Githiri S. M., Ampong-Nyarko K., Osir E. O. and Kimani P. M. (1996) Genetics of resistance to *Aphis craccivora* in cowpea. *Euphytica* 89, 271–276.

Githiri S. M., Ampong-Nyarko K., Osir, E. O. and Kimani P. M. (1996) Antixenosis component of resistance to aphids in the cowpea. *East African Agricultural and Forestry Journal* 61, 249–253.

Kaaya G. P. (1996) Mortality and pathology in tsetse flies (*Glossina* spp.) treated with neem extracts. *Tanzania Veterinary Journal* 16, 58–65.

Kaaya G. P., Mwangi E. N. and Ouna E. A. (1996) Prospects for biological control of livestock ticks, *Rhipicephalus appendiculatus* and *Amblyomma variegatum* using the entomogenous fungi, *Beauveria bassiana* and *Metarhizium anisopliae*. *Journal of Invertebrate Pathology* 67, 15–20.

Massamba N. N. and Mutinga J. (1996) Heterogeneity in *Leishmania donovani* complex (Protozoa;

Kinetoplastidae). *Insect Science and Its Application* 15, 541–550.

Mwangi E. N. and Kaaya G. P. (1997) Prospects of using parasitoids for tick management in Africa. *International Journal of Acarology* 23, 215–219.

Mwangi E. N., Hassan S. M., Kaaya G. P. and Essuman S. (1997) The impact of *Ixodiphagus hookeri*, a tick parasitoid on *Amblyomma variegatum* (Acari: Ixodidae) in a field trial in Kenya. *Experimental and Applied Acarology* 21, 117–126.

Nguu E. K., Osir E. O., Imbuga M. O. and Olembo N. K. (1996) The effect of host blood in the *in vitro* transformation of bloodstream trypanosomes by homogenates of tsetse midgut. *Medical and Veterinary Entomology* 10, 317–322.

Nyindo M., Essuman S., Chesang R. and Muteria P. (1996) Immunity induced by vaccination with *Rhipicephalus appendiculatus* salivary gland antigens does not augment protective immunity acquired naturally by exposing rabbits to the adult tick. *Journal of Medical Entomology* 33, 559–565.

Omollo E. O., Thomson J. A., Osir E. O. and James D. (1997) Cloning and expression of *Bacillus thuringiensis* gene encoding a M_r 130,000 crystal protein active against *Glossina* spp, *Chilo partellus* and *Spodoptera exempta*. *Current Microbiology* 34, 118–121.

Osir E. O. and Vundla W. R. M. Characterization of the endotoxins of a *Bacillus thuringiensis* isolate active against *Glossina morsitans* and a stem borer, *Chilo partellus*. *Biocontrol Science and Technology* (In press).

Osir E. O., Abubakar L., and Imbuga M. O. (1995) Properties of a bloodmeal-induced midgut lectin-trypsin complex from the tsetse fly, *Glossina longipennis*. *Parasitology Research* 81, 271–275.

Osir E.O. and Wamunyokoli F. W. (1995) Characterization of *Bacillus thuringiensis* variety *israelensis* delta-endotoxin. *Insect Science and Its Application* 16, 343–349.

Osir E. O., Magoma G. N., Ochanda J. O. and Olembo N. K. (1997) Purification and characterization of delta endotoxin from the parasporal body of *Bacillus thuringiensis* strain MF4B/2. *Comparative Biochemistry and Physiology* (In press).

Sebitosi E., Kaaya G. P. and Agbede R. I. Detection of lectins in the haemolymph and gut of *Rhipicephalus appendiculatus*. *International Journal of Acarology* (in press).

Solomon G. and Kaaya G. P. (1996) Comparison of resistance in three breeds of cattle against African Ixodid ticks. *Experimantal and Applied Acarology* 20, 223–230.

Solomon G. and Kaaya G. P. Development, reproductive capacity and survival of *Amblyomma variegatum* and *Boophilus decoloratus* in relation to host resistance and climatic factors under different field conditions. *Veterinary Parasitology* (in press).

Solomon G., Kaaya G. P., Gebreab F., Gemetchu T. and Tilahun G. Population studies of ticks feeding on indigenous cattle and incidence of tick-borne parasites in Didtuyura ranch in southern Ethiopia. *Insect Science and Its Application* (in press).

Tawfik A. I., Osir E. O., Hassanali A. and Ismail S. (1997) The effect of juvenile hormone on phase change and pheromone production of the desert locust, *Schistocerca gregaria* (Forskal) (Orthoptera: Acrididae). *Journal of Insect Physiology* 43, 1177–1182.

Zulu F. P., Okello-Onen J., Punyua D., Essuman S. and Malonza M. M. Ticks of wild and domestic animals from the coastal province of Kenya. *Insect Science and Its Application* (in press).

Research proposals

(Proposals submitted involving members of this department)

Development of an Integrated Strategy for the Management of Livestock Ticks (Funding: Toyota Foundation; ending in Nov. 1998) ICIPE, JIRCAS, KARI.

Validation of the Australian Model of the Tick, *Rhipicephalus appendiculatus* and Investigation of Its Use to Facilitate Collaboration with NARS (Funding: CSIRO; Just ended) ICIPE, CSIRO, KARI.

Evaluation of Entomogenous Nematodes for Tick Control (Funding: USAID, 3 years) ICIPE, KIMRON (Israel).

Sustainable IPM Program for the Control of Armyworm, *Spodoptera exempta* (Funding: USAID, 3 years) ICIPE, Tel Aviv, University of Vermont.

Entomopathogenic Fungus, *Metarhizium anisopliae*, for the Management of Thrips in Vegetable and Flower Crops (Funding: FPEAK, 1 year).

Microbial Control of Termites in Africa (Funding: ODA, starts Oct. 1998, 3 years) IITA, IIBC, ICIPE, NARS.

Studies on the Genetic Biodiversity in Banana Weevil, *Cosmopolitus sordidus*, Populations (Funding: Rockefeller Foundation, ends 1998) IITA, NARS.

Molecular Characterization of Factors Involved in Development of Trypanosomes in Tsetse Midgut (Funding: WHO/ TDR, 3 years) University of Nairobi; University of Bern; Yale University.

Development of Vaccines for the Sustainable Management of Ticks and Tick-Borne Diseases in Africa (Under prep. 4 years) University of Victoria, KARI, Vrije Universiteit, Brussel.

On-Farm Trials of Fungal Biopesticides for the Management of Harmful Termites in Small Scale Agriculture in Africa (Submitted: IFAD).

Development of *Metarhizium anisopliae*-based Biopesticides for Control of Thrips on Tropical Vegetable Crops (Concept note submitted: DANIDA) ICIPE, IIBC.

The Use of Neem for Tick Control (Under prep. 4 years) ICIPE, KARI, SUA.

Development of Environmentally-Friendly Control Methods for Tick and TBD for Small Holder Dairy Farms (Submitted; ADB, 4 years) ILRI, KARI.

Studies of Genetic Diversity in *Rhipicephalus appendiculatus* Populations in East, Central and Southern Africa (Concept note submitted: Wellcome Trust) ICIPE, KARI, OVI.

Conferences attended and papers presented

Osir E. O. Cloning and expression of *Bacillus thuringiensis* toxin active against two stemborers. 11th Scientific Conference of the African Association of Insect Scientists (AAIS), Cote d'Ivoire, 6–11 August 1995.

Osir E. O. A glucosamine-specific lectin complex: Role in tsetse-trypanosome interactions. Third International Conference on Tropical Entomology, Nairobi, Kenya.

Osir E. O., Wamunyokoli F. W., Ochanda J. O. and Olembo N. K. (1995) Studies on *Bacillus thuringiensis* delta-endotoxin effective against *Aedes aegypti* larvae. In *Proceedings of the African Regional Symposium on Biotechnology for Rapid Development*. Nairobi, Kenya, 17 March–1 February 1992.

Capacity building

Post-graduate students trained in 1995–1997 include the following:

F. Wamunyokoli (MSc). Isolation and characterisation of mosquito larval specific *Bacillus thuringiensis* endotoxin.

G. Magoma (MSc). Studies on the endotoxin of *Spodoptera exempta* specific *Bacillus thuringiensis*.

E. Omolo (PhD). Cloning and sequencing of endotoxins active against *Glossina morsitans* and *Chilo partellus*.

E. U. Kenya (PhD). Mechanisms for selective toxicity of newly isolated strains of *Bacillus thuringiensis*.

A. Saraswathi (PhD). Biology and control of *Tabanus triceps* (Thunberg) (Diptera: Tabanidae) using *Bacillus thuringiensis* as a potent larvicidal agent.

Harald Henninger (MSc). Development of production of *Bacillus thuringiensis israelensis (Bti)* (H-14) based biopesticide and its formulation for control of mosquito larvae (*Aedes aegypti* and *Culex quinquefasciatus*) using cheap and locally available materials in Kenya.

Godwin M. Zimba (PhD). Synthesis on the lectin-trypsin complex and its role in trypanosome differentiation in tsetse.

Abakar H. Mahamat (PhD). Isolation of *Glossina* trypanolysin and assessment of its use in the interruption of trypanosome differentiation.

E.K Nguu (PhD). Influence of host blood and its digestive products on trypanosome differentiation in tsetse fly, *Glossina morsitans morsitans* Westwood.

J. Kongoro (PhD). Vectorial capacity of tsetse in relation to midgut trypsin-like enzymes and other molecules.

IV. Social Sciences Department

Background, approach and objectives

The objectives of the Social Sciences Department (SSD) encompass both research and capacity-building activities as highlighted.

The basic challenge facing research institutions such as ICIPE is one of developing technologies which have the potential for wide adoption within the production and social systems which prevail in rural Africa and elsewhere in the tropics. An effective response to this challenge necessitates a research approach which is focused on meeting the technological needs of the potential clientele. The SSD has progressively come to play a catalytic role in promoting such a user-focused approach.

The scope of research activities of SSD has reflected the nature and stage of development of biological research in pest and vector management. However, the achievements made by the Department to-date can be appreciated from its activities in those projects in which it has played a leadership role. These projects include the Interactive Socioeconomic Research for Biointensive Pest Management (ISERIPM) in Kenya's Coast Province and the Community-Based Management of Tsetse and Trypanosomosis (CMTT) in Lambwe Valley.

In both of these projects, social scientists work hand-in-hand with biological scientists in order to effectively adapt pest and vector management technologies for the benefit of the rural populations of these regions. It is believed that these projects will make significant contributions to the development of research methodologies in this field. Among the guiding principles which underlie the methodologies being applied are interdisciplinarity, institutional collaboration and user participation.

In the ISERIPM project, the interdisciplinary team of researchers at the outset included an agroecologist, biocontrol specialist, plant scientists as well as an economist and a sociologist. The collaborating institutions have been the Kenya Agricultural Research Institute (KARI) and the Ministry of Agriculture, Livestock Development and Marketing (MOALDM). Close to 100 farmers participated in the various stages of adaptive research along with the scientists and extension staff of the MOALDM. They participated in the evaluation of technological components, on-station and on-farm, in the selection of research sites and participating farmers, and in the final selection of IPM menus based on their own evaluations of their appropriateness and efficacy.

In the CMTT project, the interdisciplinary team consists of a social anthropologist, economist, tsetse ecologist, agronomist and environmental specialist. The collaborators consist of the MOALDM, International Livestock Research Institute (ILRI) and from time to time representatives of other institutions. Community participation in tsetse and trypanosomosis control is the most central feature of this project. The farmers have taken on full responsibility for the construction of traps, their deployment, servicing, and the financing of the entire enterprise. As a result of their efforts, tsetse and trypanosomosis have been brought down to negligible levels in the study community. Key research tasks which remain are the monitoring of the on-going activities in order to ensure the sustainability of community-based approach of tsetse and trypanosomosis control, and the evaluation of the impacts on land use, the environment and human welfare.

Strategic discussions on the future of the Social Sciences Department were undertaken in 1997, primarily by means of strengths, weaknesses, opportunities and threats (SWOT) analysis. Based on the SWOT analysis and the discussions of the SSD scientists, the following were proposed as thematic areas of research focus of the Department:

(a) technology design, adaptive research;
(b) farmer / pastoralist participation, gender analysis;
(c) adoption studies;
(d) sustainability;
(e) technology impact assessment; and
(f) policy issues in pest and vector management.

However, given the limited research capacity of the Department, it was proposed that the focus should be on impact assessments and policy issues (e and f).

It is increasingly being recognised that changes that occur as a result of technological interventions in vector and pest management need to be monitored and systematically evaluated. Often, there are primary impacts followed by secondary ones in the medium and long-term periods of technology application. Technologies may also have intended and unintended effects which need to be identified and evaluated. The dimensions of impact studies are also multiple and include material benefits, community empowerment, and environmental consequences among others. Such impacts need to be evaluated by means of methodologies which are holistic and which combine quantitative and qualitative techniques.

The success of research and capacity-building efforts of institutions such as ICIPE will ultimately depend on the conditions which prevail in the policy environment. Although the policy domain encompasses numerous actors, the focal area of research in developing countries is likely to continue to be the government domain. Many research issues need to be addressed from a policy perspective, including pests and vector management capacities, legal and policy prescriptions, economic and political forces affecting policies, etc.

Below are highlights of the Department's activities.

1. INTERACTIVE SOCIOECONOMIC RESEARCH FOR BIOINTENSIVE PEST MANAGEMENT (ISERIPM) PROJECT

1.1 SOCIOECONOMIC ASPECTS OF CROP COMPONENT

Participating scientists: *F. G. Kiros*, G.T. Lako, K. Ampong-Nyarko, A. Odulaja, P. Chitere (*Project coordinator)*

Assistants: *P.E. Ragama, Z. Ngalo, G.O.G. Nyambane, B.A. Omolo, O. Nyapela, G. Nengo, S. Oluoch, N. Dibogo, M. Mungai, M.O. Wango*

Donor: *Rockefeller Foundation*

Collaborators: • *Kenya Agricultural Research Institute (KARI)* • *Ministry of Agriculture, Livestock Development and Marketing* • *Provincial Administration* • *Farmers*

The ISERIPM Project has two main components: the crop pests component being implemented in the Coast Province and the Livestock Ticks component being carried out on Rusinga Island in Nyanza Province. The project was collaboratively conceived by ICIPE's social and biological scientists. It has two principal objectives:

- to undertake adaptive and evaluative research on pest management technologies pertaining to selected staple food crops and livestock in appropriate agroecological zones of Kenya; and
- to develop interactive socioeconomic interface research methodologies for crop and livestock pest management.

The IPM technologies adapted in Kwale and Kilifi Districts were: insect-pest resistant maize and sorghum cultivars; strip and relay intercropping of these cereals with selected component crops; the application of *Bacillus thuringiensis* (*Bt*) for control of stemborers; and use of neem extracts primarily for control of cowpea pests.

The first phase (1993) of implementation consisted of on-station trials during which IPM technologies that had been developed in western Kenya were tested for adaptability under conditions at the Kenyan coast. In the second phase (1994), on-farm scientist-managed trials were carried out at eight sites and permitted further evaluation of the adaptability of the technologies under varying coastal conditions. This was also a phase during which 89 farmers were chosen to participate in the on-farm trials. They assisted in evaluating the performance of the technologies and attended a number of educational sessions including workshops, and an educational tour that were aimed at imparting know-how to them about insect pests and their control using IPM components.

Phase 3 of the project (1995) sought to achieve the following objectives:

(a) application of suitable IPM options by farmers with some guidance by scientists;
(b) monitoring farmer adoption process, modifications of IPM and emerging constraints to the process;
(c) strengthening farmers' management capabilities in the use of resources;
(d) performing economic analysis and evaluation of IPM options; and
(e) assessing potential for sustainability of IPM technologies.

In mid-1995, a thorough review was made of the research activities carried out since 1993 which revealed the need for extension of the Project for two more years (1996–1997). However, an extension was granted for only one year. This necessitated that the activities of 1996 focus on two main objectives: (a) to enhance the adoptability of the IPM technologies by responding to farmers' evaluations and suggestions; and (b) to provide adequate support in order to enable the continued use of the technologies by the participating farmers as well as others. This was done through capacity building of extension staff and farmers, and making provisions for the supply of essential inputs such as seeds and *Bt* for use during the final phase (1997).

Accordingly, a plan of work was developed and strenuous efforts made to implement it throughout the 1996 season. In spite of the many difficulties encountered, not least of which was the loss of the Senior Research Assistant in the field, the planned activities were substantially achieved.

1.2 BIOLOGICAL ASPECTS OF CROP PESTS COMPONENT

1.2.1 *Farmer-managed trials*

Participating scientists: *K. Ampong-Nyarko, S. Sithanantham*

Assistants: *Z.N. Ngalo, J.A. Mwanda, P.O. Akello*

The various components of the ICIPE improved pest management technology contributed to the reduction in yield loss due to stemborers in the 1994 on-farm scientist managed results. Strip relay intercropping reduced borer infestation and increased multiple cropping index and land use intensity. Sorghum Hyd-6 and maize ICZ5 were demonstrated to be tolerant to the stemborers. *Bt* gave significant reductions in insect infestations.

On-farm trials were conducted in 1996 to modify IPM components based on the experiences of 1995 to enable a fine tuning of recommendations. The specific objectives were:

(i) To introduce technological options for the control of the main pests of maize, sorghum and cowpea;
(ii) To improve efficacy, profitability and sustainability of IPM technologies by introducing different companion crops.

Without initiating another cycle of on-station testing, farmers were encouraged to modify the technologies. This was a straight comparison of researcher-recommended technology that had been tested in the previous two years with current farmer practice under a wide range of farmers' conditions. Farmers were encouraged to modify the technology (cropping pattern, cultivar, *Bt*/neem application) on their own plots (size was 25 x 25) for maize trials. As part of farmer modification of technologies, farmers were encouraged to plant companion crops of their choice instead of cassava and cowpea used in earlier years.

Farmers also made their own decisions on plant spacing of their crops and they had the option to use either neem or *Bt* for stemborer control in their maize and sorghum crops. In addition, those farmers who planted cowpea could use neem against the multiple pests of cowpea. Maize cultivars ICZ-5, IC92M5 and Coast Composite were provided for the farmer to make a choice. The project technicians advised farmers to plant early in the season. Project technical staff were also at hand during planting to offer assistance during planting experiments. In addition to farmer modification of technologies, there were two controls that were planted by some farmers who had additional land to spare: the initial proposed technology, and modification of that technology.

The IPM menus were also tested in 1996 in other agroecological zones of Kenya.

1.2.2 *On-station back up testing of technologies for on-farm trials*

Participating scientists: *S. Sithanantham, K. Ampong-Nyarko*

Assistant: *Z. Ngalo*

Collaborators: • *KARI* • *Ministry of Agriculture Livestock Development and Marketing (MOALDM), Kenya*

One of the components of pest management being evaluated in this project was early intercropping of cowpea in maize with the aim of reducing the severity of stemborer in the latter crop. This practice involves a shift from the locally common relay intercropping of cowpeas. The extent of avoidable losses due to insect pests among cowpea genotypes when planted early and the scope for minimising the losses by neem sprays were to be determined as a backup for the on-farm testing of this technology component.

(The full report is found in report VIII in the section on Plant Health Management.)

1.3 LIVESTOCK TICKS COMPONENT

Participating scientists: *G.P. Kaaya*, J. W. Ssennyonga, S. M. Hassan (*Project leader)*

Assistants: *P.O. Ngoko, J.O. Odhiambo, R.O. Yogo, M. Ayugi*

Collaborators: *Ministry of Agriculture, Livestock Development and Marketing (MOALDM), Kenya*

Ticks and tick-borne diseases (T&TBDs) constitute the second most important constraint (after tsetse) to livestock production in Africa. Unfortunately, conventional methods of managing T&TBDs are both costly and environmentally unsafe. This is why ICIPE's strategy is to develop low-cost and environment-friendly control strategies. Two of these strategies were incorporated into this project.

First, biological work focused on two related cultural control strategies, namely, the generation of information on tick host-seeking behaviour and the drop-off rhythms of engorged ticks. Complementary socioe-conomic studies investigated the grazing behaviour of livestock to determine the feasibility of farmers modifying the grazing behaviour of their livestock so as to incorporate the biological information into their tick control strategies.

Second, the potential of chickens as biological control agents of livestock ticks had been demonstrated by the finding that chickens, under experimental conditions, reduced, through predation, up to 47% of the ticks on cattle. Complementary socioeconomic research had also showed that: (i) the chicken population managed under indigenous husbandry was unstable, due largely to endemic lethal diseases; (ii) chickens, owned and managed by women, were housed in 2–5 different shelters, making it difficult to achieve significant predation.

Farmers were trained in 1995 in key aspects of tick biology, TBDs and chicken health. Following this, researchers in close collaboration with farmers, designed two interventions in the health and housing of chickens. Starting in October 1995, through 1996, farmers implemented these interventions.

(The full report of this aspect of the ISERIPM project is to be found under the Ticks report XIII).

2. COMMUNITY-BASED MANAGEMENT OF TSETSE AND TRYPANOSOMOSIS (CMTT)

2.1 AN INTEGRATED APPROACH TO TSETSE AND TRYPANOSOMOSIS CONTROL TECHNOLOGIES AND THEIR IMPACTS ON AGRICULTURAL PRODUCTION, HUMAN WELFARE AND NATURAL RESOURCES

Participanting scientists: *J.W. Ssennyonga, J.M. Maitima, M. Mohamed Ahmed, F.G. Kiros*

Assistants: *M. Were, R. Tumba, J. Obinga, S. Akinyi*

Donors: *IFAD, NRI, ODA*

Collaborators: *• ILRI • Ministry of Agriculture, Livestock Development and Marketing (MOALDM), Kenya*

Background

ICIPE tackles the control of tsetse transmitted trypanosomosis through the control of the tsetse vector. The overall aim has been to develop technologies that are acceptable and sustainable. To ensure adoption and sustainability of the technologies, socioeconomic and cultural considerations have to be incorporated into R&D as well as other phases of technology development.

Since March 1996, the community in Nguruman has held meetings to mobilise themselves and resources for the purpose of tsetse control in the area. In all, 16 meetings were held to date with a total attendance of 461 persons.

Olkiramatian location has four sub-locations and all the four are involved in tsetse trapping. The community is organising itself and executing new ways of raising resources.

2.1.1 *Socioeconomic component*

The development of control technologies for trypanosomosis, the single most important vector-borne disease constraining agricultural development in 37 African countries spanning 10 million km^2, reached a turning point at the close of the 1980s. Researchers reached a consensus that focus should shift away from developing new control technologies to finding solutions to three problems:

(1) Models should be developed for putting the technologies in the hands of end-users. Reports of efforts to involve communities in managing trypanosomosis using traps had indicated that after the initial success, enthusiasm tended to wane in the course of time, highlighting the need for focusing on issues of sustainability.
(2) The impact of control technologies on livestock productivity and incomes needed to be demonstrated.
(3) There was concern that tsetse control would lead to environmental degradation (through overstocking and deforestation) and eventual extermination of wildlife.

Against this background, ICIPE, with funding from ODA through the Natural Resources Institute (NRI), and in collaboration with Kenyan ministries, carried out a study, 1992–1996, in Lambwe Valley, western Kenya, focusing on the three problems.

Financial support from IFAD enabled ICIPE, in collaboration with the International Livestock Research Institute (ILRI), to continue with research on the same issues at greater depth and on a longer term. The new project was envisioned as a two phase, six year research programme, 1995–2000.

(The full report is in the section on Tsetse Research, projects X–XII).

2.1.2 *Environmental impact assessment component*

Participating scientist: *J.M. Maitima*

Assistant: *R.O. Tumba*

Donor: *IFAD*

Collaborator: *ILRI*

The ecological impacts of controlling tsetse-transmitted livestock and human trypanosomosis, has been the centre of controversy for nearly a century. In the last few decades, research in this area has focused on the impacts of pesticides on non-target organisms. However, the strongest concerns about controlling trypanosomosis have always revolved around the fear that the release of this constraint on livestock production will lead to over-grazing, deforestation, and inappropriate land-use across the 10 million km^2 of territory inhabited by tsetse flies in Africa. Unfortunately until recently, there has been no research to investigate these indirect environmental consequences of tsetse control.

In 1995 ICIPE undertook research to study the ecological impacts of trypanosomosis control in Lambwe Valley of western Kenya as one of the research components in this project. The aim of this component was to assess the impacts of increased livestock production on the farm, household, natural resources and ecosystem function. Specific environmental research areas included impact studies on changes in land-use and other resource use, the structure and function of ecosystems, and biodiversity.

(The full report is in the section on Tsetse Research, report XII).

2.2 ADOPTION OF TRAPPING TECHNOLOGIES BY AGROPASTORAL COMMUNITIES IN NGURUMAN

Participating scientist: *G.T. Lako*

Assistants: *R. Emongor, G.O. Nyambane, D.K. Kahuria, P. Mwasa*

Donor: *EU*

Collaborators: *• Ministry of Agriculture, Livestock Development and Marketing (MOALDM), Kenya • Kajiado District Development Committee • KETRI • Ethiopian Science and Technology Commission (ESTC)*

(See the Tsetse report X, item 14).

2.3 GENDER ANALYSIS OF COMMUNITY-BASED MANAGEMENT OF TSETSE

Gender is an important organising principal, especially for the division of labour. In many Third World regions, women perform most of IPM activities. Yet, little has been done to incorporate gender sensitivity into the development and implementation of IPM technologies. Apropos of this, ICIPE and ODG/UEA designed and are implementing a project aiming at carrying out gender analysis of community-based management of tsetse as part of a comparative study of the effectiveness, impact and sustainability of community-managed tsetse (CMT) in East and Southern Africa.

Participating scientists: *J. W. Ssennyonga, C. Okali (ODG/UEA), Karen Barret (ODG/UEA)*

Donors: *ODA*

Collaborators: *• ODG/UEA • NARES in Kenya and Zambia*

The initial step was to develop a theoretical and methodological framework base on which a research protocol was drawn up. This was followed by the compilation, analysis and write-up of data from secondary sources. Gaps in data were identified and are being filled up with material collected from field work now underway.

Output

Report

Gender as a Factor in Community-Managed Tsetse and Trypanosomosis in Lambwe Valley, Western Kenya.

3. NEEM AWARENESS PROJECT

Participating scientists: *R. C. Saxena (Project Coordinator) P. O. Chitere (University of Nairobi)*

Donor: *Government of Finland, UNEP*

Collaborator: *University of Nairobi*

The use of simple formulations or mixtures of bioactive components in the neem seed is an attractive option for pest management, especially for the resource-poor farmers in Africa.

The Social Sciences Department has been active in promoting this useful 'botanical' agent. Approximately 550 persons from seven East African countries, and non-target countries such as South Africa, Mozambique, the Sudan and Somalia (on special request or sponsorship), have been trained in six regular and four satellite training workshops. A special seminar was organised for over 50 senior government officers, policymakers, and others in Nairobi in September 1997. Another 200 persons were trained on uses of neem in one-day seminars held during the same period. One student has completed his PhD thesis on 'Management of the maize weevil with neem' and others are about to complete. Also, a number of students from technical schools completed their non-degree training programmes under the project.

As a result of the awareness created under the Neem Project, planting of neem trees and production and use of neem derivatives from pest control are gaining popularity in many countries in sub-Saharan Africa.

Awareness of neem is growing in the eastern and southern African region, in large part, due to ICIPE's Neem Awareness Project. Since 1994, more than 50,000 seedlings and about 200 kg of viable seed have been distributed among farmers, schools, churches, NGOs and other interested groups in Kenya. Since inception of the Neem Project in Mbita, awareness of neem's potential has already been created and the communities have planted more than 2000 neem trees; the Rusinga United Development Group, a local women's organisation, has raised a nursery of 6000 neem seedlings from the seed provided by the Project. This has stimulated the establishment of numerous private nurseries in Kenya and its neighbours. At Kwimba Afforestation Project site in Tanzania, neem is being planted at the rate of 0.5 million seedlings annually.

(See report IX for more details).

Output

(See under the various project reports).

Proposal written

IPM Impact Assessment in Coastal Kenya (as a follow-up to the ISERIPM Project)

Capacity building

Capacity building constitutes an integral part of the research process in the SSD. Indeed, the training of farmers constitutes at once the launching pad and engine of community participation in technology adaptation, evaluation, adoption and management processes. This is especially the case in the CMTT project where the entire research activity began with the training of a catalytic group of farmers who then undertook the responsibility for the mobilisation and training of the rest of the population for tsetse and trypanosomosis control.

The training of research collaborators, especially extensionists, is also an on-going process. Often, representatives of collaborating institutions take part in all community training activities and consultative meetings. It is believed that such information sharing and interaction can facilitate the wider adoption of pest and vector management technologies.

In addition to the training of farmers and extensionists, the SSD also takes part in the international group training programmes organised by the Centre from time to time, and in the supervision of PhD students.

When course work was provided as part of the training of the ARPPIS PhD programme, SSD staff also presented lectures on selected topics in the Social Sciences.

CONTENTS

Research Support Units and Services

I. Biostatistics Unit

Background, approach and objectives

During 1995 and 1996, the Biomathematics Unit catered for biostatistics research and services, modelling, and GIS at the Centre. The Unit operated within a sub-optimal staffing level during this period; however, it made significant contributions and achievements in all the areas. In 1997, the Unit was renamed Biostatistics Unit and catered for biostatistical research, consultation and training at the Centre. The Unit also provided modelling and statistical ideas to many research projects during this period.

Modelling activities were undertaken in the areas of tsetse and ticks research, and biostatistical research aimed at improving design and analysis of experiments in field crops research. Research also included in-depth statistical exploration of research data to elucidate optimum information. Biostatistical consultations were offered in the areas of design of experiments, analysis of data, interpretation of results, statistical software installation, trouble shooting and programming.

GIS services, which continued to be demanded by most projects, were provided in collaboration and consultation with relevant institutions such as the Department of Resource Survey and Remote Sensing (DRSRS), the Regional Centre for Services in Surveying, Mapping and Remote Sensing (RCSSMRS), and the GIS sections of the International Livestock Research Institute (ILRI), and the International Centre for Research in Agroforestry (ICRAF).

Participating scientists: *A. Odulaja (1995, 1996, 1997) (Head of Unit), D.M. Munyinyi (1995, 1996), C.N. Olando (1995, 1996, 1997), H.H. Meena (1995), O.O. Okello (1995, 1996), P.K. Ogino (1996)*

Donors: *ICIPE Core Funds, EU, UNDP*

Collaborators: *ICIPE scientists: M. M. Mohamed-Ahmed, I. M. Abu-Zinid, L. C. Madubunyi, S. Mihok*

Work in progress

1. IMPROVING DESIGN AND ANALYSIS OF EXPERIMENTS IN TSETSE RESEARCH

1.1 HOW EFFICIENT IS THE LATIN SQUARE DESIGN FOR TSETSE TRAPPING EXPERIMENTS?

The superiority of the latin square design (LSD) over the simpler and more-flexible-to-execute alternative—the randomised complete block design (RCBD)—is usually taken for granted. The LSD is able to eliminate two sources of variation compared to one eliminated by the RCBD, in addition to treatment effect. However, the LSD is less efficient than the RCBD when the day x site interaction effect is appreciable or when one of the two sources of variation (site and day) is statistically unimportant.

We extensively quantified both the efficiency of the LSD relative to RCBD, and the relative importance of site and day variations, in tsetse trap catches. The conditions, in terms of number of sites and days, under which the LSD is most advantageous were discovered. The dependency of this advantage on the relative size of site effect was elucidated, while the relative importance of site and day effects was also quantified. This information is important in determining the most appropriate sampling method for tsetse, and for the design and interpretation of results of tsetse trapping experiments. Details are given under the Tsetse Megaproject report.

1.2 ESTIMATION OF THE ABSOLUTE EFFICIENCY OF TSETSE TRAPS

The usually employed technique for determining the absolute efficiency of tsetse traps involves placing an incomplete ring of electrified nets around a test trap to estimate the total number of flies which approached and the proportion actually caught by the trap. The method assumes that the flies neither avoid nor fly over the ring of nets while approaching or departing from the trap. We developed a hypothesis to test these assumptions and obtained results to the effect that the assumptions are not satisfied in the case of *Glossina fuscipes fuscipes*.

We then developed analytical approaches to correct for the assumptions in the estimation of absolute efficiency of the tsetse trap. These approaches were employed to estimate the absolute efficiency of the unbaited biconical trap for *G. f. fuscipes*. This gave a more reliable estimate of trap efficiency, and hence, should allow for better planning of trap optimisation and deployment for tsetse suppression. Details are given under the Tsetse Megaproject report X.

1.3 QUANTIFICATION OF THE SAMPLING BIAS OF TSETSE TRAPS

Various studies have suggested that all tsetse traps are biased in one way or another. A detailed knowledge of these sampling biases is needed to enable the translation of sample data into field population data. This knowledge could also lead to better evaluation of traps for tsetse control and better planning of tsetse control using traps. The sampling bias, in addition to the efficiency of tsetse traps, determines how effective the traps can be in controlling the fly population. We therefore developed models for quantifying the sampling bias of odour baited traps, in relation to the hunger status of tsetse flies.

Using this model, we investigated the changes in the tsetse population due to natality and mortality. We also investigated the probable effect of the bias on the overall population loss rate in a tsetse control campaign. We then used simulation techniques to quantify the sampling bias, and its effects, of the ICIPE NGU traps baited with cow urine. Details are given under the Tsetse Megaproject report X.

1.4 HOW IMPORTANT IS SPATIAL BY TEMPORAL INTERACTION EFFECT IN TSETSE TRAP CATCHES?

Site and time effects are important factors determining trap catches of tsetse flies. These factors may interact significantly and therefore confound interpretation of time series data used for population monitoring. We therefore investigated the magnitude and importance of site x time interactions in trap catches of *Glossina pallidipes* Austen and *G. longipennis* Corti (Diptera: Glossinidae) using a 2200 trap-days (400 trap-months) data set.

The interaction was found to be significant ($P < 0.05$) in 46–100% of the combination of different numbers of months and sites between 2 and 12. The mean percent variance due to the interaction, ranged between 4 and 28% for *G. pallidipes* and 12 and 36% for *G. longipennis*. The interaction was usually less important than the effect of site alone, but more important than the effect of time alone.

These results suggest that tsetse researchers should examine critically the adequacy of existing approaches to population monitoring with traps and testing new traps and odour baits. Details are given under the Tsetse Megaproject report X.

(See also the Ticks Megaproject report (XIII) for other work of this unit).

Output

Publications

Ajala S.O., Smith L.M. and Odulaja A. (1995) Potential of Kenyan local maize (*Zea mays* L.) germplasm as sources of resistance to the spotted stem-borer, *Chilo partellus* (Swinhoe). *Tropical Agriculture (Trinidad)* 72, 297–302.

Dossa S.C., Kaaya, G.P., Essuman S., Odulaja A. and Assoku R.G.K. (1996) Acquisition of resistance to the tick *Amblyomma variegatum* in Boran cattle, *Bos indicus* and the effects of *Trypanosoma congolense* and *Babesia bigemina* on host resistance. *Veterinary Parasitology* 62, 317–330.

Kitron U., Otieno L.H., Hungerford L.L., Odulaja A., Brigham W.U., Okello O.O., Joselyn M., Mohamed-Ahmed M.M. and Cook E. (1996) Spatial analysis of the distribution of tsetse flies in the Lambwe Valley, Kenya, using TM satellite imagery and GIS. *Journal of Animal Ecology* 65, 371–380.

Mohamed-Ahmed M. M. and Odulaja A. (1997) Diel activity patterns and host preference of *Glossina fuscipes fuscipes* along Lake Victoria shores, Homa Bay District, Western Kenya. *Bulletin of Entomological Research* 87, 179–186.

Mutinga M.J., Odhiambo T.R., Kamau C.C., Odulaja A., Amimo F.A. and Wachira D.W. (1995) Choice of resting sites by *Anopheles gambiae* (Diptera: Culicidae) in Mwea rice irrigation scheme, Kirinyaga District, Kenya. *East African Medical Journal* 73, 170–175.

Odulaja A. (1995) A modelling study of agricultural production of African small scale farmers, pp. 132–139. In *Proceedings of the Fourth Meeting of the East, Central and Southern African Network of the International Biometric Society*, Stellenbosch, Republic of South Africa. 5–7 December, 1995.

Odulaja A. (1996) Modifications to the evaluation of intercropping advantage. *Tropical Agriculture* 73, 231–233.

Odulaja A. (1997) Detecting significant differences in comparative experiments, pp. 85–88. In *Proceedings of the Fifth Scientific Conference of the East, Central and Southern African Network of the International Biometric Society*, Mombasa, Kenya. 22–25 September 1997.

Odulaja A. and Abu-Zinid I.M. (1997) The relative efficiencies of the latin square design and complete randomised design for insect trapping experiments: An investigation using field data on tsetse flies. *Ecological Entomology* 22, 184–188.

Odulaja A. and Kiros F.G. (1996) Modelling agricultural production of small-scale farmers in sub-Saharan Africa: A case study in Western Kenya. *Agricultural Economics* 14, 85–91.

Odulaja A. and Madubunyi L.C. (1997) A sampling bias model for odour-baited traps in relation to tsetse hunger cycle and population suppression. *Ecological Modelling* 104, 165–173.

Odulaja A. and Mohamed-Ahmed M. M. (1997) Estimation of the efficiency of the biconical trap for *Glossina fuscipes fuscipes* along the Lake Victoria shores, Kenya. *Entomologia Experimentalis et Applicata* 82, 19–24.

Odulaja A. and Nokoe S. (1995) A serial correlation analysis of experimental field scores. *Discovery and Innovation* 7(1), 6–10.

Odulaja A. and Nokoe S. Conversion of yield data from experimental plot to larger plot units. *Discovery and Innovation* (In press).

Odulaja A., Mihok S. and Abu-Zinid I. M. The magnitude of site x time interaction effect in tsetse flies (Diptera : Glossinidae) trap catches. (In press).

Conferences/workshops attended

Tenth International Conference on State of the Art of Ecological Modelling (ISEM'95), Beijing, China. 11–15 August 1995.

Fourth meeting of the East, Central and Southern African Network of the International Biometric Society, Stellenbosch, Republic of South Africa. 5–7 December 1995.

National Workshop to Revise the Tsetse Distribution Map of Kenya, Kenya Trypanosomiasis Research Institute, Muguga, Kenya. 17–18 April 1996.

First International Conference on Multiple Comparison Procedures, Tel Aviv, Israel. 23–26 June 1996.

XVIIIth International Biometric Conference, Amsterdam, The Netherlands. 1–5 July 1996.

CTA Workshop on 'Strengthening Biometry and Statistics in Agricultural Research', University of Hohenheim, 7–9 October 1996.

International study workshop on 'Integrated Rural Development Through Sustainable Management of Tsetse, Trypanosomosis / Mosquito, and Malaria: The Way Forward', Addis Ababa and Axum, Ethiopia, 3–8 February 1997.

AMS-IMS-SIAM Summer Research Conferences in the Mathematical Sciences: "Statistics in Molecular Biology", Seattle, Washington, USA, 22–26 June 1997.

AMS-IMS-SIAM Summer Research Conferences in the Mathematical Sciences: "New developments and applications in experimental design", Seattle, Washington, USA, 29 June–3 July 1997.

International workshop on Global Change Impact Assessment Approaches for Vector and Vector-Borne Diseases, ICIPE, Nairobi, Kenya, 3–6 September 1997.

Tick Modelling Workshop, ICIPE, Nairobi, Kenya, 9–19 September 1997.

Fifth Scientific Conference of the East, Central and Southern African Network of the International Biometric Society, Mombasa, Kenya, 22–25 September 1997.

Capacity building

The Unit continued to assist ARPPIS students in design and analysis of their experiments. A one-month course in biostatistics was conducted for ARPPIS students during 1997. In 1996, a PhD student graduated, who was also the first woman to earn a doctorate in Mathematics at Makerere University, Kampala, Uganda:

- Nabasirye M. (1996) Statistical inference on pest resistance indexes. PhD (Biometrics), Makerere University, Kampala, Uganda. Awarded 18 September 1996.

The Unit presented lectures in the 'International Group Training Course on Integrated Tsetse Management', held at ICIPE, Nairobi, during 1–30 November 1995 and 5 November–5 December 1997.

The Unit also gave lectures at the first refresher statistical course for Kenya Agricultural Research Institute (KARI) biometricians, organised by KARI/ODA Biometric Support Project, and held at the CMRT, Egerton University, Njoro, Kenya. (16–20 December 1996).

Six students from institutions of higher learning in Kenya were hosted by the Unit for industrial attachment training in statistics and statistical computing, during these three years.

Impact

- Considerable increase in biostatistical awareness among students and scientists.
- Improved design and analysis of experiments.

II. Animal Rearing and Quarantine Unit

Background, approach and objectives

Provision of quality laboratory-reared insects and experimental animals in adequate quantities and of quality for use within the various research projects and research units, is the main focus and activity of the Animal Rearing and Quarantine Unit (ARQU). In order to meet this objective, ARQU carries out research and development (R&D) on new techniques of arthropod rearing and mass production, and in the breeding and handling of small laboratory mammals. An important attribute of this work is the assessment of the quality of the insects and animals produced so as to ensure that their biological performance and fitness is as near and representative of the original populations as possible.

Over the years, ARQU has considerably developed its potential as a regional, international resource and advisory centre of excellence in insect rearing technology. In 1997, the unit upgraded its facilities to provide a biologically secure laboratory facility. This facility was built and equipped under the Wageningen Agricultural University/ICIPE collaborative project on the biological control of cereal stemborers. This quarantine facility will enable ICIPE to import a variety of arthropod species, potential plant and animal microorganisms and maintain their cultures under biologically secure conditions that exclude possible escape.

To fulfill the R&D and training needs of ICIPE as outlined in its current five year plan, the ARQU has organised its activities to reflect the areas of mandate of the Centre. ARQU provides three key services to ICIPE's R&D, namely Insectary Services, Animal Breeding Services and Quarantine Services. The Insectary Services is the major activity and provides arthropod rearing services in seven areas, namely gramineous crop pests, mosquito rearing, migrant pests, horticultural pests, ticks, tsetse and rearing of beneficial organisms for Biodiversity Conservation. The Animal Breeding Services provides support in terms of the breeding of small mammals (rabbits, rats, mice and hamsters) and a facility for large animal holding (currently cattle and goats).

ARQU also carries out capacity building programmes for a variety of R&D practitioners ranging from scientists, technologists and technicians from national programmes on techniques of insect rearing.

Participating scientists: *M. O. Odindo, (Unit Head 1995–1997), J.P.R. Ochieng'-Odero (Unit Head from November 1997)*

Assistants: *F. O. Onyango, A. G. Nyangwara, P. O. Wagara, J. H. Ongudha, F. M. Thuo, J. O. Kokungu, S. A. Patya, M. M. Miti, J.M. Onyango, P. S. Muchisu, A. Majanje*

Donors: *ICIPE Core Funds, Netherlands Government, IFAD, USAID, UNDP, EU, Austrian Development Cooperation (ADC)*

Collaborators: *• KARI • KEMRI • KETRI • NMK*

Work in progress

1. PRODUCTION AND SUPPLY OF TARGET PEST SPECIES

1.1 INSECTARY SERVICES

1.1.1 *Gramineous pests rearing*

During the period under report, ARQU has met the demands of the various research projects by production and supplying target cereal pests (*Chilo partellus, Busseola fusca, Eldana saccharina* and *Sesamia calamistis*). The production of the cereal stemborers was a major preoccupation of the unit. Various departments and projects within ICIPE used egg, larval, pupal and adult stages of the pest species. The demand for *C. partellus* continued to dominate those of other species. Most of the borers produced were used by the Stemborer Biological Control Project for the production of the parasitoid *Cotesia flavipes*.

Rearing of *C. partellus* is now well established within based on rearing on a semi-synthetic diet in which the main constituent is local Rosecoco bean (*Phaseolus vulgaris*) powder, and ground sorghum leaves. An average of 30 jars are inoculated with blackheads or newly emerged larvae every two days. Diet contamination is a major challenge to the shelf-life of the diet and sterilisation of eggs, and folding the blackheads in sterilised tin foil is an important technique used to minimise diet spoilage.

The rearing of *Busseola fusca* solely on a semi-synthetic diet continues to be a major success of the unit. However, it is important to occasionally replenish the laboratory culture with field collected material to ensure that fitness and biological performance are maintained. The total supply of the various stemborers produced within ARQU in the three year period is indicated in Figure 1.1 and Figure 1.2 indicates the proportions of the various stages supplied in 1997. Percentages of semi-synthetic diet supplied to various users in 1997 is represented in Figure 1.3.

1.1.2 *Mosquito rearing*

Mosquito production has steadily declined from 1995. Limited colonies of *Aedes aegyti* and *Culex quinquefasciatus* were maintained to meet the requirements of the ICIPE/Hebrew University Project, the Molecular Biology and Biotechnology Department (MBBD) and to support a number of ARPPIS postgraduate scholars. In 1997 alone, some 98,363 *A. aegypti* and 71,169 *C. quinquefasciatus* were produced. *Anopheles gambiae* rearing has recently been initiated in the unit in anticipation of expanded malaria research. In this regard, the unit has expanded its mosquito rearing facilities to meet the challenges of the future, especially to handle both clean and infected

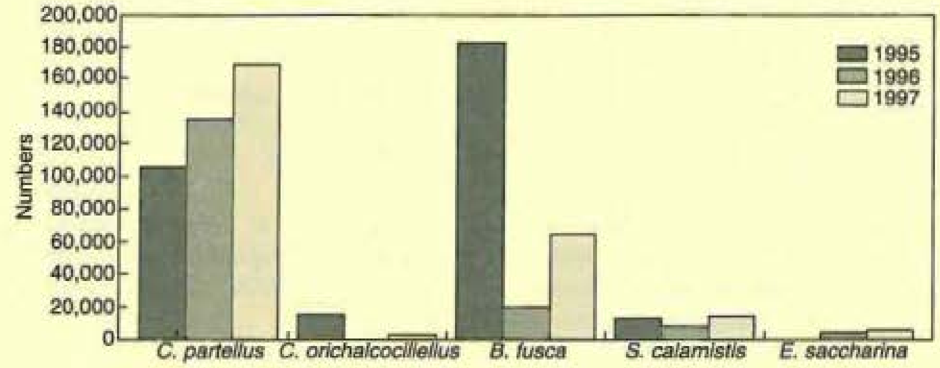


Figure 1.1. Total supply of cereal stemborers over a 3-year period

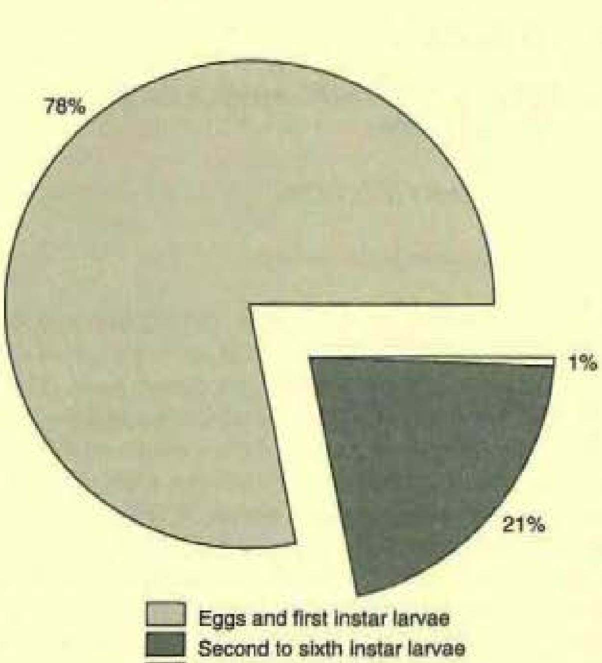


Figure 1.2. Proportion of different stemborer stages supplied in 1997

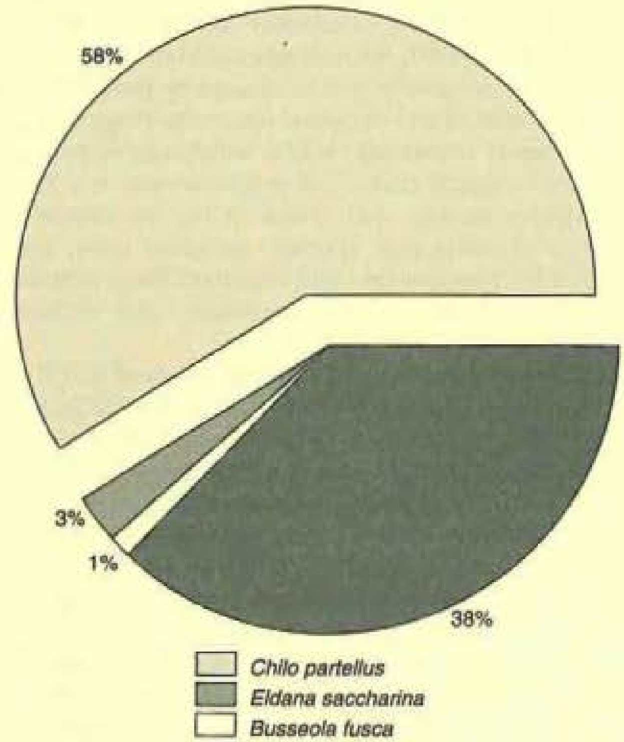


Figure 1.3. Proportion of artificial diets for stemborer species supplied in 1997

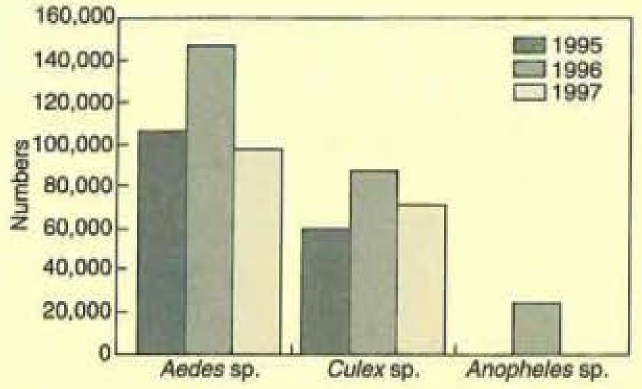


Figure 1.4. Total supply of mosquito species over a three year period

mosquitoes. Figure 1.4 represents the total supply per annum of the various mosquito species from ARQU.

1.1.3 *Migrant pests rearing*

Rearing of solitaria and gregaria phases of the desert locust has continued throughout the three years. The solitary locust culture has been kept at a level of 600 individually reared insects. A strict rearing protocol and regimen is maintained to minimise the gregarisation of the isolated locusts, by eliminating visual, olfactory and tactile contacts between the individual locusts. The rearing rooms for the solitaria phase are also maintained at positive pressure to reduce pheromonal contact. By the end of 1997, 43 continuous generations of the solitary locust had been successfully maintained.

The monthly production of the gregarious locust averages 2000–3000 insects, with fluctuation rising to meet user needs (see Figures 1.5 and 1.6). The strict

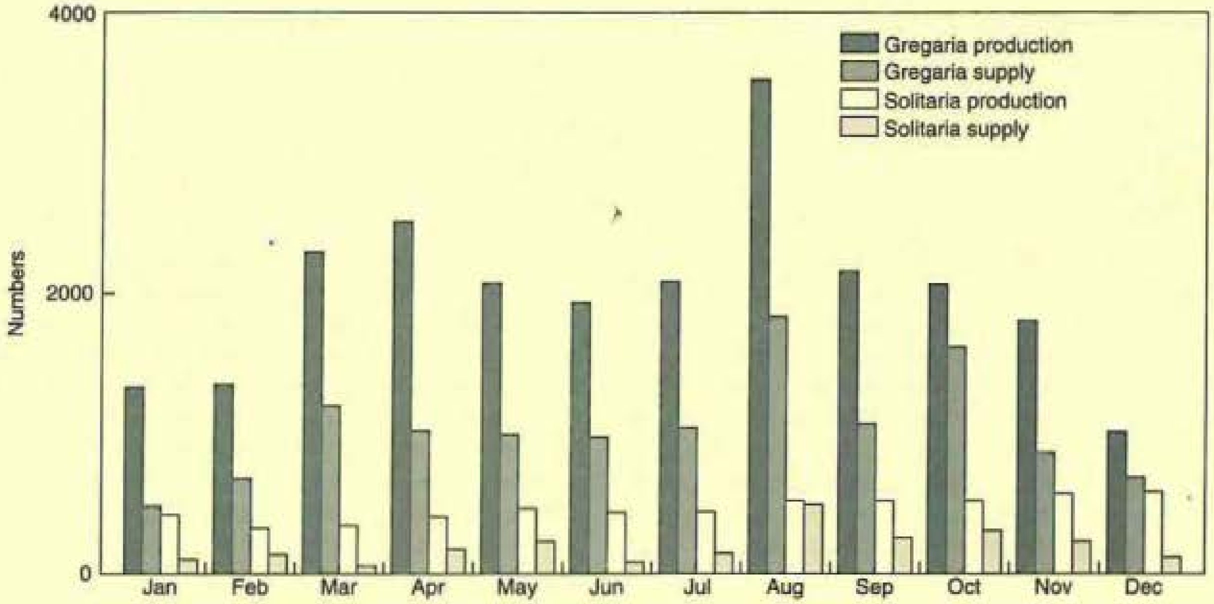


Figure 1.5. Production/supply from insectary culture of *Schistocerca gregaria* (1995)

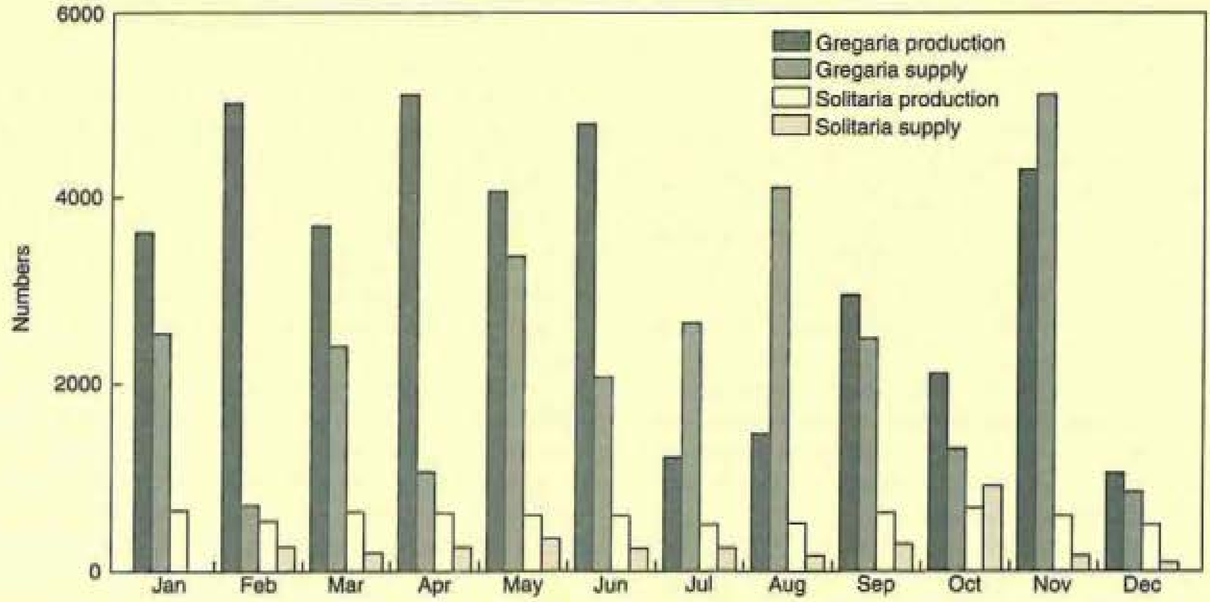


Figure 1.6. Production/supply from insectary culture of *Schistocerca gregaria* (1996)

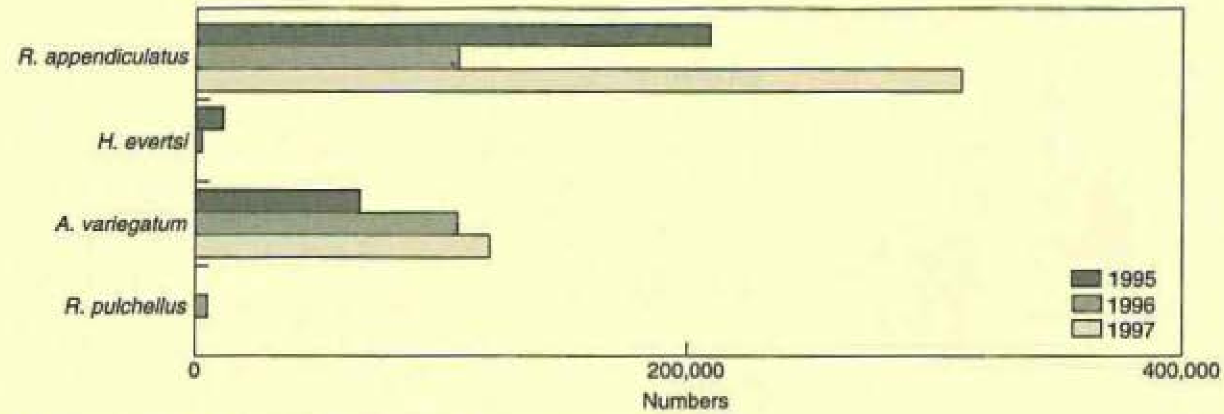


Figure 1.7. Number of ticks produced for research in 1995–97

rearing protocol ensured the production of quality insects, which did not exhibit unexpected mortality or a reduction of fecundity in both phases.

Plans are currently underway to initiate cultures of the red locust, *Nomadacris septemfasciata* and the migratory locust, *Locusta migratoria*.

1.1.4 *Tick rearing*

Three tick species, *Rhipicephalus appendiculatus*, *Hyalomma evertsi* and *Amblyomma variegatum* were produced and supplied from the unit as indicated in Figure 1.7. Both *R. appendiculatus* and *A. variegatum* were in most demand by ARPPIS scholars and staff within the Ticks Megaproject with total annual production of 153,050 and 114,400 ticks, respectively in 1997. A new tick species, *R. pulchellus* was introduced in 1997. Tick rearing, especially of *A. variegatum*, is set to increase to meet the demands of rearing the tick parasitoid, *Ixodiphagus hookeri*.

1.1.5 *Tsetse rearing*

Four tsetse species, *Glossina morsitans morsitans*, *G. m. centralis*, *G. fuscipes fuscipes* and *G. pallidipes* were under continuous rearing in 1995 and 1996. *Glossina m. morsitans* and *G. m. centralis* accounted for the largest number of tsetse produced during the two years, with levels of 91,371 and 103, 176, respectively, produced in 1995. The rearing of *G. f. fuscipes* was based mainly on pupae supplied by the IAEA Seibersdorf Laboratories in Austria. Earlier attempts to rear the species from flies collected from Rusinga Island and the environs of Mbita in South Nyanza did not succeed, due to the low reproductive rate of the species under colonisation. *Glossina pallidipes* was kept in small quantities, derived from pupae collected from Nguruman sites in Kenya. Due to several major activities in tsetse research coming to an end in 1996 and in 1997, there has been emphasis on production at the levels demanded earlier.

A major preoccupation of the unit in 1997 has been the development of an improved and cost-effective tsetse mass rearing system, in line with the objectives of the project on sustainable management of trypanosomiasis and tsetse flies through the development of the lethal insect technique (LIT). The improvement aims at developing a set of techniques associated with tsetse rearing, handling, synchronisation and automated self-sexing of emerging females and males. As a result, a simple, inexpensive and secure system is under development during the last year supported by funds from the Austrian Development Cooperation (ADC) and is currently under validation for the production of a large number of flies. The technique relies on selected donor cattle bred under zero grazing conditions, which are bled when required to supply the tsetse feeding system. Using the system, the unit began producing *Glossina austeni* and *G. fuscipes* for use in the Tsetse Megaproject and LIT-related activities. The colony strength using the improved system at the end of 1997 stood at over 15,000 females with a total of about the same number of pupae for *G. austeni* and 2000 females with a total of 2500 pupae for *G. f. fuscipes*.

2. ANIMAL BREEDING SERVICES

2.1 SMALL MAMMALS BREEDING

Over the years, ARQU has bred and maintained small mammals for supply to various research projects. Most of the mammals produced, especially rabbits, have been used in the rearing of blood feeding arthropods, principally ticks and tsetse and for use in experimental work. As at the end of 1995, some 1132 rabbits, 2378 mice, 1132 rats and 34 hamsters were produced and supplied to various users. Production of high quality animals was a principal prerequisite as was the humane handling. Minimum quality parameters monitored included weight, packed cell volume (PCV), haemoglobin and reticulocyte counts. The levels of the small mammals produced declined in 1996 and 1997 as demands fell due to changing research priorities and as tsetse feeding was initiated on membrane techniques (as indicated in Figure 2.1). At the end of 1997, production was 694 rabbits, 378 mice, 240 rats and 70 hamsters.

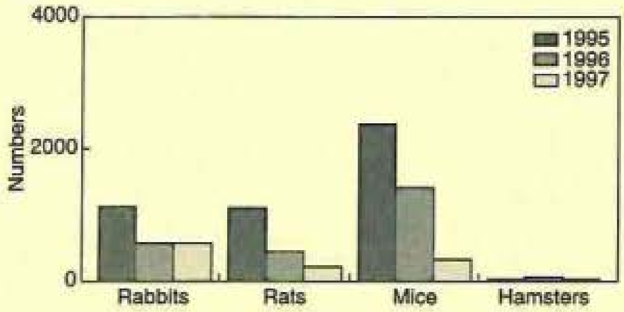


Figure 2.1. Total supply of laboratory animals over a three year period

Output

Publications

Odindo M. O., Nour A. M., Ajala S.O., Kiros F. G., Chitere P. O., A,pong-Nyarko K., Mohamed Ali M.A, and Ngalo Z.O. (1997) Integration of *Bacillus thuringiensis* with elite sorghum and maize genotypes to enhance productivity of small-scale farms in the coastal region of Kenya, pp. 144–153. In *Integrating Biological Control and Host Plant Resistance.* Proceedings of a CTA/IAR/IIBC Seminar, Addis Ababa, Ethiopia, 9–14 October 1995–CTA Publication, The Netherlands.

Conferences

Odindo M. O. (1997) Rearing of tsetse flies: Some important considerations in the establishment and sustained production of tsetse fly colonies. International Group Training Course on Tsetse Management, Monitoring, and Control, Nairobi.

Odindo M. O. (1997) Critical factors in the development and maintenance of sustainable colonies of *Glossina* species. AAIS/ESSA Conference on 'Insects in African Economy and the Environment' 30 June–4 July, 1997. Stellenbosh, South Africa.

Capacity building

Training of both technical and scientific cadres is an important responsibility of the unit. The unit has continued to receive staff and students for in-house attachments from polytechnics and universities. Trainees from the Kenya Polytechnic, Mombasa Polytechnic, Nairobi Technical Training Institute, Mawego Polytechnic, Muranga Institute of Technology and Jomo Kenyatta University of Agriculture and Technology (JKUAT) have spent 3–6 months on training attachments.

Impact

The work of the ARQU continues to receive international acclaim. Insect rearing is a specialised discipline that requires intensive training. As a result, a number of institutions and research personnel continue to show interest in the work of the unit. The rearing methodologies under use in ARQU are currently in use in a number of institutions in countries such as Zambia, Ethiopia and Uganda.

III. Biosystematics Support Unit

Background, approach and objectives

Many of ICIPE's research activities require an accurate identification of plants and arthropods. Reliable identifications are particularly important for ecological investigations on arthropod pests and their natural enemies; importation of biological control pests; and studies on arthropod biodiversity. In the past, ICIPE relied almost entirely on outside expertise for taxonomic assistance. This reliance on external expertise is becoming increasingly expensive, and often results in lengthy delays. The International Institute of Entomology in the UK now charges about £ 100 per arthropod identification, and delays of 6–12 months in receiving identifications are not uncommon.

In order to facilitate plant and arthropod identifications, it was proposed that ICIPE develop an intrinsic capability in biosystematics by establishing a Biosystematics Support Unit to provide taxonomic support to other units, departments and programmes at ICIPE, and to other institutions when possible.

The Biosystematics Support Unit (BSU) at ICIPE was established in August 1995 and currently consists of one PhD level arthropod taxonomist and two curators. The Unit coordinates the curation, identification and preservation of plant and animal specimens of relevance to ICIPE's programmes. The Unit has established a network of experts in various arthropod groups in taxonomic institutions worldwide who assist in the identification. Voucher specimens from the identified material are preserved at the BSU for future reference and the rest are deposited at the National Museums of Kenya, Entomology section for bulk keeping.

A reference collection of stemborers and their natural enemies in Africa has already been established at the BSU. This has greatly reduced reliance on external expertise. The collection will be of value both for research and for short and long-term training. Additionally, it is anticipated that taxonomists from within and outside of Africa will be interested in visiting ICIPE for extended periods to conduct research in collaboration with the BSU. The Unit also conducts biosystematics research in collaboration with other projects at ICIPE and other institutions.

Participating scientist: *S. W. Kimani-Njogu*

Technicians: *T. Ondiek, H. Mburu*

Donor: *Directorate General for International Cooperation, The Netherlands*

Collaborators: *• National Museums of Kenya (NMK) • National Agricultural Research Laboratories (NARL), Kenya • Kenya Agricultural Research Institute (KARI) • Coffee Research Foundation (CRF), Kenya • Plant Protection Research Institute (PPRI) Agricultural Research Council, South Africa • International Institute of Entomology (IIE), UK • Texas A&M University, USA • South African Museum, Cape Town • Wageningen Agricultural University, The Netherlands*

The BSU has established a network of taxonomists in the above institutions who collaborate in the identification of the specimens.

Work in progress

1.1 • CURATION, IDENTIFICATION AND DATABASING OF ARTHROPOD MATERIAL

1.1.1 *Stemborer projects*

1. ICIPE/WAU field monitoring of the establishment and dispersal of *C. flavipes* at the Coast Province, Kenya.
2. Phenology of stemborers and natural enemies in Eastern Province, Kenya.
3. Impact of predators on cereal stemborers at the Kenya Coast. So far 34 species of beetles (Coleoptera) and 31 species of ants have been received and identified.
4. Multiple parasitism by *C. flavipes* and *C. sesamiae* on *Busseola fusca*. In order to understand the effect of multiple parasitism by the two closely related species, each specimen in the two studies had to be identified. A total of 4000 specimens in the two ongoing projects have so far been identified.
5. Survey of stemborer and natural enemies in Ethiopia, Somalia and Zanzibar.

1.1.2 *IPM, Horticulture*

1. Pests and natural enemies of cabbage in east and southern Africa.
2. Bioecology of thrips in French bean growing agroecosystems in Kenya.
3. Leafminers (Diptera: Agromyzidae) of tomato in Kenya: Population dynamics, yield loss and control.

1.1.3 *African fruit fly initiative*

1. Exploration for indigenous natural enemies of fruit flies.
2. Systematics of indigenous parasitoids of fruit flies in Africa, in collaboration with Dr John LaSalle of International Institute of Entomology and Dr Robert Wharton of Texas A&M University.

1.1.4 *Animal Rearing and Quarantine Unit*

1. Quality control—insect cultures are checked regularly to ensure that they are free from contaminants from other insect cultures.

Output

Publications

Kimani-Njogu S. W. and Overholt W. A. (1997) Biosystematics of *Cotesia flavipes* species complex (Hymenoptera: Braconidae) parasitoids of the gramineous stemborers. *Insect Science and Its Application* 17, 119–130.

Kimani-Njogu S.W., Overholt W.A., Woolley J.B. and Omwega C. Electrophoretic and phylogenetic analysis of selected allopatric populations of *Cotesia flavipes* complex (Hymenoptera: Braconidae) parasitoids of cereal stemborers. *Biochemical Systematics and Ecology*. (In press).

Polaszek A. and Kimani-Njogu S. W. Scelonidae. In *Cereal Stemborers in Africa: Taxonomy, Natural Enemies and Control* (Edited by A. Polaszek). Technical Centre for Agricultural and Rural Cooperation (CTA), Wageningen, The Netherlands (in press).

Conferences attended

Congress of the Entomological Society of Southern Africa and the Association of Insect Scientists. Stellenbosch 30 July 1997. Poster presented: Phylogenetic analyses of selected allopatric populations of the *Cotesia flavipes* complex (Hymenoptera: Braconidae).

Project proposals

Systematics of Indigenous Parasitoids of Medfly and its relatives in East Africa. Funded by USDA.

Distribution of GIS mapping of gramineous stemborers and their natural enemies in Africa as a first step towards redistribution biological control. Not funded, sent to GEF.

Capacity building

Stemborer project—Internships of field and technical assistants from Ethiopia, Somalia, Mozambique, Eritrea and Kenya at the Biosystematics Unit and individual training on field sampling, curation and identification of commonly occurring stemborers and their natural enemies. Among those trained are Abu Jone and Elsa Mambo of Plant Protection Department, Maputo, Adugna Haile of Eritrea, Afra Shurie of International Committee of the Red Cross and Salome Tibebu of IAR Ethiopia. These parataxonomists will be involved in field sampling and identification of specimens in their respective countries in the stemborer classical biological control programme.

Fruitfly Project—One technician (Hellen Mburu) was trained on all aspects of insect curation.

USAID Export Vegetable Project—three field assistants were trained on insect sampling, data recording and preservation of arthropod specimens.

Students on attachment from polytechnics—One diploma student (Hellen Heya), was attached to the unit for 5 months. She conducted two short projects on biosystematics.

Impact

ICIPE/WAU project—Identification of natural enemies sampled from various localities enables the project to analyse the parasitism rates, spread, establishment of the introduced parasitoid and study of multiple parasitism by *C. flavipes* and *C. sesamiae* on *Sesamia calamistis*. Identification of material in this project enabled the PhD student to write a thesis that explained the possible coexistence of the introduced parasitoid and the indigenous one.

Gatsby Project—Identification of pests and natural enemies in natural and agroecosystems enabled the project to work out parameters, such as abundance and population dynamics in the two habitats, which resulted in a publication in *Nature* magazine.

Fruitfly project—Preliminary sampling and identification of pest and parasitoid species has resulted into a USDA funded project on taxonomy of the species.

IV. Computer Unit

Background, approach and objectives

The Computer Unit (CU) was created in May 1995 to enhance computer applications and computer related research at ICIPE. This function was formerly taken care of by the Biomathematics Unit before the CU was separated to address the increasing needs of computer applications at the Centre, and more importantly to upgrade the computer application level.

The newly-created Unit aimed at improving the efficiency of operations at ICIPE as its primary goal, such as e-mail service, information upload/download services, e-library, administrative and financial systems, etc. Its secondary objective was to be active in computer-related research to develop the following computer systems with the relevant programme/department/project:

1. Management Information System (MIS) for target insect pests
2. Computer-based target crop pests/area pests/vectors management advisory system
3. Expert system for target pest/crop pests/area pests/vector(s) management
4. Geographical Information System (GIS) application
5. Early warning system for long-distance migrant pests or very destructive pests
6. Computer simulation system for population, metapopulation, community, ecosystem or metasystem studies
7. Computer visual system for behaviour and development biology studies
8. Computer auto-control system for insect mass rearing, semiochemicals or DNA/RNA extraction and identification.

Hence, the Computer Unit provides computer hardware and software support, software application and training, and networking, for both research and management at the Centre. Apart from this, the CU was also to assist programme/department/project scientists on desired software/database development and maintain computer-related electronic equipment in the Centre.

To achieve those goals, CU planned the following:

1. Set-up and manage ICIPE local area network (LAN).
2. Establish gateways to worldwide area networks (WANs) and bridges to other LANs, for providing desk-to-desk e-mail service, information upload/download services for the staff.
3. Procurement of computer hardware and software.
4. Preventive maintenance and troubleshooting for computer and computer-related electronic equipment.
5. Provide software application support.
6. Training of staff on networking and software applications.
7. Maintain software library, manuals and journals.
8. Cooperate with Projects and Biomathematics Unit on modelling and computer simulation.
9. Cooperate with Photography and Microscopy Unit in making computer graphics and slide preparations.
10. Cooperate with Library, Public Relations and Science Press to provide information services to the Centre.
11. Cooperate with programme/department/project scientists for developing software packages for the Centre.
12. To maintain an inventory database of computer and computer related electronic equipment at the Centre for quick reference by the management.

Participating scientists: *Yunlong Xia, D. Murali*

Assistants: *M. Gathoga, M. N. Akello*

Donor: *ICIPE Core Funds*

Work in progress

Apart from daily maintenance and trouble shooting of both IBM-compatible and Macintosh computers and helping staff in software application and slide preparation, CU has achieved a lot in spite of understaffing. A Macintosh network of both Ethernet and LocalTalk for Senior Management and Administration was established in 1995. CU has developed a software, BMIS (Biodiversity Management Information System) together with the ICIPE Arthropod Biodiversity Mega-Project. Funds have been raised from participating scientists to procure the necessary equipment for expanding a local area network (LAN) for the Centre. A separate MS Remote Mailbox through CGNET was initiated to help scientists communicate with colleagues around the world. Two accounts with UNEP were started in 1995 to surf the Internet for providing a better information service to the Centre.

In 1995, CU put a lot of energy into looking for reliable and economic service provider of both e-mail and Internet for the Centre. CU organised a multimedia PC demonstration for all staff to update their skills in fast developing computer technology. The CU helped 25 staff to procure multimedia PC to be used at home, which is one part of ICIPE's computer networking through modem remote access.

In late 1997, the Computer Unit was merged into the newly created Information Technology division.

Output

Proposal

CU developed a research proposal on AINA (Arthropod Information Network in Africa), which was announced through several e-mail discussion groups for selecting potential collaborators for future implementation of the AINA project.

V. Information Services

Background, approach and objectives

The Information Services division was created in September 1997 from four previously separate and financially autonomous units:

- Science Editing Department
- *Insect Science and Its Application* (The International Journal of Tropical Insect Science)
- ICIPE Science Press (a cost-recovery unit)
- The Information Resources Centre (library)

The objective in combining these related activities was to consolidate and coordinate the Centre's current information activities and to expand the range of activities and services provided. These will eventually include multimedia productions such as videos, CDs, mobile displays; preparation of materials for electronic information dissemination such as via the Internet; improved digitally produced graphic displays, posters, slide presentations, etc. Photographic services for PR events and for publishing purposes were also incorporated in the new division, while scientific photography remains in the Molecular Biology and Biotechnology department.

Participating staff: *A. Ng'eny- Mengech*, A. Katama (1995,1996), D. Ouya (1996,1997), W. Oyuko (1995,1996)*
*(*Head of Information Services)*

Assistants: *I. Ogendo, N. M. Komeri, D. Osogo, J. Malombe, J. Kamau, L. Matingi, D. Njau (1996, 1997), S. Nyakwara, R. Musyoka, C. Kimeu, C. Njunge (1996), M. Njau (1996,1997), M. Kageche, J. Kisini, M. Mbatha, A. N. Musau, A. Musau (1996)*

Donors: *ICIPE Core Funds; IDRC (ENVIRONET Project, 1996); Electronic Publishing Trust and Bioline Publications, UK (for* Insect Science and Its Application*); Swiss Academy of Sciences (for the Information Resource Centre)*

Work in progress

1. EDITORIAL AND PUBLISHING SERVICES

1.1 SCIENCE EDITING

This department was formed in 1996 to coordinate and supervise the editorial activities and publications emanating from ICIPE. The editorial services provided by this office include writing and compiling information and documents about ICIPE and its projects and activities, and providing advice to staff about publishing. The science editors also ensure that the scientific manuscripts of ICIPE researchers undergo a preliminary editing and peer review before they are submitted to international journals.

Among the ICIPE documents originated and produced over this reporting period were the *Annual Report Highlights* for 1995,1996,1997; the present consolidated *Annual Scientific Report* for 1995–97, *ICIPE's Vision and Strategy towards 2020*, the *Five-Year Plan (1986–2000)*, a list of *ICIPE Publications (1991–95)*, and a special booklet commemorating ICIPE's 25th Anniversary in 1994. Several of these publications were produced in full colour. The layout, design and DTP of the foregoing ICIPE documents was also done in this section.

An important exercise in 1995 was the editing of a book culminating from a joint project of UNEP and ICIPE titled *Integrated Pest Management in the Tropics: Current Status and Future Prospects* (published for UNEP by John Wiley & Sons, UK). The book, now in its second printing, contains papers by IPM experts on three continents about the practice and scope for employing IPM in their regions: South America (authored by C. Campanhola, G. Jose De Moraes, L. A. N. de Sa), South and SE Asia (by A.K. Raheja), and Africa (by O. Zethner). These three reports were among the 11 commissioned by UNEP and ICIPE to provide the background material for another book with the title, *Beyond Silent Spring: Integrated Pest Management and Chemical Safety*, compiled and authored by H.F. van Emden and D. P. Peakall (published for UNEP in 1996 by Chapman and Hall).

Several others of the aforementioned background papers were published as a special issue on 'Current Issues in IPM' in the journal *Insect Science and Its Application* (Volume 15 No. 6) with R.W. Mwangi as Guest Editor (see below).

The Science Editor also serves as an 'authors' editor' and is responsible for registering and editing the scientific manuscripts written by ICIPE staff for submission to international journals. About 30 papers were edited each year with an ICIPE researcher as the senior author. Public relations materials also benefit from editorial review, for example press releases and the monthly *ICIPE Update*, as well as other documents, brochures, pamphlets about the centre, project proposals, reports, etc. Still in limbo is the Centre newsletter, *Dudu*, whose publication was temporarily interrupted in 1995 due to lack of funds for publication and departure of the editor.

Information about the Centre is now being put on-line on the new Web Page (http://www.icipe.org) on an occasional basis, but is expected to become more regular in 1998. Shortage of editorial staff continue to limit the range and amounts of information being produced and disseminated.

Training of ICIPE's ARPPIS PhD students *(see under Capacity Building)* in science writing was achieved through a series of lectures and seminars given by the Science Editors, while apprenticeship of students from Kenyan universities and polytechnics in the department in science editing and information science continued throughout this reporting period.

1.2. ICIPE SCIENCE PRESS (ISP)

ICIPE Science Press (ISP) was formed in 1988 as a service unit for the Centre. Since that time, it has undergone a transformation into a cost-recovery unit. The Press publishes work for the Centre itself, for project-related activities, and for selected external clients (e.g. universities, NGOs, UN agencies, IFS, etc.). ISP was moved into the newly created Information Services division in September 1997.

The 15 staff include science illustrators, graphic artist/DTP designer, typesetters/imagesetters, proofreaders, a printing technician and assistants, as well as an accounts/business assistant. Editorial input comes from the Science Editing Department or from consultant editors.The Head of Information Services has served as the overall supervisor/manager of ISP since September 1997 following the departure of the former manager in late 1996. Plans are to hire a multimedia specialist and production editor when funding permits.

The Press covers such publishing activities as copy editing, proofreading, typesetting, layout and design, science illustration and graphics (both digital and manual) and related DTP activities in a MacIntosh environment.A small printshop does one-colour jobs and spot colour, as well as trimming and finishing. More complex, four-colour work is subcontracted to commercial printers in town. A 'multimedia room' was installed in 1997, with excellent facilities for digital graphics and other multimedia services such as CD production, video and slide displays, PowerPoint presentations, etc. The Press is currently improving its expertise to use the available equipment.

The Press was reviewed in 1997 by a prominent international scholarly publisher and editor, Dr Miriam Balaban, who made many useful suggestions relevant to the management and business aspects of a small tertiary publisher such as ISP. Among her recommendations was that ISP move its premises from the Chiromo Campus of the University of Nairobi to be nearer the ICIPE Headquarters at Kasarani. Plans are now being made to move in early 1998. Another recommendation was that ISP favour co-publishing agreements rather than itself taking the risk of publishing manuscripts unless financial sponsorship can be assured.

In the last two years, ISP has obtained business from many other agencies and organisations in Kenya and in other countries. For example, the Press is currently editing and publishing eight books of a series for the United Nations University, Institute of Natural Resources in Africa (UNU/INRA). Other examples are the publication of a book on climate change for UNEP and one on IPM in the Sudan for FAO. ICIPE itself, however, continues to be the major customer, and over the period several training manuals in the FAMESA series have been published for the Centre, as well as a 2-volume manual on mass rearing of insects and a directory of neem workers. In addition, numerous brochures, programmes, institutional stationery, name cards, etc. are routinely produced. In 1996, the Press was requested to become a cost-recovery unit, and each year since then has seen it improving its balance sheet, such that expectations are that by 1998 it will break even.

Of all the publishing done worldwide, only 2% originates in Africa, with most of this being done in South Africa and Kenya. ISP is an active member of the publishing community in East Africa. Activities such as presenting book displays at conferences, participation in international bookfairs (e.g. in Zimbabwe, Kenya and Ghana), and participating in meetings and seminars of the Consortium of African Scholarly Publishers (CASP), the Kenya Publishers Association and the International Federation of Science Editors (Africa branch), all helped to publicise ISP and were useful in acquainting others with the Press' work. ISP has an important role to play in this region by serving as a medium for publishing manuscripts from African scholars and researchers. For instance, over the past 3 years, ISP helped publish the maiden issues of two African journals, namely the *African Crop Science Journal* and *Horizen DAT, Toward a Developing Architectural Tradition.* Furthermore, several other scholarly publishers in Kenya have closed down recently, making the Press' work even more important to the African scientific and academic/

research/development community.

In order to share some of its expertise and promote publishing in the East African region, ISP was involved in two important training programmes in 1996/97. The Environmental Publishing Network (ENVIRONET LINKS), funded by IDRC, was formed to promote environmental publishing. Staff of ISP provided a series of lectures and hands-on learning sessions in desk top publishing (DTP) to six participants from Kenya and Uganda. At the end of the course, the participants were presented with a computer system for DTP for beginning their own publishing activities. The crop science journal mentioned above is now produced in Kampala. A second training activity, the University Students' Attachment Programme (USAP), enlisted young women to work at the Press for 6–12 weeks during their holidays, and helped expose them to the business of publishing and graphic art. ICIPE provided a small stipend to the girls. This activity was later extended to students from the Kenya Polytechnic and to both men and women.

1.3 *INSECT SCIENCE AND ITS APPLICATION*: THE INTERNATIONAL JOURNAL OF TROPICAL INSECT SCIENCE (ISA)

The year 1997 marks the 18th year of the journal *Insect Science and Its Application (ISA).* Founded in 1980 under the aegis of the African Association of Insect Scientists (AAIS), the journal has since been supported financially and editorially by ICIPE, with moral support from AAIS. However, the journal has an independent editorial policy, and therefore should not be seen as an 'ICIPE-owned' publication. *ISA* was first published by Pergamon Press in the UK, but production and printing was centralised in Nairobi beginning with Volume 8 of 1987.

Over the past two years, ISA has undergone major changes in its editorial organisation. The former Scientific Editor left in late 1994, and her position was eventually filled in 1996 by the hiring of a new Science Editor who was trained in-house by the ICIPE Editor and by Dr J.O. Mugah of the *East African Journal of Agriculture and Forestry*. Following the retirement of Professor K. N. Saxena as Editor-in-Chief in 1996, Dr Hans Herren was appointed to this position from Volume 16.The Associate Editor, Professor Richard Mwangi, now of Egerton University in Kenya, assists on an honorary basis by helping set policy, and by assigning reviewers and drafting correspondence. From August 1995, the Head of Information Services at ICIPE has served as Coordinating Editor.

In order to improve the statistical presentation of the papers, Dr A. Odulaja of the Biomathematics unit at ICIPE was appointed a member of the international Editorial Advisory Board with Volume 16 and now regularly provides valuable review of the manuscripts. Other secretariat staff include an editorial assistant, a proofreader, and DTP designer/imagesetter. The journal is currently being printed by Regal Press (Kenya) Ltd.

Due to the fact that the secretariat lost both the Science Editor and Secretary over a 2-year period from 1994–1996, the journal fell behind in its production schedule. A concerted effort was made to clear the backlog of manuscripts and to increase the efficiency of office operations. On the recommendation of a noted editorial consultant, Dr Miriam Balaban, and with the concurrence of a noted abstracting service, the journal reverted to being a quarterly and also skipped a year in its publication date, with Volume 17 now being defined as the 1997 issue. Issues 1 and 2 were printed in 1997 and No. 3/4 is in press as is volume 18 No. 1. Issue 17 (1) is a special issue on the 'Ecology and Management of Tropical Gramineous Stemborers'.

A well-known editorial consultant, Dr Miriam Balaban, visited the secretariat in April 1997 and made many useful recommendations, especially those pertaining to the journal's management and production. Computerisation of the reviewers' and subscribers' databases, automatic formatting for standard letters, and design of a manuscript tracking database in 1997 has also helped to make the secretariat operations more efficient. From Volume 16 (3/4), all graphics have been digitally produced. The journal has adopted a slightly enlarged format and new design for the printed version beginning with Volume 17. More durable matt art paper has been substituted for the bond previously used.

Beginning with Volume 17 (1997), the journal has been made available on-line via Bioline Publications UK (http://www.bdt.org.br/bioline), a site visited by over 40,000 users annually. This can be accessed free of charge by ICIPE staff from the Internet laboratory. The contents are also being put on the Centre's Web Page (http://www.icipe.org). *ISA* will continue to publish a printed version in the foreseeable future, however, until we are certain that most of our users, especially those in the Third World, have access to the electronic media. (At any rate, considerable debate still exists internationally about issues such as copyright, duplication of articles, interlibrary loans, and methods of payment for electronically produced publications.These issues are especially pertinent to users in developing countries who often have no credit cards, etc.). The on-line version of *ISA* has been available from Volume 17 No. 1 (released in late 1997), and it is still too early to determine what impact this has had on the level of readership, although indications are that users of Bioline in Brazil are taking advantage of this. The journal typesetter is currently being trained to convert the Pagemaker text and graphics into html. In future, *ISA* plans to issue the journal on diskettes and CD-ROMS as well as the print and internet versions.

The turnover time has been reduced to 6–8 months for papers in a good editorial state. However, *ISA* still believes it has a capacitating role for Third World scientists, and is generally willing to spend more editorial and peer review time than many other journals.The issue of accessibility and usership of the research information generated in the tropics (mainly the developing countries of the South) to Southern citizens is one of concern. A profile of the journal's subscribers and contributors is shown in Figures 1.1 and 1.2 and in Table 1.1 As can be seen, most of the readership is centred in the North, a profile that is common to almost all journals produced in the South. Efforts are being made to interest more scientists from other tropical regions such as Latin America, the Caribbean and Asia in contributing to and reading the journal. It is planned to open regional offices in South America and South/SE Asia as soon as funding permits, in order to facilitate manuscript processing from those regions. A grant proposal is being prepared that will seek funding to help subsidise the cost of subscriptions to institutions in developing countries that would benefit from the research results reported in the journal.

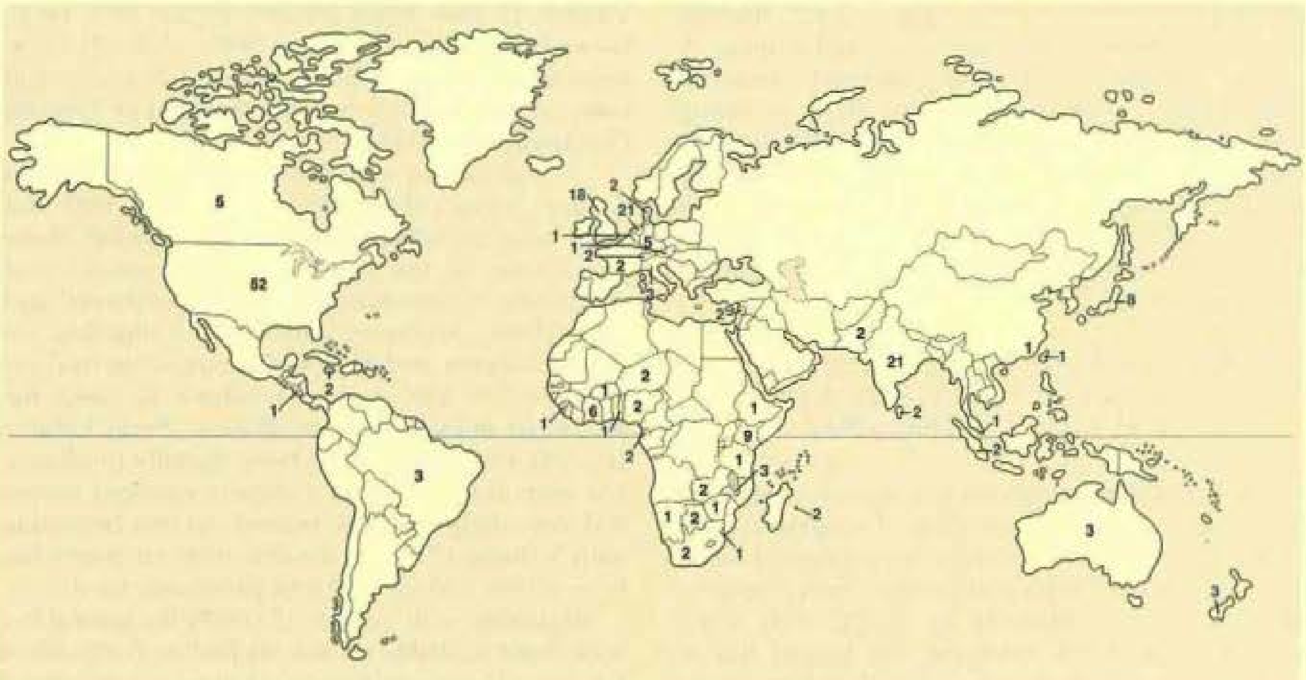


Figure 1.1. Global distribution of subscribers to *Insect Science and Its Application*

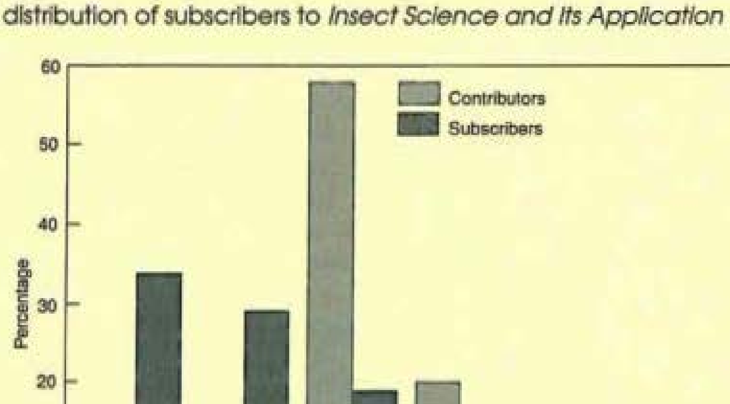


Figure 1.2. Regional disparity of contributors and subscribers to *Insect Science and Its Application* (1997/98)

This graph illustrates that much of the published research emanating from the South is inaccessible to the South's own institutions and is actually more available to countries in the North. ISA's two-year outreach inititative seeks to redress this situation, by making the journal available to more Third World countries

Table 1.1. Geographical distribution of contributors to *Insect Science and Its Application*

	Percentage of papers published in ISA	
	1989–1994	1997
	N = 577 %	N = 52 %
Africa	58	61
India	21	15
Rest of Asia	8	4
Europe and UK	6	10
North America	4	6
China and the Far East	1	0
South America	1	4
Oceania	1	0

2. INFORMATION DISSEMINATION

2.1 INFORMATION RESOURCES CENTRE (IRC)

The IRC (library) was brought into the Information Services division in September 1997. The IRC is located in a purpose-built building on the Duduville campus with a small branch library at the Mbita Point Field station. The IRC serves as an important resource not only for ICIPE staff but for users from other research centres, universities, NARS, and other institutions especially in the East and Southern Africa region.

The IRC houses about 7000 books, and over 150 journals, of which about 130 titles are current subscriptions; about 3000 monographs; and several databases on CD-ROM (e.g AGRIS, CAB Abstracts). Most journals and reference materials are currently being received as their print version, but an effort is being made to obtain the on-line versions as well in lieu of these in the future.

As well as handling about 7000 in-house user requests per annum, the library staff also order books and other reference materials for staff and interested parties; maintain an archive of ICIPE publications, reprints and photographs; operate a microfiching and photocopying service; perform about 100 literature services yearly for clients; and organise for interlibrary loans. In future, searches may also be done on the Internet. The IRC intends to keep pace with the times, by increasing its use and access to electronic information resources, but at the same time keeping its feet on the ground by maintaining hard copies of the most important journals and maintaining its collection of the 'grey literature'.

The IRC also helps to produce as well as to provide information. The staff scan all recent publications in the areas of ICIPE's research interests and enter it into a Pest Management Database (PMD) accessible to all library users, and which is published occasionally as funds permit. This important resource is shared with other research centres and organisations; for instance much information has been used by ILRI-Ethiopia and UNECA/PADISS in their CD-ROMs on African insect crop and livestock pests. ICIPE also regularly provides input into the AGRIS database of FAO via the IRC and the journal. Two databases, Pestbook and ICIPE's PMDISS), were combined in 1995 using Fargon software to increase the accessibility of the two to users in the region.

The IRC is grateful to the Swiss Academy of Sciences for their continued support in the purchase of some of the important journals in ICIPE's areas of research interest. The ISIS software used in the library is the gift of UNESCO.

Output

Publications by ICIPE Science Press for ICIPE

ANNUAL REPORTS

- *1994 ICIPE Annual Report.* ISBN 92 9064 091 X. 48 pp. October 1995.
- *1994 ICIPE Annual Scientific Report.* Edited by A. Ng'eny-Mengech and M. F. B. Chaudhury. ISBN 92 9064 092 8. 199 pp. November 1995.
- *1995 ICIPE Annual Report.* ISBN 92 9064 098 7. 72 pp. October 1996.

ANNUAL REPORT HIGHLIGHTS

- *1996/97 Annual Report Highlights.* ISBN 92 9064 112 6. 56 pp. September 1997.
- *1997 ICIPE Annual Report Highlights.* ISBN 92 9064 115 X. 40 pp. March 1998.

OTHERS

- *Directory of Neem Workers in Eastern and Southern Africa.* Edited by R. C. Saxena. ICIPE Science Press, Nairobi. ISBN 92 9064 107 X. 30 pp. April 1997.
- *ICIPE 5-Year Plan: Research and Capacity Building Plan for the Period 1996–2000* (temporary cover). ISBN 92 9064 104 5. 132 pp. December 1996.
- *ICIPE. 25 Years of Research in Tropical Insect Science.* Edited by A. Ng'eny-Mengech. ISBN 9064 086 3.
- Financial and Administrative Management of Research Projects in Eastern and Southern Africa (FAMESA) Management Manuals:
  - *Productive R&D Institute Facilities and Materials Management.* ISBN 92 9064 076 6, 284 pp.
  - *Productive R&D Project Planning, Monitoring and Evaluation.* ISBN 92 9064 072 3, 262 pp.
  - *Productive R&D Scientific, Technical and Management Information Systems.* ISBN 92 9064 074 X, 259 pp.
  - *Productive R&D Strategic and Project Planning and Budgeting.* ISBN 92 9064 075 8, 323 pp. (Released in 1995)
- *Techniques of Insect Rearing for the Development of Integrated Pest and Vector Management Strategies* (Vol. 2). Edited by J. P. R. Ochieng'-Odero. Proceedings of the International Group Training

Course on Techniques of Insect Rearing for the Development of Integrated Pest and Vector Management Strategies. 16 March–3 April 1992, ICIPE, Nairobi, Kenya. ISBN 92 9064 065 X. 252 pp.

- *Improved Insect Pest Management for Maize, Sorghum and Cowpea Production in Coastal Kenya. Technology Handbook for Extensionists.* Compiled by S. Sithanantham, G. M. Kamau, E. Wekesa and K. Mwangi. ICIPE Science Press, Nairobi for the Kenya Agricultural Research Institute. ISBN 92 9064 106 1. 12 pp. December 1996.
- *Vision and Strategic Framework towards 2020.* ISBN 92 9064 111 8. 74 pp. September 1997.

Insect Science and Its Application (The International Journal of Tropical Insect Science). Founded by Thomas R. Odhiambo. ISSN 0191-9040

- Volume 15 (1994). Editor-in-Chief, K. N. Saxena.
- Volume 16 (1995). Editor-in-Chief, H. R. Herren.
- Volume 17 (1997). Editor-in-Chief, H. R. Herren.

Additional publications of Social Sciences Department

- Kiros F. G. Interactive research methods in social and natural sciences: Some lessons of practical experience from an adaptive integrated pest management research. *ICIPE Research Methodology Report No. 7*, 1995.
- Omollo E. O., Ssennyonga J. W., Kiros F. G., Ngugi A. and Okali C., Community mapping exercises: An evaluation. Overseas Development Institute, *Network Paper 52*, 1995.
- Chitere P. O., Kiros F. G. and Mutinga M. Report on the study of adoption and households capacity to manage and sustain permethrin impregnated MBU cloth technology in Marigat Area, Kenya. *Research Paper No. 19*, SSD, ICIPE, 1995.
- Lako G. T. Causes of the apparent failure to maintain the community-based approach to tsetse control in Nguruman, Kenya. *Research Paper No. 16*, SSD, ICIPE, 1995.
- Ssennyonga J.W., Mohamed-Ahmed M.M. and Kiros F.G. (1996) The development and validation of a model for community-managed tsetse trapping technology in Lambwe Valley, Kenya. *Research Methodology Paper No. 20* May 1996. SSD, ICIPE.

Publications of ISP for outside clients

Journals

- *African Urban Quarterly Journal.* Cultural Political and Social-Economic Effects of Aids, HIV and STDs in Eastern and Southern Africa . Edited by R. A. Obudho. 457 pp. ISSN 0747-6108.
- *The Horizon DAT* .Edited by Samson K. Umenne, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya. ISSN 1026-0552. 98 pp.

(UNU/INRA) Monograph series

- *Use of African and Foreign Food Preparations in Commercial Eating Places: Indigenous African Food Crop Preparations as Compared to Those from Introduced Foods Produced in Africa and Imported Foods in Southwestern Nigeria.* S. H. Abiose and T. O. Omobuwajo. Series Editor: Bede N. Okigbo. January, 1997. ISBN 92 9064 101 X.
- *Use of Indigenous African, Introduced and Imported Foods in Commercial Establishments: Indigenous African Food Crop Preparations as Compared to Those of Introduced Foods Produced in Africa and Imported Foods in Southeastern Nigeria.* M. J. F. Isoun. Series Editor: Bede N. Okigbo. July, 1997. ISBN 92 9064 102 9.
- *Indigenous African Food Crops and Useful Plants: Survey of Indigenous Food Crops, Their Preparations and Home Gardens in Ethiopia.* Zemede Asfaw. Series Editor: Bede N. Okigbo. September, 1997. ISBN 92 9064 109 6.
- *Mineral Resources of Africa: Field Survey of African Mineral Resources—Status and Management for Sustainable Development in Lesotho, Swaziland and Zimbabwe.* H. Munyanyiwa and M. S. Lipalile. Series Editors: M. W. Chanda and Bede N. Okigbo, November, 1997. ISBN 92 9064 105 3. (Titles produced for the United Nations University, Institute for Natural Resources in Africa—UNU/INRA).

Others

- *Reader on Information Management Strategies for Africa's Development.* N. M. Adeyemi (Ed.) 1995, 165 pp. ISBN 92 9064 088 X. (Published for United Nations Economic Commission for Africa/Pan African Documentation and Information System—UNECA/PADIS) .
- *Strategies for Human Resources Development for Information Management in Africa.* F. Inganji (Ed.) 1995, 99 pp. ISBN 92 9064 089 8. (Published for United Nations Economic Commission for Africa/Pan African Documentation and Information System—UNECA/PADIS).
- *The Political Economy of Development: An African Perspective.* S. Rasheed and S. Tomori (Eds) Vols I and II, 486—I, 339—II 1996. 825 pp. ISBN 92 9064 095 1 (Published for the Association of African Universities, Accra-North, Ghana).
- *Sharing Coastal Management Experience in the Western Indian Ocean.* S. Humphrey and J. Francis (Eds),1997, 142 pp. (Printed for the Western Indian Ocean Marine Science Association).
- *Broomrape-Halouk* (Orobanche *spp.) in the Sudan.* Z. T. Dabrowski and A. Hamdoun (Eds) 1995.

58 pp. ISBN 92 9064 094 4. (Published for FAO/ ARC Cooperative Project GCP/SUD/025/NET).

- *Integrated Pest Management of Vegetables, Wheat and Cotton in the Sudan: A Participatory Approach.* Z. T. Dabrowski (Ed).1997, 245 pp. ISBN 92 9064 100 2. (Published for FAO/Government of the Sudan Cooperative Project GCP/SUD/025/ NET).
- *Equity and Social Considerations Related to Climate Change.*Proceedings of IPCC WG III Workshop, Nairobi, 1994. A. Katama (Ed.). 1995, 441 pp. ISBN 92 9064 084 7. (Published for World Meteorological Organisation/United Nations Environment Programme—WMO/UNEP).
- *Conservation of Hymenopteran Parasitoids for Management of the Citrus Blackfly in Oranges.* S. K. Raina and W. A. Overholt (Eds) 1996, 78 pp. (Printed for the Centre for Sericulture & Biological Pest Management Research, Nagpur University, India).
- *Development Communication Principles.* C. Okigbo, (Ed.) 1996. (Printed for the African Council for Communication Education (ACCE).

Conferences attended

A. Katama. Zimbabwe and Ghana Book Fairs, 1995 and 1996.

A. Mengech. Issues in Electronic Publishing for Third World Countries. Seminar presentation at Council of Biology Editors Annual Meeting. Philadelphia, PA, May 1997.

A. Mengech. African Association of Science Editors International Conference, Nairobi, October 1996

A. Mengech and D. Ouya. Consortium of African Scholarly Publishers (CASP) Conference, 1997.

Proposals written

Environmental Publishing Network (ENVIRONET)—to IDRC. Funded in 1996.

Support for *Insect Science and Its Application*—to UNESCO. Being explored.

Support for putting *Insect Science and Its Application* on line—to Electronic Publishing Trust and Bioline Publications, UK. Funded for Volume 17 and Volume 18 (1997 and 1998).

Capacity building

ARPPIS PhD students offered courses in Research Management, including scientific writing and reporting, peer review procedures, ethics of publication, etc.

Undergraduate and postgraduate students of information science, mass communications, science editing and library science programmes from University of Nairobi, Moi University, Kenyatta University and Kenya Polytechnic offered short-term practical training and/or internship period (av. 8 per year).

Training visits organised for professionals in information science and publishing from the OAU, AAU, etc.

Professionals from East African scientific organisations (e.g. Makerere University, University of Nairobi) trained in Desk Top Publishing.

Seminars on various issues of academic publishing offered to members of the Nairobi publishing community during professional meetings.

I. Field Stations

Background, approach and objectives

The position of Scientist-in-Charge of the field station was created in January 1995 to carry out organisational and administrative functions, including effective management of human and material resources as well as the coordination of research support services. To carry out these functions, a management committee comprised of scientists at MPFS was set up with the Scientist-in-Charge as the chairman.

Participant: *K. V. Seshu-Reddy, (Scientist-in-Charge). For others, see staff lists.*

1. MBITA POINT FIELD STATION (MPFS)

Following the recommendation of this committee and using funds donated by DANIDA, work was carried out to upgrade and improve on most of the facilities at MPFS. Consequently, electric perimeter fencing of 2569 m was carried out; leakages in the guest house and flats were repaired; the bat menace was eradicated; roofs, floors and pavement were repaired; and window screens and glasses fitted as appropriate. General repairs were done on all staff houses including major rehabilitation of two maisonettes. Upgrading of certain facilities in the staff houses and construction of a pier has been completed. The station's three generators that had begun showing signs of weakening due to age were overhauled with new spare parts purchased from USA/UK and pressure on them reduced by the introduction of gas cookers. The water works were expanded by the purchase and installation of one sedimentation tank, two sand filters and one balance tank was completed. MPFS also received a new PABX Meridian machine and a Mita photocopier.

A survey was carried out around the perimeter fence and beacons replaced and arrangement for grading the area was made. The Mbita Point/Homa Bay access road was improved by the Government of Kenya which, in turn, dramatically improved the accessibility of Mbita Point Field Station.

During the period the station was a host to a number of important visitors representing renowned organisations from various countries, a few of whom are listed below:

- H.E. Daniel T. arap Moi, President of the Republic of Kenya
- Hon. Madame Marie Louise Correa, Minister for Scientific Research and Technology, Senegal
- H.E. Hans-Peter Erismann, Swiss Ambassador to Kenya
- H.E. Mrs Prudence Bushnell, Ambassador of the United States of America to Kenya.
- Prof. Peter Esbjerg, Member, ICIPE Governing Council, Denmark
- Dr Jack Meagher, Member, ICIPE Governing Council, Australia
- Dr Heinz Rembold, Member, ICIPE Governing Council, Germany
- Dr Hans Wilps, Member, ICIPE Governing Council, Germany
- Mr Joseph Kaguthi, Provincial Commissioner, Nyanza Province, Kenya
- Prof. Jürg Huber, Director, Biological Control Institute, Germany
- Dr Claes Kjellström, SIDA/SAREC, Sweden
- Dr B.A. Okwakpam, University of Science & Technology, Port Harcourt, Nigeria
- Dr Johnnie van der Berg, Grain Crops Institute, South Africa
- Dr John A. Pickett, Dr Lester Wadhams, Dr Lester Smart, Dr Cliff Brookes, Dr Brian Kerry, all of Rothamsted Experimental Station, UK
- Dr Didier Fontenille, Dr Vincent Robert, ORSTOM, Senegal
- Dr F. Mosha, TPRI, Tanzania
- Dr S.K. Subba Rao, Malaria Research Centre, Delhi, India
- Mr Andreas Schriber, Swiss-TV, Zürich, Switzerland
- Dr Frederick Lyons, Resident Representative, UNDP, Nairobi
- H.E. Pamela Mboya, Kenya Permanent Representative to UN, HABITAT, Nairobi
- Prof. Richard Sikora, University of Bonn, Germany

- Dr Christine Okali, School of Developmental Studies, UK
- Dr David Bergvinson, CIMMYT, Mexico
- Dr F. Schulthess, IITA, Benin
- Dr Claus Winkel, DANIDA, Denmark
- Dr Ebbe Schioler, Department of Evaluation, Research and Documentation, DANIDA, Denmark
- Dr William S. Bowers, Univ. of Arizona, USA
- Dr James L. Nation, Florida, USA
- Prof. W.L. Kilama, National Institute for Medical Research, Tanzania
- Prof. Barbara Ekbom, Swedish University of Agricultural Sciences, Sweden and ICIPE Governing Council Member
- Prof. Yang Yansheng, Vice-President, Chinese Academy of Agricultural Sciences (CAAS), accompanied by a delegation of six, Beijing, China
- Dr William S. Romoser, Director, Department of Biological Sciences, Ohio, USA
- Dr Barbro Nedstam, VI Tree Planting Project, Uganda
- Dr Joan Kagwanja, ILRI, Ethiopia
- Dr David J. Campbell, Michigan State University, USA
- Prof. Peter Langley, University of Wales, UK
- Dr Willi Graf, Swiss Agency for Development and Cooperation (SDC) Switzerland
- Dr Joseph M. Ndungu, Deputy Director, KETRI, Kenya
- Mr R.M.J. Shingirah, General Manager, Telecom Services, Nairobi
- Mr J.K. Agenga, Director of Information, Nairobi
- Mr O. Kajumbi, District Commissioner, Suba
- Mr J.G. Kibera, District Commissioner, Homa Bay
- Dr E.W. Kairu, Kenyatta University, Nairobi
- Prof. J.M. Mweke, Kenyatta University, Nairobi
- Mrs. Luddy Angira, Director, IOGT, Nairobi
- Mr Martin Vogt, International Organisation for Migration, Nairobi
- Dr Hein van Asperen, Royal Netherlands Embassy, Nairobi
- Dr Lawrence Cockcroft, the Gatsby Charitable Foundation, UK
- Dr Peter Markham, John Innes Centre, UK
- Dr Gina Banks, John Innes Centre, UK
- Prof. Ed. Rybiciki, University of Cape Town, South Africa
- Dr Florence Wambugu, ISAAA, AfriCentre, Nairobi.

The following megaprojects had certain subprojects operating at MPFS:

1. Horticulture:	(a)	IPM of Vegetables (ICIPE/USAID)
	(b)	Banana weevil IPM (BMZ)
2. Food and Perennial Crops:	(a)	Wild habitat for cereal stem borers management project (Gatsby)
	(b)	Maize streak virus project (ICIPE/Rockefeller Foundation)
	(c)	Neem Awareness Project (ICIPE/FINIDA/UNEP)
3. Social Sciences:	(a)	Community managed tsetse project (ICIPE/ILRI/IFAD)
4. Mosquitoes:	(a)	Malaria project (ICIPE/DANIDA)
5. Tsetse:	(a)	Tsetse project (EU)
6. Ticks:	(a)	Ticks ecology and IPM (ICIPE/Rockefeller Foundation)
7. Capacity Building:	(a)	Seven PhD scholars and three MSc students carried out their research work at the station

Ungoye Field Site (UFS)

Renovation of laboratories, guest house and staff houses was completed. Sisal planting for fencing of 73 ha was established. The station maintains facilities for experimental work on development of odour attractants for *Glossina f. fuscipes* and other riverine tsetse files and studies on basic ecology of the fly; studies on dispersal of *Chilo partellus* and *Busseola fusca*; and studies on the options for the control of the banana weevil.

Kuja River Field Site (KRFS)

NGUKU

The land (3.6 ha) that had hitherto been registered under the owner's name at Nguku has been acquired and a title deed in the name of ICIPE received. Application had been lodged with County Council of Homa Bay to have a further 0.8 ha leased to ICIPE for 33 years.

AMOYO

Approval had been obtained from the Homa Bay County Council for 99 years lease for 116 ha of land at Amoyo, in which 12 ha of six paddocks has been completed and a further 12 ha of six paddocks were under construction. An experiment was started on 62 ha of paddocks, each with five zebu cattle, for testing of the efficacy of two entomogenous fungi, *Beauveria bassiana* and *Metarhizium anisopliae* against two tick species *Rhipicephalus appendiculatus* and *Amblyomma variegatum* in vegetation.

Oyugis Field Site (OFS)

ICIPE land measuring 0.8 ha was used for maintaining banana germplasm. A house has been secured which provides laboratory/office facilities. The base has been a host to several expert visits, open days, IPM training for both farmers and Ministry of Agriculture technical personnel and banana IPM resource. On-going research includes:

- development, validation and transfer of integrated technologies for the management of banana weevil, in collaboration with KARI, MOALDM, IITA, INIBAP and the banana farming community;
- assessment of socioeconomic implications of IPM;
- application of neem for its potential role in the management of banana pests.

Chamaunga Islands (CI)

Two islands with an area of 12.7 ha in Lake Victoria, Suba District, adjacent to MPFS, have been acquired by ICIPE for pest and vector management studies.

2. MUHAKA FIELD STATION (MFS)

This station represents the coastal-lowland ecology, especially of eastern/southern Africa.

A new laboratory was constructed with funds from the Wageningen Agricultural University (WAU), to accommodate its project on the biological control of cereal stemborers. As a result, the laboratories/offices which were previously on rental premises at Bamburi and Muhaka were shifted to the field station and necessary equipment and furniture were purchased. A canteen has been started as one of the staff welfare measures. ICIPE staff organised donations to establish a modest station library.

Efforts are underway to acquire a field site of 5 ha in Shimba Hills, Kwale District to accommodate research on plant pests, biodiversity and commercial insects.

Landscaping was carried out on a limited scale, and improvement of soil fertility and structure was done on a 2 ha piece of land, out of the 6 ha sandy soil plot already developed by transporting and applying black soil to facilitate development for annual crops. To sustain continuity, a simple irrigation facility was provided for crops planted during the off-season. Consequently, the following sub-projects were operated at MFS as part of the respective mega-project's activities:

1. Food and Perennial Crops:	Biological control of cereal stem borers (WAU); crop pests (ICIPE), and Kwale-Kilifi Adaptive Reasearch (UNDP)
2. Horticulture:	IPM of vegetables (ICIPE/USAID), Fruit flies (ICIPE)
3. Ticks:	Biocontrol (ICIPE)
4. Tsetse:	Kwale Kilifi Adaptive Research Project (ICIPE/UNDP)
5. Social Science:	Interactive Socioeconomic Research on Integrated Pest Management (ISERIPM) (Rockefeller Foundation).

These projects' research results were demonstrated during Open Day at the station and many people, including Provincial Administration Officials, local leaders and farmers were in attendance. As a resource base, a brain-storming session was also conducted for the local leaders in Kwale District to enhance production of honey and other valuable hive products.

During the three year reporting period, the Muhaka field station was under the supervision of Dr S. Sithanantham (1995–1996) and Dr K.V. Seshu Reddy (1997).

II. Staff Lists—1995 Personnel≠

(Professional staff as at 31 December, 1995)

MANAGEMENT AND GENERAL OPERATIONS

OFFICE OF THE DIRECTOR GENERAL
Dr H. R. Herren, *Director General*
Prof. A. Hassanali, *Interim Deputy Director General*
Mrs R. D. P. Ortega, *Senior Public Relations Officer*
Mrs D. W. Njoroge, *Principal Internal Auditor*
Ms D. Ndabameye, *Personal Assistant to the Director General*

MANAGEMENT AND FINANCE DIVISIONS
Mr V. Tandon, *Director of Management*
Mr G. W. Kanza, *Chief Accountant*
Mr Z. Kigecha, *Project Accountant*
Mr G. J. Rugendo, *Treasury Supervisor*
Mr P. N. Ndiangui, *Project Accountant*
Mr G. W. S. Fedha, *Personnel Officer*
Mr G. O. Onyach, *Transport and Building Supervisor*
Ms J. W. Mburu, *Deputy Manager, Mbita Point International Guest Centre*

INTERNATIONAL COOPERATION
Mrs R. A. Odingo, *Director of International Cooperation*
Mr J. R. Kapkirwok, *Project Development Officer*

CORE RESEARCH AND TRAINING DEPARTMENTS

CAPACITY BUILDING
Dr V. O. Musewe, *Head of Capacity Building*

ARPPIS PhD Scholars
Miss S. R. M. Kheir, *Year 3*
Mr J. J. Randriamananoro, *Year 3*
Mrs E. N. R. Sebitosi, *Year 3*
Mr N. Abdoulaye, *Year 3*
Mr M. H. Abakar, *Year 3*
Mr A. I. Tawfik, *Year 3*
Mr H. A. F. Mohamed, *Year 3*
Mr K. M. Kega, *Year 3*
Mr F. A. Demas, *Year 2*
Mr J.-B. S. Muhigwa, *Year 2*
Mr Abiy-Yenesew, *Year 2*
Ms S. Akinyi, *Year 2*
Mr G. M. Zimba, *Year 2*
Miss V. C. Ofomata, *Year 2*
Mrs Z. W. Njagu, *Year 2*
Mr M. N. S. Sallam, *Year 2*
Ms R. O. Maranga, *Year 1*
Ms M. A. Groepe, *Year 1*
Mr J. P. Mbugi, *Year 1*
Mr A. G. Malual, *Year 1*
Mr S. Ekesi, *Year 1*

Plant Pests Management Programme
Dr S. Sithanantham, *Senior Scientist and Ag. Programme Leader*

Arthropod Biodiversity, Conservation and Utilisation Programme
Dr H. R. Herren, *Interim Programme Leader*

Disease Vectors Management Programme
Dr S. Mihok, *Senior Scientist and Ag. Programme Leader*

APPLIED ECOLOGY DEPARTMENT
Dr K. Ampong-Nyarko, *Scientist and Ag. Head*
Dr K. V. Seshu Reddy, *Senior Scientist and Scientist-in-Charge of Mbita Point Field Station*
Dr W. A. Overholt, *Visiting Research Scientist*
Dr R. O. Olubayo, *Scientist*
Dr C. M. Mutero, *Scientist*
Dr M. O. Bashir, *Scientist (Sudan-based)*
Dr E. Mwangi, *Associate Scientist*
Dr M. L. A. Owaga, *Associate Scientist*
Dr M. M. Mohamed-Ahmed, *Associate Scientist*
Dr C. Kyorku, *Associate Scientist*
Dr C. O. Omwega, *Associate Scientist*
Ms A. J. Ngi-Song, *Postdoctoral Fellow*
Mrs S. W. Kimani-Njogu, *Postdoctoral Fellow*
Dr S. M. Hassan, *Scientific Officer*
Mr L. Ngode, *Associate Scientific Officer*
Mr H. T. Abdel-Rahman, *Associate Scientific Officer (Sudan-based)*
Mr G. Tikubet, *Country Coordinator (Ethiopia)*

BEHAVIOURAL BIOLOGY DEPARTMENT
Dr R. K. Saini, *Scientist and Ag. Head*
Dr Z. R. Khan, *Scientist*
Dr L. C. Madubunyi, *Scientist*
Dr S. A. Lux, *Visiting Scientist*
Dr M. M. Rai, *Postdoctoral Fellow*
Dr M. Girma, *Postdoctoral Fellow*

CHEMICAL ECOLOGY DEPARTMENT
Prof. A. Hassanali, *Principal Scientist*
Dr W. Lwande, *Scientist and Ag. Head*
Dr B. Torto, *Scientist*
Prof. S. Yagi, *Visiting Research Scientist*
Dr P. G. N. Njagi, *Associate Scientist*
Dr H. Mahamat, *Associate Scientist*
Dr Y. O. H. Assad, *Research Associate*
Dr M. Mugunga, *Visiting Scholar*
Dr A. L. Deng, *Research Associate*
Mr B. O. K. Wanyama, *Associate Scientific Officer*
Mr N. K. Gikonyo, *Associate Scientific Officer*

MOLECULAR BIOLOGY AND BIOCHEMISTRY DEPARTMENT
Dr E. O. Osir, *Scientist and Head*
Dr N. N. Massamba, *Scientist*
Dr S. Essuman, *Scientist*
Dr M. Imbuga, *Scientist*
Dr M. K. Limo, *Associate Scientist*
Dr R. M. W. Vundla, *Postdoctoral Fellow*

PATHOLOGY AND MICROBIOLOGY DEPARTMENT
Dr N. K. Maniania, *Scientist and Ag. Head*
Dr G. P. Kaaya, *Scientist*
Dr S. K. Raina, *Scientist*
Dr M. Makayoto, *Scientist*
Mrs M. A. Okech, *Scientific Officer*

SOCIAL SCIENCES DEPARTMENT
Prof. K. G. Fasil, *Senior Scientist and Head*
Dr R. C. Saxena, *Senior Scientist*
Dr J. W. Ssennyonga, *Scientist*
Dr G. T. Lako, *Scientist*
Dr P. A. Chitere, *Associate Scientist*
Dr J. M. Maitima, *Postdoctoral Fellow*

RESEARCH SUPPORT UNITS AND SERVICES

ANIMAL REARING AND QUARANTINE UNIT
Dr M. O. Odindo, *Scientist and Head*
Dr G. W. Oloo, *Scientist*
Mr F. O. Onyango, *Scientific Officer*

BIOMATHEMATICS UNIT
Dr A. Odulaja, *Scientist and Head*
Mr D. M. Munyinyi, *Principal Computer Applications Specialist*
Mr H. H. Meena, *Senior Applications Specialist*

COMPUTER SERVICES UNIT
Dr Yunlong Xia, *Scientist and Head*
Mr D. Murali, *Electronics Engineer*

SCIENCE EDITING DEPARTMENT AND ICIPE SCIENCE PRESS
Dr A. Ng'eny-Mengech, *Principal Science Editor and Head of Science Editing*
Ms A. K. Katama, *Project Leader, ICIPE Science Press*

1996 Personnel≠

MANAGEMENT AND GENERAL OPERATIONS

OFFICE OF THE DIRECTOR GENERAL
Dr Hans R. Herren, *Director General*
Mr Jason R. Kapkirwok, *Projects Administrator*
Mrs Remedios Dela Paz Ortega, *Public Relations Officer*
Ms Lucy W. Gacheru, *Programme Assistant*
Mrs Dinah W. Njoroge, *Internal Auditor*
Mrs Shamim A. Hashmy, *Executive Assistant*
Mr Julius K. Kamau, *Assistant Internal Auditor*
Mrs Purity N. Kaweru, *Executive Secretary*
Mrs Rose V. A. Onyango, *Executive Secretary*
Mr Titus M. Kaviti, *Clerical Assistant*
Mr Francis O. Ujiji, *Driver*
Mr Susan W. Muna, *Office Assistant*

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Dr Vitalis O. Musewe, *Head, Capacity Building*

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Ms Zipporah Njagu, *Outgoing 1994 Class#*
Mr Fanuel A. Demas, *Outgoing 1994 Class#*
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Mr Sunday Ekesi, *Year 3*
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Mr Nicolas K. Gikonyo, *Year 2*
Ms Deolinda S. Pacho, *Year 2*
Mr Sileshi W. Gudeta, *Year 1*
Mr Vincent O. Oduol, *Year 1*
Mr Abera T. Haile, *Year 1*

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Mr Vinod Tandon, *Director, Management*
Mr Khrisnahsamy Appadu, *Head of Financial Accounting*

ACCOUNTING SERVICES
Mr Patrick N. Ndiangui, *Project Accountant*
Mr Jasper R. Gitonga, *Treasury Accountant*
Mr Henry V. Lidegere, *Assistant Accountant*
Mr Eustace N. Mbuthia, *Assistant Accountant*
Mr Peter O. Ngugi, *Assistant Accountant*
Mr Vincent M. Kamanyi, *Assistant Accountant*
Mr James M. Katule, *Asst. Project Accountant*
Mr George M. Kiondo, *Asst. Project Accountant*
Mr Martin A. Kawaka, *Asst. Project Accountant*

Mr Peter N. Onsongo, *Accounts Assistant*
Mr Edward O. Ogola, *Data Input Clerk*
Mr Alphonse Bubusi, *Mail Clerk*

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Mr Peter D. K. Ndirangu, *Procurement Supervisor*
Mr Protus N. K. Kathenya, *Purchasing Officer*
Mr Elias M. Aosa, *Purchasing Officer*
Mr Zachary B. Awino, *Purchasing Officer*
Mr John O. Gombe, *Purchasing Officer*
Mr Daniel O. O. Olalo, *Storekeeper*

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Ms Veronique Tournier, *Personnel Officer (Recruit.)**
Mr Anthony O. Alexis, *Personnel Officer (Admin.)**
Mr John M. Mwendar, *Personnel Assistant*
Mrs Maryam Hussein, *Secretary*
Mr Michael M. Kinguu, *Security Coordinator*
Mrs Simprose O. Oyugi, *Telephonist/Receptionist*
Ms Lydiah W. Mwaura, *Telephonist/Receptionist*
Mr Elijah Asami, *Mail Clerk*
Mr Wilfred O. Adhiambo, *Office Attendant*
Mr Tom O. Adongo, *Office Attendant*
Mr Richard M. Masaka, *Office Attendant*
Mr Simon M. Mkamba, *Office Attendant*
Ms Lucy W. Mwaura, *Office Attendant*
Mrs Margaret A. Ochanda, *Office Attendant*
Mr Bernard M. Oketch, *Office Attendant*
Mr Elias Ondeyo, *Office Attendant*
Ms Phoebe Siva, *Office Attendant*
Ms Esinas J. Tirop, *Office Attendant*
Mr Fredrick O. Athula, *Office Attendant*
Ms Anne W. Karanja, *Office Attendant*
Mr George S. K. Kariuki, *Office Attendant*
Mr Peter O. Apodo, *Security Guard*
Mr Paul B. Chepkoimet, *Security Guard*
Mr Geoffrey M. Kinyua, *Security Guard*
Mr Jeremiah M. Kobaai, *Security Guard*
Mr Dickson M. Mwilu, *Security Guard*
Mr Edwin H. Otieno, *Security Guard*
Mr Gilbert O. Omondi, *Security Guard*

WORKSHOP AND LABORATORY SERVICES UNIT
Mr Abdul R. S. Abdalla, *Workshop Manager**
Mr Kennedy Ogedah, *Research Assistant*
Mr Daudi M. Muubi, *Storekeeper*
Ms Acharia C. M. M. Macharia, *Data Input Clerk*
Mr Tony L. Ngutu, *Mechanic*
Mr Patroba Nyachieo, *Senior Artisan*
Mr Charles O. Odhiambo, *Artisan/Electrician*
Mr Jacob O. Omondi, *Artisan/Carpenter*
Mr Patrick Otieno, *Artisan/Panel Beater*
Mr Andrew M. Wanyama, *Artisan/Plumber*
Mr Dominic O. Wanjara, *Artisan Assistant*
Mr Robert M. Nzioka, *Artisan Assistant*
Mr Eliud O. Ndiao, *Artisan Assistant*
Mr Samwel M. Karanja, *Generator Operator*

TRANSPORT UNIT
Mr David M. M. Kimotho, *Transport Assistant*
Mr Umar Ibrahim, *Artisan Assistant*
Mr Richard M. Mugi, *Artisan Assistant*
Mr Joseph R. Makumi, *Driver/Mechanic*
Mr Alex O. Kirimba, *Driver*
Mr Peter N. Mahogo, *Driver*
Mr John M. Mutunga, *Driver*
Mr Henry N. Njachi, *Driver*

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Mr Alphonse Lweya, *Head Chef*
Mr George Gichuru, *Chef*
Mr Simon M. Aritho, *Assistant Accountant*
Mrs Petronila A. Ocholla, *Housekeeper*
Mr Benson M. Lihanda, *Pastry Cook*
Mr Lawrence M. Mulae, *Room Steward*
Mrs Tabitha A. Ogongo, *Room Steward*
Mrs Ruth M. Wekesa, *Telephonist/Receptionist*
Mrs Margaret Asseto, *Telephonist/Receptionist*
Mr George M. Ongoncho, *Accounts Assistant*
Ms Naomi Ifire, *Barman/Waiter*
Mr Patrick Mungithya, *Barman/Waiter*
Mr Josphat K. Mutugi, *Barman/Waiter*
Mr Patrick A. Omollo, *Barman/Waiter*
Mr Kenneth O. Kwemoi, *Kitchen Assistant*
Mr Joseph O. Mukhobi, *Kitchen Assistant*
Mr Silas O. Ojwang', *Kitchen Assistant*
Mr Moses K. Wepukhulu, *Kitchen Assistant*
Mrs Hoan A. Awich, *Laundry Assistant*
Mr John N. Kipserem, *Laundry Assistant*

MBITA POINT INTERNATIONAL GUEST CENTRE
Mr Johnstone O. Koyaa, *Catering Officer*
Mr Peter O. Odote, *Chef*
Miss Mary A. Nalo, *Telephonist/Receptionist*
Mr Charles O. Nyagaya, *Room Steward*
Mr Samuel A. Alos, *Barman/Waiter*
Mr Fredrick O. Orwa, *Kitchen Assistant*
Mr Wilson M. Esirenyi, *Kitchen Assistant*
Mr Stephen O. Odhako, *Kitchen Assistant*
Mrs Helen A. Ouma, *Laundry Assistant*
Mr Francis N. Omutsembi, *Laundry Assistant*

DUDUVILLE TRAVEL AGENCY
Mr Fraser J. Utanje, *Travel Officer*
Ms Peris W. Njenga, *Travel Assistant*

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APPLIED ECOLOGY DEPARTMENT
Dr Kwesi Ampong-Nyarko, *Scientist and Ag. Head*
Dr William A. Overholt, *Principal Scientist*
Dr Suresh K. Raina, *Senior Scientist*
Dr Steven Mihok, *Senior Scientist*
Dr Magzoub O. Bashir, *Senior Scientist*
Dr Kundam V. Seshu-Reddy, *Senior Scientist*
Dr Srinivasan Sithanantham, *Senior Scientist*
Dr Mohamed M. Mohamed-Ahmed, *Scientist*
Dr Esther Mwangi, *Scientist*

Dr Charles O. Omwega, *Scientist*
Dr Robert S. Copeland, *Scientist*
Dr Getachew Tikubet, *Scientist*
Dr John Githure, *Consultant Scientist*
Dr Lucie Rogo, *Consultant Scientist*
Dr Cliff M. Mutero, *Consultant Scientist*
Dr Charles M. Mbogo, *Consultant Scientist*
Dr Mohamed Ali Bob, *Associate Scientist*
Dr Vishnu V. Adolkar, *Postdoctoral Fellow*
Dr Ballo Shifaw, *Postdoctoral Fellow*
Dr Paul N. Ndegwa, *Postdoctoral Fellow*
Dr Susan W. Kimani-Njogu, *Postdoctoral Fellow*
Dr Adele J. Ngi-Song, *Postdoctoral Fellow*
Mr Hassan T. Abdel-Rahman, *Scientific Officer*
Dr Shawgi M. Hassan, *Senior Research Assistant*
Mr Lucas Ngode, *Senior Research Assistant*
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Mr Eli M. Ng'ong'o, *Research Assistant*
Mr Walter O. Ogutu, *Research Assistant*
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Mr James K. Likhanga, *Technical Assistant*
Mr Michael O. Majua, *Technical Assistant*
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Mr Moses A. Mbeke, *Technical Assistant*
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Mr Joseph G. Mugane, *Technical Assistant*
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Mr Patrick O. Ochanjo, *Technical Assistant*
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Mr Maurice O. Odoyo, *Technical Assistant*
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Mr Peter A. Ongele, *Technical Assistant*
Mr Zedekia B. Ooko, *Technical Assistant*
Mr Richard K. Orengo, *Technical Assistant*
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Ms Jael A. Odindo, *Technical Assistant*
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Mr Joseph S. Ole Soinkei, *Field Attendant*
Mr Stephen M. Pukare, *Field Attendant*
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Dr Zeyaur R. Khan, *Senior Scientist*
Dr Slawomir A. Lux, *Senior Scientist*
Dr Melaku Girma, *Postdoctoral Fellow*
Mr Andrew Mbiru, *Senior Research Assistant*
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Mr Peter M. Chiliswa, *Research Assistant*
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Mr Enock Mpanga, *Technician*
Mr Gerson O. Asino, *Technical Assistant*
Mr Timothy W. W. Chole, *Technical Assistant*
Mr Stephen G. Ogechi, *Technical Assistant*
Mr Pascal A. Oreng', *Technical Assistant*
Mr Philip O. Owuor, *Technical Assistant*
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Dr Wilber Lwande, *Scientist and Ag. Head*
Dr Hassane Mahamat, *Scientist*
Dr Peter G. N. Njagi, *Scientist*
Dr Baldwyn Torto, *Scientist*
Dr Muhinda Mugunga, *Visiting Scholar*
Mr David M. Omogo, *Special Package*
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Mr James O. Mbayi, *Research Assistant*
Mr Edward Nyandat, *Research Assistant*
Mr Willis P. Ouma, *Research Assistant*
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Mr Dalmas O. Otieno, *Technician*
Mr Saul A. Patya, *Technician*
Mr Mohamed O. Suliman, *Technician*
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Mr Abdel R. W. Bashir, *Technical Assistant*
Mr Habert A. Chanzu, *Technical Assistant*
Mr David M. Mbesi, *Technical Assistant*
Ms Charity W. Mwangi, *Secretary*
Mr Mohamed A. I. El Sheikh, *Driver*
Mr Hassan I. Ishag, *Driver*

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Dr Ellie O. Osir, *Senior Scientist, Head*
Dr Suliman Essuman, *Scientist*
Dr Ne Ngangu Massamba, *Scientist*
Mr James G. Kabii, *Research Assistant*

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Mr Peter Lisamula, *Technician*
Mrs Joyce K. Muriithi, *Technician*

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Dr Suresh K. Raina, *Senior Scientist*
Mrs Matilda A. Okech, *Senior Research Assistant*
Mr James O. Adino, *Research Assistant*
Mr David M. Kimbu, *Research Assistant*
Mr Harrison G. Muiru, *Technician*
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Mr Dickens A. Ogollah, *Technical Assistant*
Mr Julius O. Omondi, *Technical Assistant*

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Dr George T. Lako, *Scientist*
Dr Joseph M. Maitima, *Postdoctoral Fellow*
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Mr Philip E. Ragama, *Senior Research Assistant*
Mr Gerald G. O. Nyambane, *Research Assistant*
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Mr Boniface A. Omolo, *Technician*
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Mr Naftali O. Dibogo, *Technical Assistant*
Mr David K. Kahuria, *Technical Assistant*
Mr Moses K. Mungai, *Technical Assistant*
Mr George O. Nengo, *Technical Assistant*
Mr Rashid M. Ogongo, *Technical Assistant*
Mr John S. Oluoch, *Technical Assistant*
Mr Richard O. Tumba, *Technical Assistant*
Mr Moses W. Were, *Technical Assistant*
Mr Richard O. Yogo, *Technical Assistant*

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Mr Francis O. Onyango, *Senior Research Assistant*
Mr Fred M. Thuo, *Technician*
Mr James H. Ongudha, *Technician*
Mr Geoffrey M. Nganga, *Technician*
Mr Alphonse Majanje, *Technical Assistant*
Mr Mathew M. Miti, *Technical Assistant*
Mr Patrick S. Muchisu, *Technical Assistant*
Mr Joanes M. Onyango, *Technical Assistant*

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Mr Amos G. Nyagwara, *Technical Assistant*

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Dr Adedapo Odulaja, *Scientist, Head of Unit*
Mr Christopher N. Olando, *Senior Research Assistant*
Mr Paul K. Ogino, *Research Assistant*

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Mr Darisi Murali, *Senior EDP Specialist*
Mr Mohamed D. M. Gathoga, *Computer Technologist*
Mr Michael N. Akello, *Technician*

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Mrs Eddah Wasike, *Assistant Librarian*
Mr Joash A. Lago, *Library Assistant*
Mr Wellington Ambaka, *Clerical Assistant*

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Mr Richard Nyaridi, *Clerical Assistant*
Mr Elijah Sonye, *Clerical Assistant*
Mr George K. Khisa, *Telephonist/Receptionist*
Mrs Susan A. Otila, *Cleaner*

TRANSPORT SERVICES
Mr William N. Omino, *Transport Assistant*
Mr John O. Obinga, *Driver/Mechanic*
Mr Eric O. Ogutu, *Tractor Operator*
Mr Alois A. Awich, *Groundsman*
Mr Zablon O. Nyandere, *Groundsman*
Mr Johannes D. Orimbo, *Groundsman*

SECURITY SECTION
Mr George O. Aunga, *Security Guard*
Mr John M. Motari, *Security Guard*
Mr Emmanuel O. Kotana, *Security Guard*
Mr Samuel O. Okumu, *Security Guard*
Mr Michael O. Ongara, *Security Guard*
Mr Hazaria A. Oweya, *Security Guard*
Mr Peter O. Kisaria, *Security Guard*

MARIGAT
Mr Richard K. Leitich, *Security Guard*

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Mr Douglas C. Kalume, *Office Attendant*
Mr Peter O. Kijana, *Office Attendant*
Mrs Grace W. Nganga, *Office Attendant*
Mrs Bint H. C. Mwachiyama, *Farm Assistant*

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*Until mid-1997.
#On extension until December 1997.

1997 Personnel[+]

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Dr Christiane D. Weigner, *Personal Assistant to the DG****
Mrs Dinah W. Njoroge, *Internal Auditor*
Mrs Remedios Dela Paz Ortega, *Public Relations Officer*
Mrs Rose V. A. Onyango, *Executive Secretary*
Ms Shamim A. Hashmy, *Executive Secretary**
Mrs Purity N. Kaweru, *Executive Secretary*
Mr Julius K. Kamau, *Assistant Internal Auditor*
Mr Titus M. Kaviti, *Clerical Assistant*
Ms Susan W. Muna, *Office Assistant*
Mr Francis O. Ujiji, *Driver*

OFFICE OF THE DEPUTY DIRECTOR GENERAL

Prof. Ahmed Hassanali, *Interim Deputy Director General**
Dr Akke J. van der Zijpp, *Deputy Director General, Research***
Ms Susan M. Kagondu, *Executive Assistant*

FINANCE

ACCOUNTING

Mr Vinod Tandon, *Director, Finance and Budget##*
Mr Khrisnahsamy Appadu, *Head of Financial Accounting***
Ms Serah N. Mungai, *Project Accountant*
Mr Patrick N. Ndiangui, *Project Accountant*
Mr Dominic F. Sifuna, *Project Accountant*
Mr Jasper R. Gitonga, *Treasury Accountant*
Mr Martin A. Kawaka, *Asst. Project Accountant*
Mr George M. Kiondo, *Asst. Project Accountant*
Mr Peter O. Ngugi, *Assistant Accountant*
Mr Henry V. Ligedere, *Assistant Accountant*
Mr Vincent M. Kamanyi, Assistant Accountant*
Mr John M. Kibera, *Accounts Assistant*
Mr Edward O. Ogola, *Accounts Assistant*
Mr Peter N. Onsongo, *Accounts Assistant*
Ms Nancy M. Wangui, *Accounts Assistant*
Mr Eustace N. Mbuthia, *Accounts Assistant*
Mr John M. Kibera, *Accounts Assistant*
Ms Agripina V. N. Ramoya, *Executive Assistant*
Mr Alphonse Bubusi, *Mail Clerk*

PROCUREMENT

Mr Peter D. K. Ndirangu, *Procurement Supervisor*
Mr Maurice K. Bisau, *Purchasing Officer*
Mr John O. Gombe, *Purchasing Officer*
Mr Protus N. K. Kathenya, *Purchasing Officer*
Mr Elias M. Aosa, *Purchasing Officer*
Mr Daniel O. O. Olalo, *Storekeeper*

ADMINISTRATION

HUMAN RESOURCES

Mrs Tina M. Kuklenski, *Director of Administration***
Ms Emily A. Alwala, *Personnel Officer (R&T)*
Mr John M. Mwendar, *Personnel Officer (C&B)*
Mr Michael M. Kinguu, *Security Coordinator*
Mrs Simprose O. Oyugi, *Telephonist/Receptionist*
Mrs Esther N. Goitte, *Telephonist/Receptionist*
Ms Evelyn A. Odhiambo, *Telephonist/Receptionist*
Mrs Grace W. Nganga, *Data Input Clerk*
Mr Elijah Asami, *Mail Clerk*
Mr Fredrick C. Makhulo, *Office Assistant*
Ms Syprine A. Abongo, *Office Assistant*
Mr Wilfred O. Adhiambo, *Office Attendant*
Mr Fredrick O. Athula, *Office Attendant*
Ms Anne W. Karanja, *Office Attendant*
Mr George S. K. Kariuki, *Office Attendant*
Mr Richard M. Masaka, *Office Attendant*
Mr Simon M. Mkamba, *Office Attendant*
Ms Lucy W. Mwaura, *Office Attendant*
Mrs Margaret A. Ochanda, *Office Attendant*
Mr Benard M. Okech, *Office Attendant*
Mr Elias Ondeyo, *Office Attendant*
Ms Phoebe Siva, *Office Attendant*
Ms Esinas J. Tirop, *Office Attendant*
Mr Peter O. Apodo, *Security Guard*
Mr Samuel K. Chesang, *Security Guard*
Mr Geoffrey M. Kinyua, *Security Guard*
Mr Emmanuel O. Kotana, *Security Guard*
Mr Nelson N. Munyinyi, *Security Guard*
Mr Dickson M. Mwilu, *Security Guard*
Mr Lawrence M. Nzomo, *Security Guard*
Mr Vitalis O. Okello, *Security Guard*

Mr Samuel O. Okumu, *Security Guard*
Mr Gilbert O. Omondi, *Security Guard*
Mr Michael O. Ongara, *Security Guard*
Mr Edwin H. Otieno, *Security Guard*
Mr Hazaria A. Oweya, *Security Guard*
Mr Joseph N. Tanchu, *Security Guard*
Mr Paul B. Chepkoimet, *Security Guard*

PHYSICAL PLANTS AND TRANSPORT UNIT
Mr Alfred Lustenberger, *Head***
Mr Abdul R. S. Abdalla, *Workshop Manager**
Mr William P. Habaradas, *Fleet Manager***
Mr Daudi M. Muumbi, *Storekeeper*
Ms Susy N. Khaemba, *Assistant Storekeeper*
Mr John M. Mutua, *Electrician*
Mr Joseph O. Oluk, *Electrician*
Mr Julius O. Okeyo, *Electrician*
Mr Tony L. Ngutu, *Mechanic*
Mr Patroba Nyachieo, *Senior Artisan*
Mr Jacob O. Omondi, *Artisan/Carpenter*
Mr Patrick E. Otieno, *Artisan/Panel Beater*
Mr Andrew M. Wanyama, *Artisan/Plumber*
Mr Dominic O. Wanjara, *Artisan Assistant*
Mr Robert M. Nzioka, *Artisan Assistant*
Mr Eliud O. Ndiao, *Artisan Assistant*
Mr Samwel M. Karanja, *Generator Operator*
Mr Dick K. Mutisya, *Artisan/Metal Plastic Fabricator*
Mr Elijah Y. Odeny, *Data Input Clerk*
Ms Catherine M. M. Macharia, *Data Input Clerk*
Mr Joseph R. Makumi, *Driver/Mechanic*
Mr Rogers M. Emali, *Mechanic*
Mr Humphrey K. Kungu, *Mechanic*
Ms Anastasia K. Macharia, *Mechanic*
Mr Donald M. Nyambu, *Mechanic*
Mr Walter K. Warui, *Mechanic*
Mr John P. Nyongesa, *Artisan/Carpenter*
Mr David M. M. Kimotho, *Transport Assistant*
Mr Umar Ibrahim, *Artisan Assistant*
Mr Richard M. Mugi, *Artisan Assistant*
Mr Jospeh M. Gachugu, *Driver*
Mr Benard M. Musee, *Driver*
Mr Joseph M. Mwarania, *Driver*
Mr Kennedy O. Onyango, *Driver*
Mr Alex O. Kirimba, *Driver*
Mr Peter N. Mahogo, *Driver*
Mr John M. Mutunga, *Driver*
Mr Henry N. Njachi, *Driver*

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Mr Darisi Murali, *Senior EDP Specialist*
Mr Mohamed D. M. Gathoga, *Computer Technologist*

DUDUVILLE INTERNATIONAL GUEST CENTRE
Mr Kurt B. Iten, *General Manager, Guest Centre System***
Mr Alphonse Lweya, *Head Chef*
Mr George Gichuru, *Chef*
Mr Simon M. Aritho, *Assistant Accountant*
Mrs Petronila A. Ocholla, *Housekeeper*
Mr Lawrence M. Mulae, *Room Steward*
Mrs Tabitha A. Ogongo, *Room Steward*
Mr George M. Ongoncho, *Accounts Assistant*
Mrs Ruth M. Wekesa, *Telephonist/Receptionist*
Mr Benson M. Lihanda, *Kitchen Assistant*
Ms Marystella M. Wanjala, *Kitchen Assistant*
Mr Silas O. Ojwang', *Kitchen Assistant*
Mr Kenneth K. Omari, *Kitchen Assistant*
Mr Joseph O. Mukhobi, *Kitchen Assistant*
Mr Moses K. Wepukhulu, *Kitchen Assistant*
Mr John N. Kipserem, *Laundry Assistant*
Mrs Joan A. Awich, *Laundry Assistant*
Ms Naomi Ifire, *Barman/Waiter*
Mr Patrick Mungithya, *Barman/Waiter*
Mr Patrick A. Omollo, *Barman/Waiter*
Mr David O. Orinda, *Barman/Waiter*
Ms Jane A. Asaba, *Cleaner*
Mr David Nyaribo, *Cleaner*
Ms Naomi M. Stephen, *Cleaner*

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Mr Johnstone O. Koyaa, *Catering Officer*
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Mr Fredrick O. Orwa, *Kitchen Assistant*
Mr Wilson M. Esirenyi, *Kitchen Assistant*
Mr Charles O. Nyagaya, *Room Steward*
Mr Francis N. Omutsembi, *Laundry Assistant*
Mrs Helen A. Ouma, *Laundry Assistant*
Mr Samuel A. Alos, *Barman/Waiter*

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Ms Peris W. Njenga, *Travel Assistant*

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Dr Vitalis O. Musewe, *Head, Capacity Building*
Mr Jason R. Kapkirwok, *Projects Administrator*
Mrs Lucy W. Gacheru, *Projects Assistant*
Ms Lizzie W. Chongoti, *Training Officer****
Mrs Florence M. Adhiambo, *Training Assistant*
Ms Marie L. Mukakalisa, *Executive Assistant****

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Kangethe, Mr Charles M. Mboya, Mr Samuel M. Kagunda, Mr Joseph M. Baya, Ruth K. Gathu

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Dr Scott E. Miller, *Principal Scientist****
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Dr Kundam V. Seshu-Reddy, *Senior Scientist*
Dr Srinivasan Sithanantham, *Senior Scientist*
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Dr Shawgi M. Hassan, *Senior Research Assistant*
Mr Lucas Ngode, *Senior Research Assistant*
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Mr Japheth A. Orwa, *Technical Assistant*
Mr Maurice O. Wanga, *Technical Assistant*
Mr Michael O. Majua, *Laboratory/Field Assistant*
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Mr Hassan I. Ishag, *Driver*
Mr John O. Asimba, *Field Trial Assistant*
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Mr Julius N. Tanchu, *Field Attendant*
Mr Joseph N. Ole Kobaai, *Field Attendant*
Mr Stephen M. Pukare, *Field Attendant*
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Mr Enock Mpanga, *Research Assistant*
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Mr Willis P. Ouma, *Research Assistant*
Mr Aloice O. Ndiege, *Field Trial Assistant*
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Mr Peter M. Chiliswa, *Research Assistant*
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Mr William N. Omino, *Transport Assistant*

Mr Richard Nyaridi, *Clerical Assistant*
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Mr John M. Motari, *Security Guard*
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Mr Assefa A. Lanteyidru, *Driver*
Mr Alemu Tesfaye, *Mail Clerk*

PORT-SUDAN FIELD STATION
Dr Magzoub O. Bashir, *Senior Scientist*

As of March 1998 (Staff joining or leaving in 1997 or joining in 1998 are shown with asterisks).
*Until mid-1997.
**From mid-1997.
***Staff joining in 1998.
#On extension until December 1997.
##Until February 1998.
###From February 1998.

III. Financial Statements 1995–1997

Income and Expenditure Account for the Year Ended 31 December 1995

	US$ 000	
	1995	*1994*
Income		
Grants	8,629.6	*9,081.6*
Currency translation gains	502.2	-
Miscellaneous	99.6	*115.5*
	9,231.4	*9,197.1*
Expenditure		
Core Research	5,969.9	*5,779.0*
Research Support Services	534.7	*446.1*
Training and International Cooperation	908.5	*1,098.7*
Information	135.9	*125.7*
Management and General Operations	1,281.6	*1,093.7*
Currency Translation Loss	-	*299.7*
	8,830.6	*8,842.9*
Land and Buildings	41.7	*159.2*
Scientific Equipment	30.1	*70.7*
Office Equipment and Furniture	130.2	*70.2*
Vehicles	32.7	*54.9*
	9,065.3	*9,197.9*
Surplus (Loss) for the year	166.1	*(0.8)*
Cost of Restructuring	166.1	*219.5*
Total Surplus (Loss) For The Year	Nil	*(220.3)*

Balance Sheet as at 31 December 1995

	US$ 000	
	1995	*1994*
Fixed Assets		
Nominal Value	*	*
Icipe Riverside House	269.2	*276.9*
Current Assets		
Consumable Stores	30.4	*13.4*
Grants Receivable	2,321.5	*1,712.0*
Debtors And Pre-payments	1,187.1	*1,554.2*
Deposits — Building Maintenance Fund	239.3	*215.2*
Bank Balances And Cash	1,850.6	*1,686.2*
	5,628.9	*5,181.0*
Current Liabilities		
Bank Overdraft (Secured)	1,453.4	*2,037.2*
Loan Repayable Within One Year	91.0	*32.8*
Creditors And Accruals	1,814.5	*1,912.1*
Unexpended Operating Grants	2,198.6	*1,016.6*
	5,557.5	*4,998.7*
Net Current Assets	71.4	*182.3*
Total Net Assets	340.6	*459.2*
Financed by:		
Reserve Funds	(59.9)	*(59.9)*
Buildings Maintenance Fund	239.3	*215.2*
	179.4	*155.3*
Deferred Financing	70.4	*80.4*
Long Term Loan (Secured)	90.8	*223.5*
	340.6	*459.2*

*In accordance with the ICIPE Accounting Policy, all assets are written off to the Income & Expenditure account in the year of purchase. However, the Fixed Assets held by ICIPE as at 31 December, 1995, at cost, amount to US$ 6,941,020. (1994—US$ 6,750,680)

1995 Donors

Grants Received and Receivable

	(US$ 000) 1995	1994
Arab Fund for Economic and Social Development (AFESD)	430.0	*241.9*
Danish International Development Agency (DANIDA) — Danish Government	1,062.6	*746.8*
European Union—European Development Fund (EDF)	1,540.5	*1,463.4*
Finnish Government	439.6	*120.0*
Gatsby Charitable Foundation	178.6	*166.6*
German Academic Exchange Service (DAAD)	202.5	*230.0*
German Federal Ministry of Economic Cooperation	-	*374.5*
Hebrew University of Jerusalem	42.4	*30.7*
International Bank for Reconstruction and Development (World Bank)	200.0	*480.0*
International Development Research Centre (IDRC)	18.1	*39.9*
International Fund for Agricultural Development (IFAD)	650.0	*349.2*
Japan International Research Centre for Agricultural Sciences (JIRCAS)	21.6	-
Japan Society for the Promotion of Science (JSPS)	6.0	*5.7*
Kenya Government	118.1	*29.3*
Natural Resources Institute (NRI) —UK	114.5	*246.8*
Netherlands Government, Directorate of NGO, International Education and Research Programme	1,214.1	*752.0*
Norwegian Government	481.1	*549.6*
Rockefeller Foundation	434.3	*328.5*
Swedish Agency for Research Cooperation with Developing Countries (SAREC)	624.9	*697.8*
Swiss Government	1,100.0	*6.0*
United Nations Development Programme (UNDP)	907.3	*1,891.3*
United Nations Environment Programme (UNEP)	11.0	*18.1*
United Nations High Commission for Refugees (UNHCR)	-	*54.8*
United States Agency for International Development (USAID)	7.6	*13.8*
World Resources Institute (WRI), USA	6.8	-
Total Grants Received and Receivable	9,811.6	*8,836.7*
Add : Unexpended Grants — brought forward	1,016.6	*1,261.5*
	10,828.2	*10,098.2*
Less : Unexpended Grants — carried forward	(2,198.6)	*(1,016.6)*
Grants taken into income	8,629.6	*9,081.6*

Income and Expenditure Account for the Year Ended 31st December 1996

	US$ 000	
	1996	*1995*
Income		
Grants	9,864.5	*8,629.6*
Currency translation gains	208.5	*502.2*
Miscellaneous	241.1	*99.6*
	10,314.1	*9,231.4*
Expenditure		
Core Research	4,724.2	*5,969.9*
Research Support Services	484.2	*534.7*
Training and International Cooperation	1,049.7	*908.5*
Information	145.0	*135.9*
Management and General Operations	2,403.0	*1,281.6*
	8,806.1	*8,830.6*
Land and Buildings	158.4	*41.7*
Scientific Equipment	506.1	*30.1*
Office Equipment and Furniture	415.8	*130.2*
Vehicles	428.8	*32.7*
	10,315.2	*9,065.3*
(Loss) Surplus for the year	(1.1)	*166.1*
Cost of Restructuring	-	*(166.1)*
Total (deficit) surplus for the year	(1.1)	-

Balance sheet as at 31 December 1996

	US$ 000	
	1996	*1995*
Fixed Assets		
Nominal value	*	*
ICIPE Riverside House	260.2	*269.2*
Current Assets		
Consumable Stores	31.8	*30.4*
Grants Receivable	1,565.3	*2,321.5*
Debtors and Pre-Payments	851.3	*1,187.1*
Deposits—Buildings Maintenance Fund	127.4	*239.3*
Bank Balances and Cash	2,192.5	*1,850.6*
	4,768.3	*5,628.9*
Current Liabilities		
Bank Overdraft (secured)	112.7	*1,453.4*
Loan (repayable within one year)	81.0	*91.0*
Creditors and Accruals	1,933.9	*1,814.5*
Unexpended Operating Grants	2,804.1	*2,198.6*
	4,931.7	*5,557.5*
Net Current Assets	(163.4)	*71.4*
Total Net Assets	96.8	*340.6*
Financed by:		
Reserve Funds (deficits)	(146.2)	*(59.9)*
Buildings Maintenance Fund	127.4	*239.3*
	(18.8)	*179.4*
Deferred Financing	60.4	*70.4*
Long-Term Loan (secured)	55.2	*90.8*
	96.8	*340.6*

*In accordance with ICIPE accounting policy, all fixed assets are written off to the Income and Expenditure Account in the year of purchase. However, the fixed assets held by ICIPE as at 31st December 1996 at cost amount to US$ 8,386,066 (1995—6,941,020).

1996 Donors

Grants Received and Receivable	US$ 000	
	1996	*1995*
Arab Fund for Economic and Social Development (AFESD)	200.0	*430.0*
Australian Centre of International Agricultural Research (ACIAR)	55.8	–
Austrian Government	500.0	–
Danish International Development Agency (DANIDA), Danish Government	786.6	*1,062.6*
European Union, European Development Fund (EDF)	2,484.6	*1,540.5*
Finnish Government	150.0	*439.6*
Gatsby Charitable Foundation	349.7	*178.6*
German Academic Exchange Service (DAAD)	245.0	*202.5*
German Federal Ministry of Economic Cooperation	240.6	–
Hebrew University of Jerusalem	31.0	*42.4*
International Bank for Reconstruction and Development (World Bank)	200.0	*200.0*
International Development Research Centre (IDRC)	5.4	*18.1*
International Fund for Agricultural Development (IFAD)	1,429.6	*650.0*
International Institute of Tropical Agriculture (IITA)	16.0	–
Japan International Research Centre for Agricultural Sciences (JIRCAS)	27.5	*21.6*
Japan Society for the Promotion of Science (JSPS)	6.0	*6.0*
Kenya Government	115.9	*118.1*
Natural Resources Institute (NRI), UK	37.0	*114.5*
Netherlands Government, Directorate of NGO, International Education and Research Programme	1,229.1	*1,214.1*
Norwegian Government	309.1	*481.1*
OPEC Fund for International Development	40.0	–
Rockefeller Foundation	528.1	*434.3*
Swedish Agency for Research Cooperation with Developing Countries (SAREC)	1,200.1	*624.9*
Swiss Government	2,075.0	*1,100.0*
Toyota Foundation	18.4	–
United Nations Development Programme (UNDP)	249.7	*907.3*
United Nations Environment Programme (UNEP)	1.0	*11.0*
United States Agency for International Development (USAID)	249.6	*7.6*
University of East Anglia, UK	5.6	–
University of Hawaii, USA	5.0	–
World Resources Institute (WRI), USA	–	*6.8*
Total Grants Received and Receivable	12,791.4	*9,811.6*
Add: Unexpended Grants—brought forward	2,198.6	*1,016.6*
	14,990.0	*10,828.2*
Less: Unexpended Grants—carried forward	(2,804.1)	*(2,198.6)*
	12,185.9	*8,629.6*
Less: Grants for 1995 paid in 1996	2,321.4	–
Grants taken into income	9,864.5	*8,629.6*

Audited Income and Expenditure Account for the year ended 31st December 1997

	US$ 000	
	1997	*1996*
Income		
Grants	9357.3	*9,864.5*
Currency translation gains	134.7	*241.1*
Miscellaneous	124.9	*208.5*
	9616.9	*10,314.1*
Expenditure		
Core Research	5840.9	*4,724.2*
Research Support Services	781.9	*484.2*
Training and International Cooperation	539.1	*1,049.7*
Information	142.4	*145.0*
Management and General Operations	1855.6	*2,403.0*
	9159.9	*8,806.1*
Land and Buildings	14.2	*158.4*
Scientific Equipment	138.3	*506.1*
Office Equipment and Furniture	292.1	*415.8*
Vehicles	141.8	*428.8*
	9746.3	*10,315.2*
Total (deficit) surplus for the year	(129.4)	*(1.1)*

Balance sheet as at 31 December 1997

	US$ 000	
	1997	*1996*
Fixed Assets		
Nominal value	*	*
ICIPE Riverside House	251.2	*260.2*
Current Assets		
Consumable Stores	25.9	*31.8*
Grants Receivable	1329.9	*1,565.3*
Debtors and Pre-payments	401.4	*851.3*
Deposits—Buildings Maintenance Fund	37.6	*127.4*
Bank Balances and Cash	2423.9	*2,192.5*
	4218.7	*4,768.3*
Current Liabilities		
Bank Overdraft (secured)	1091.0	*112.7*
Loan (repayable within one year)	66.7	*81.0*
Creditors and Accruals	925.8	*1,933.9*
Unexpended Operating Grants	2687.1	*2,804.1*
	4770.6	*4,931.7*
Net Current Assets	(551.9)	*(163.4)*
Total Net Assets	(300.7)	*96.8*
Financed by:		
Reserve Funds (deficits)	(404.9)	*(146.2)*
Buildings Maintenance Fund	37.6	*127.4*
	(367.3)	*(18.8)*
Deferred Financing	50.3	*60.4*
Long-Term Loan (secured)	16.3	*55.2*
	(300.7)	*96.8*

*In accordance with ICIPE accounting policy, all fixed assets are written off to the Income and Expenditure Account in the year of purchase. However, the fixed assets held by ICIPE as at 31st December 1997 at cost amount to US$ 8,971,559 (1996—$ 8,386,066).

1997 Donors

Grants Received and Receivable

	US$ 000	
	1997	*1996*
Arab Fund for Economic and Social Development (AFESD)	200.0	*200.0*
Australian Centre of International Agricultural Research (ACIAR)	51.3	*55.8*
Austrian Government	876.9	*500.0*
Danish International Development Agency (DANIDA), Danish Government	876.2	*786.6*
European Union, European Development Fund (EDF)	1,310.7	*2,484.6*
Finnish Government	202.7	*150.0*
Gatsby Charitable Foundation	298.6	*349.7*
German Academic Exchange Service (DAAD)	222.5	*245.0*
German Federal Ministry of Economic Cooperation	971.9	*240.6*
Hebrew University of Jerusalem	52.4	*31.0*
ICIPE/IFAD/ILRI Collaborative Project	179.7	–
International Bank for Reconstruction and Development (World Bank)	–	*200.0*
International Centre of Tropical Agriculture (CIAT)	136.5	–
International Committee of the Red Cross (ICRC)	11.8	–
International Crops Research Institute for Semi-Arid Tropics (ICRISAT)	5.0	–
International Development Research Centre (IDRC)	37.3	*5.4*
International Fund for Agricultural Development (IFAD)	671.0	*1,429.6*
International Institute of Tropical Agriculture (IITA)	15.0	*16.0*
Japan International Research Centre for Agricultural Sciences (JIRCAS)	15.5	*27.5*
Japan Society for the Promotion of Science (JSPS)	–	*6.0*
Johnson Wax	5.0	–
Kenya Government	109.8	*115.9*
Natural Resources Institute (NRI), UK	–	*37.0*
Netherlands Government, Directorate of NGO, International Education and Research Programme	1,645.4	*1,229.1*
Norwegian Government	444.0	*309.1*
OPEC Fund for International Development	30.0	*40.0*
Rockefeller Foundation	399.8	*528.1*
Swedish International Development Agency (SIDA)	973.5	*1,200.1*
Swiss Government	400.0	*2,075.0*
Toyota Foundation	27.0	*18.4*
United Nations Development Programme (UNDP)	–	*249.7*
United Nations Educational, Scientific and Cultural Organisation (UNESCO)	1.7	–
United Nations Environment Programme (UNEP)	–	*1.0*
United States Agency for International Development (USAID)	600.0	*249.6*
University of East Anglia, UK	4.5	*5.6*
University of Hawaii, USA	21.7	*5.0*
World Health Organisation (WHO)	8.2	–
Total Grants Received and Receivable	10,805.6	*12,791.4*
Add: Unexpended Grants—brought forward	2804.1	*2,198.6*
	13,609.7	*14,990.0*
Less: Unexpended Grants—carried forward	(2687.1)	*(2,804.1)*
	10,922.6	*12,185.9*
Less: Grants receivable—1·1·97	(1565.2)	*(2,321.4)*
Grants taken into income	9357.4	*9,864.5*

IV. ICIPE Governing Council (1995–1997)

1. 1995 ICIPE GOVERNING COUNCIL

Professor J. L. Ngu
Chairman
Immuno-Biology Laboratory (WHO/IBL) (Cameroon)

Dr W. T. Mashler
formerly Senior Director, UNDP (USA)*

Professor M. Ashburner
University of Cambridge (UK)

Professor P. Esbjerg
Royal Veterinary University, Copenhagen (Denmark)

Dr D. P. Gapasin
World Bank (Philippines)

Professor S. O. Keya
University of Nairobi (Kenya)

Dr B. E. Kipkorir
Kenyan Ambassador to the United States of America (Kenya)

Dr J. W. Meagher
formerly Chairman, Centro International de la Papa (CIP) (Australia)

Dr M. Mensah
formerly of IFAD, Economic Planning (Benin)

Professor H. Rembold
Max Planck Institute (Germany)*

Professor C. Safilios-Rothschild
Professor of Sociology (Greece)

Dr R. W. Sutherst
Commonwealth Scientific and Industrial Organisation (CSIRO) (Australia)*

Professor S. Takahashi
Kyoto University (Japan)

Dr M. Toure
World Bank (Senegal)*

Dr H. Wilps
GTZ (Germany)

Dr H. R. Herren
Director General, ICIPE (Switzerland)

**Retired in 1995*

2. 1996 ICIPE GOVERNING COUNCIL

Professor J. L. Ngu
*Chairman**
Head, Immunology-Biotechnology Laboratories WHO Collaborating Centre for Research and Training in Immunology (Cameroon)

Professor L. N. Innes
Chairman
Agricultural Research Consultant and formerly Deputy Director, Scottish Crop Protection Institute (UK)

Dr J. W. Meagher
*Vice Chairman/Chairman, Nominating Committee**
Formerly Chairman, Centro Internacional de la Papa (CIP) (Australia)

Professor C. J. Chetsanga
Vice Chairman
Director General, Scientific and Industrial Research and Development Centre (SIRDC) (Zimbabwe)

Professor P. Esbjerg
*Chairman, Programme Committee**
Royal Veterinary and Agricultural University (Denmark)

Dr B. Ekbom
Chairperson, Programme Committee
Swedish University of Agricultural Sciences (Sweden)

Dr D. Merrill-Sands
Vice Chair, Programme Committee
Visiting Fellow
Simmons Institute for Leadership and Change, Simmons College (USA)

Dr B. Kipkorir
Chairman, Audit Committee
Formerly Kenya's Ambassador to the USA (Kenya)

Dr D. P. Gapasin
Chairperson, Nominating Committee
Agriculturist
The World Bank (Philippines)

Professor H. Wilps
Member, Programme Committee
Gesellshaft für Technische Zusammenarbeit (GTZ) (Federal Republic of Germany)
Professor C. Safilios-Rothschild**
Professor of Sociology (Greece)
Professor M. Ashburner*
University of Cambridge (UK)
Professor S. O. Keya**
Executive Secretary
Technical Advisory Committee (TAC) of FAO (Kenya)
Professor S. Takahashi*
Formerly of Kyoto University (Japan)
Professor J. Ribiero**
The University of Arizona (USA)
Dr M. Mensah*
Formerly of IFAD, Economic Planning (Benin)
Dr H. R. Herren
Director General, ICIPE (Switzerland)

**Retired/resigned May 1997*
***Retired March 1996*
Effective May 1997

3. 1997 ICIPE GOVERNING COUNCIL

Professor N. L. Innes
Chairman
Former Deputy Director, Scottish Crop Protection Institute (UK)
Professor C. J. Chetsanga
Vice Chairman
Director General, Scientific & Industrial Research & Development Centre (SIRDC) (Zimbabwe)
Dr D. P. Gapasin
Chairperson, Nominating Committee
The World Bank (Philippines)
Dr B. Ekbom
Chair, Programme Committee
Swedish University of Agricultural Sciences (Sweden)
Dr D. Merrill-Sands
Vice-Chair, Programme Committee
Visiting Fellow, Simmons Institute for Leadership and Change, Simmons College (USA)
Professor H. Wilps
Member, Programme Committee
Gesellshaft für Technische Zusammenarbeit (GTZ) (Federal Republic of Germany)
Dr G. Persley
Ausbiotech Alliance (Australia)
Dr P. K. arap Konuche
Director, Kenya Forestry Research Institute (KEFRI) (Kenya)
Professor N. Weiss
Swiss Tropical Institute (Switzerland)
Dr W. N. Masiga
Director, InterAfrican Bureau for Animal Resources
Organisation of African Unity (OAU) (Kenya)
Dr H. R. Herren
Director General, ICIPE (Switzerland)

Cumulative Publications List for 1995–1997

A. ARTICLES PUBLISHED IN REFEREED JOURNALS

(The list does not include manuscripts in press and those submitted)

Abubakar L., Osir E. O. and Imbuga M. O. (1995) Properties of a blood-meal-induced midgut lectin from the tsetse fly *Glossina morsitans*. *Parasitology Research* 81, 271–275. 95-1231

Ajala S. O., Saxena K. N. and Chiliswa P. (1995) Selection in maize *(Zea mays* L.) for resistance to the spotted stem borer *(Chilo partellus* Swinhoe). *Maydica* 40, 137–140. 95-1233

Ajala S. O., Smith II L. M. and Odulaja A. (1995) Potential of Kenyan local maize *(Zea mays* L.) germplasm as a source of resistance to the spotted stem borer *Chilo partellus* (Swinhoe). *Tropical Agriculture (Trinidad)* 72 (4), 297–302. 95-1284

Akai H., Nakatomi R., Kioko E. and Raina S. K. (1997) Fine structure of cocoon and cocoon filament from African *Gonometa* silkmoth (Lasiocampidae). 3, 15–22.

Annan I. B., Ampong-Nyarko K., Tingey W. M. and Schaeffers G. A. (1997) Interactions of fertilizer, cultivar selection, and infestation by cowpea aphid (Aphididae) on growth and yield of cowpeas. *International Journal of Pest Management* 43, 307–312. 97-1411

Annan I. B., Saxena K. N., Schaefers G. A. and Tingey W. M. (1994) Effects of infestation by cowpea aphid (Homoptera: Aphididae) on different growth stages of resistant and susceptible cowpea cultivars. *Insect Science and Its Application* 15, 401–410. 94-1370

Assad Y. O. H., Hassanali A., Torto B., Mahamat H., Bashir N. H. H. and El Bashir S. (1997) Effects of fifth-instar volatiles on sexual maturation of adult desert locust *Schistocerca gregaria*. *Journal of Chemical Ecology* 23, 1373–1388. 97-1365

Assad Y. O. H., Torto B., Hassanali A., Njagi P. G. N., Bashir N. H. H. and Mahamat H. (1997) Seasonal variation in the essential oil composition of *Commiphora quadricincta* and its effect on the maturation of immature adults of the desert locust, *Schistocerca gregaria*. *Phytochemistry* 44, 833–841. 97-1350

Bandara K. A. N. P. and Saxena R. C. (1995) A technique for handling and sexing *Callosobruchus maculatus* F. adults (Coleoptera: Bruchidae). *Journal of Stored Products Research* 31(1), 97–100.

Basimike M. and Mutinga M. J. (1995) Effects of permethrin-treated screens on phlebotomine sandflies, with reference to *Phlebotomus martinii* (Diptera: Psychodidae). *Journal of Medical Entomology* 32(4), 428–432. 95-1292

Beauhaire J., Ducrot P., Malosse C., Rochat D., Ndiege I. O. and Otieno D. O. (1995) Identification and synthesis of sordidin, a male pheromone emitted by *Cosmopolites sordidus*. *Tetrahedron Letters* 36(7), 1043–1046. 95-1207

Bekele A. J., Obeng-Ofori D. and Hassanali A. (1996) Evaluation of *Ocimum suave* (Willd.) as a source of repellents, toxicants and protectants in storage against three stored product insect pests. *International Journal of Pest Management* 42, 139–142. 96-1305

Bekele A. J., Obeng-Ofori D. and Hassanali A. (1997) Evaluation of *Ocimum kenyense* (Ayobangira) as source of repellents, toxicants and protectants in storage against three major stored product insect pests. *Journal of Applied Entomology* 121, 169–173. 97-1352

Binta M. G., Mushi E. Z. and Rurangirwa F. R. (1996) Effect of anti-thymocyte serum on acquisition of resistance to infestation by *Rhipicephalus appendiculatus* larvae in rabbits. *Onderstepoort Journal of Veterinary Research* 63, 213–216. 96-1325

Bonhof M. J., Overholt W. A., Van Huis A. and Polaszek A. (1997) Natural enemies of cereal stemborers in East Africa: A review. *Insect Science and Its Application* 17 (1), 19–35. 97-1409

Chitere P. and Kiros F. G. (1996) Farmers' participation in the adaptation of IPM technologies in sub-Saharan Africa: Experiences from Kenya. *The African Crop Science Journal* 4, 115–126.

Dakouo D., Essuman S. and Raina S. K. (1996) Mise en évidence de facteurs humoraux dans la defense immunitaire du criquet pélerin *Schistocerca gregaria*. *Science et Technique, Sciences naturelles* 22 (2), 70.

Dakouo D., Nacro S., Post R., Traore Y., Nokoe S. and Munyinyi D. M. (1995) Evaluating an insect pest management system in an irrigated rice environment. *Insect Science and Its Application* 16, 93–101. 95-1368

Darlington J. P. E. C. (1994) Mound structure and nest population of the termite, *Pseudacanthotermes spiniger* (Sjostedt) in Kenya. *Insect Science and Its Application* 15, 445–452 (Published in 1996). 94-1371

Deng A. L., Torto B., Hassanali A. and Ali E. E. (1996) Effects of shifting to crowded or solitary conditions on pheromone release and morphometrics of the desert locust, *Schistocerca gregaria* (Forskål) (Orthoptera: Acrididae). *Journal of Insect Physiology* 42, 771–776. 96-1324

Denlinger D. L. and Zdarek J. (1997) A hormone from the uterus of the tsetse fly, *Glossina morsitans*, stimulates parturition and abortion. *Journal of Insect Physiology* 43, 135–142. 97-1339

Dossa S. C., Kaaya G. P., Essuman S., Odulaja A. and Assoku R. G. K. (1996) Acquisition of resistance to the tick

Amblyomma variegatum in Boran cattle, *Bos indicus* and the effects of *Trypanosoma congolense* and *Babesia bigemina* on host resistance. *Veterinary Parasitology* 62, 317–330. 96-1290

Duale A. H. and Okwakpam B. A. (1997) Inter-larval competition and its subsequent effect on *Pediobius furvus* (Hym: Eulophidae) broods for the management of graminaceous stem borers. *Biocontrol Science and Technology* 7, 239–245. 97-1417.

Duale A. H. and Seshu Reddy K. V. (1995) Survival and development of *Chilo partellus* (Swinhoe) on sorghum cultivars. *Insect Science and Its Application* 16, 13–16. 95-1354

Duale A. H., Nwilene F. E. and Okwakpam B. A. (1997) Suitability of pupae of the stem borer *Chilo partellus* (Swinhoe) (Lep.: Pyralidae) of various ages for parasitism by *Pediobus furvus* (Gahan) (Hym.: Eulophidae). *Journal of Applied Entomology* 121, 147–150. 97-1360

Githiri S. M., Ampong-Nyarko K., Osir E. O. and Kimani P. M. (1996) Antixenosis component of resistance to aphids in cowpea. *East African Agriculture and Forestry Journal* 61(3), 249–253.

Hailemichael Y., Schulthess F., Smith J. W., Jr. and Overholt W. A. (1997) Suitability of West African gramineous stemborers for the development of *Cotesia* species. *Insect Science and Its Application* 17, 89–95. 97-1419

Hanson B. S., Ochieng S. A., Grosmaitre X., Anton S. and Njagi P. G. N. (1996) Physiological responses and central nervous projections of antennal olfactory receptor neurons in the adult desert locust, *Schistocerca gregaria* (Orthoptera: Acrididae). *Journal of Comparative Physiology*, A 179, 157–167.

Herren H. R., Overholt W. A. and Lwande W. (1996) Pest management for ornamental horticulture. *Horticultural Trade Journal* 4, 23–24. 96-1364

Jembere B., Obeng-Ofori D., Hassanali A. and Nyamasyo G. N. N. (1995) Products derived from the leaves of *Ocimum kilimandscharicum* (Labitae) as post-harvest grain protectants against the infestation of three major stored product insect pests. *Bulletin of Entomological Research* 85, 361–367. 95-1236

Jura W. G. Z. O. and Otieno L. H. (1994) Infectivity and virulence of *Trypanosoma brucei* metacyclics from *Glossina morsitans morsitans* salivary glands infected with tsetse DNA virus. *Insect Science and Its Application* 15, 551–556 (Published in 1996). 94-1318

Kaaya G. P. (1996) Mortality and pathology in tsetse flies (*Glossina* spp.) treated with neem extracts. *Tanzania Veterinary Journal* 16, 58–65. (Publication released in 1997).

Kaaya G. P and Munyinyi D. M. (1995) Biocontrol potential of the entomogenous fungi *Beauveria bassiana* and *Metarhizium anisopliae* for tsetse flies (*Glossina* spp.) at developmental sites. *Journal of Invertebrate Pathology* 66, 237–241. 95-1235

Kaaya G. P., Mwangi E. N. and Malonza M. M. (1995) Acaricidal activity of *Margaritaria discoidea* (Euphorbiaceae) plant extracts against the ticks *Rhipicephalus appendiculatus* and *Amblyomma variegatum* (Ixodidae). *International Journal of Acarology* 21(2), 123–129. 95-1232

Kaaya G. P., Mwangi E. N. and Ouna E. (1996) Prospects for biological control of livestock ticks, *Rhipicephalus appendiculatus* and *Amblyomma variegatum*, with entomogenous fungi *Beauveria bassiana* and *Metarhizium anisopliae*. *Journal of Invertebrate Pathology* 67, 15–20. 96-1291

Kence A., Otieno L. H. and Mahamat H. (1995) Genetic polymorphisms in natural populations of tsetse fly, *Glossina pallidipes* Austen in Kenya. *Insect Science and Its Application* 16 (3/4), 369–373. 95-1396

Khan Z. R., Abenes M. L. P. and Fernandez N. J. (1996) Suitability of graminaceous weed species as host plants for rice leaffolders, *Cnaphalocrocis medinalis* and *Marasmia patnalis*. *Crop Protection* 15, 121–127. 96-1299

Khan Z. R., Ampong-Nyarko K., Chiliswa P., Hassanali A., Kimani S., Lwande W., Overholt W. A., Pickett J. A., Smart L. E., Wadhams L. J. and Woodcock C. M. (1997) Intercropping increases parasitism of pests. *Nature* 388, 631–632. 97-1363

Khan Z. R. and Saxena R. C. (1997) Use of a surrogate stem for eliciting ovipositional response of *Busseola fusca* (Lepidoptera: Noctuidae). *Journal of Economic Entomology* 90, 1426–1429. 97-1412

Khan Z. R., Chiliswa P., Ampong-Nyarko K., Smart L. E., Polaszek A., Wandera J. and Mulaa M. A. (1997) Utilisation of wild gramineous plants for management of cereal stemborers in Africa. *Insect Science and Its Application* 17, 143–150. 97-1406

Kimani S. and Overholt W. A. (1995) Biosystematics of the *Cotesia flavipes* complex (Hymenoptera: Braconidae): Interspecific hybridization, sex pheromone and mating behaviour studies. *Bulletin of Entomological Research* 85, 379–386. 95-1238

Kimani-Njogu S. W. and Overholt W.A. (1997) Biosystematics of the *Cotesia flavipes* species complex (Hymenoptera : Braconidae) parasitoids of gramineous stemborers. *Insect Science and Its Application* 17, 119–130. 97-1422

Kimani-Njogu S. W., Overholt W. A., Woolley J. and Walker A. (1997) Biosystematics of the *Cotesia flavipes* species complex (Hymenoptera: Braconidae): Morphometrics of selected allopatric populations. *Bulletin of Entomological Research* 87, 61–66. 97-1346

Kioko E. N., Overholt W. A., Omwega C. O. and Mueke J. M. (1995) Taxonomic significance of isoenzymes in two stem borers (Lepidoptera: Pyralidae) of maize and sorghum in Kenya. *African Entomology* 3(2), 167–171. 95-1237

Kiros F. G. (1995) Toward typologies of agricultural producers in sub-Saharan Africa. *East African Social Science Research Review* XI(2), 1–15. 95-1293

Kitron U., Otieno L. H., Hungerford L. L., Odulaja A., Brigham W. U., Okello O. O., Joselyn M., Mohamed-Ahmed M. M. and Cook E. (1996) Spatial analysis of the distribution of tsetse flies in the Lambwe Valley, Kenya, using Landsat TM satellite imagery and GIS. *Journal of Animal Ecology* 65, 371–380. 96-1308

Latif A. A., Rowlands G. J., Punyua D. K., Hassan S. M. and Capstick P. B. (1995) An epidemiological study of tick-borne diseases and their effects on productivity of zebu cattle under traditional management on Rusinga Island, western Kenya. *Preventive Veterinary Medicine* 22, 169–181. 95-1225

Leitao S. G., Kaplan M. A. C., Monache F. D., Nyandat E. and Rwekika E. F. (1995) Antifeedant activity of two phenylpropanoid glucosides from *Aegiphila obducta* against *Chilo partellus* larvae. *Insect Science and Its Application* 16 (3/4), 375–378. 95-1399

Machocho A. K., Lwande W., Jondiko J. I., Moreka L. V. C. and Hassanali A. (1995) Three new flavonoids from the root of *Tephrosia emoroides* and their antifeedant activity against the larvae of the spotted stalkborer *Chilo partellus* Swinhoe. *International Journal of Pharmacognosy* 33(3), 222–227. 95-1265

Madubunyi L. C. (1995) Bloodmeal evacuation from midgut of *Glossina pallidipes* in relation to tsetse foraging activity and trappability. *Ecological Entomology* 20, 146–152. 95-1226

Madubunyi L. C., Hassanali A., Ouma W., Nyarango D. and Kabii J. (1996) Chemoecological role of mammalian urine in host location by tsetse, *Glossina* spp. (Diptera: Glossinidae). *Journal of Chemical Ecology* 22, 1187–1199. 96-1297

Mahamat H., Hassanali A. and Ferenz H.-J. (1997) Vitellogenin titres in normal and accelerated maturition of gregarious-phase *Schistocerca gregaria*. *Comparative Biochemistry and Physiology* 116B, 447–451. 97-1340

Mahamat H., Hassanali A. and Munyinyi D. (1997) Haemolymph pigment composition as a chemometric indicator of phase of the desert locust *Schistocerca gregaria*. *Insect Science and Its Application* 17, 199–204. 97-1408

Majiwa P. A. O., Maina M., Waitumbi J. N., Mihok S. and Zweygarth E. (1995) *Trypanosoma (Nannomonas) congolense:* Molecular characterization of a new genotype from Tsavo, Kenya. *Parasitology* 106, 151–162.

Maniania N. K. (1994) A laboratory technique for infecting adult tsetse with a fungal pathogen. *Insect Science and Its Application* 15, 421–426. (Published 1996). 94-1316

Massamba N. N. and Mutinga M. J. (1994) Heterogeneity in the *Leishmania donovani* complex (Protozoa: Kinetoplastidae). *Insect Science and Its Application* 15, 541–550. 94-1317

Mbapila J. C. and Overholt W. A. (1997) Oviposition, development and searching behaviour of *Cotesia flavipes* Cameron and *Cotesia sesamiae* (Cameron) (Hymenoptera: Braconidae) in relation to aestivating and non-aestivating *Chilo* spp. (Lepidoptera: Pyralidae) larvae in maize. *African Entomology* 5, 35–39. 97-1356

Mihok S. and Clausen P. H. (1996) Feeding habits of *Stomoxys* spp. stable flies in a Kenyan forest. *Medical and Veterinary Entomology* 10, 392–394. 96-1358

Mihok S., Kang'ethe E. K. and Kamau G. K. (1995) Trials of traps and attractants for *Stomoxys* spp. (Diptera: Muscidae). *Journal of Medical Entomology* 32(3), 283–289. 95-126

Mihok S., Machika C., Darji N., Kang'ethe E. K. and Otieno L. H. (1995) Relationships between host blood factors and proteases in *Glossina morsitans morsitans* subspecies infected with *Trypanosoma congolense*. *Medical and Veterinary Entomology* 9, 155–160. 95-1224

Mihok S., Maramba O., Munyoki E. and Kagoiya J. (1995) Mechanical transmission of *Trypanosoma* spp. by African Stomoxyinae (Diptera: Muscidae). *Tropical Medicine and Parasitology* 46(2), 103–105. 95-1255

Mihok S., Maramba O., Munyoki E. and Saleh K. (1996) Phenology of Stomoxyinae in a Kenyan forest. *Medical and Veterinary Entomology* 10, 305–316. 96-1322

Mihok S., Moloo S. K., Oden'y J. O., Brett R. A., Rakwar J. G., Munyoki E., Kiilu J. and Kyorku C. A. (1996) Attractiveness of black rhinoceros (*Diceros bicornis*) to tsetse flies (*Glossina* spp.) (Diptera: Glossinidae) and other biting flies. *Bulletin of Entomological Research* 86, 33–41. 96-1279

Minja E. M. and Ampofo J. K. (1995) Effect of sorghum and cowpea intercropping pattern on the spotted stemborer, *Chilo partellus* (Swinhoe) larval establishment in southwestern Kenya. *Insect Science and Its Application* 16, 217–222. 95-1367

Mohamed-Ahmed M. M. and Odulaja A. (1997) Diel activity patterns and host preferences of *Glossina fuscipes fuscipes* (Diptera: Glossinidae) along the shores of Lake Victoria, Kenya. *Bulletin of Entomological Research* 87, 179–186. 97-1341

Mohamed-Ahmed M. M. and Wynholds Y. (1997) Effects of vegetation and weather on trap catches of *Glossina fuscipes fuscipes* near Lake Victoria, Kenya. *Entomologia Experimentalis et Applicata* 14, 511–527. 97-1416

Mutinga M. J., Odhiambo T. R., Kamau C. C., Odulaja A., Amimo F. A. and Wachira D. W. (1995) Choice of resting sites by *Anopheles gambiae* (Diptera: Culicidae) in Mwea rice irrigation scheme, Kirinyaga District, Kenya. *East African Medical Journal* 72(3), 170–175. 95-1227

Mwangi E. N. and Kaaya G. P. (1997) Prospects of using parasitoids for tick management in Africa. *International Journal of Acarology* 23, 215–219. 97-1414

Mwangi E. N., Essuman S., Kaaya G. P., Nyandat E., Munyinyi D. and Kimondo M. G. (1995) Repellence of the tick *Rhipicephalus appendiculatus* by the grass *Melinis minutiflora*. *Tropical Animal Health and Production* 27, 211–216. 95-1241

Mwangi E. N., Hassan S. M., Kaaya G. P. and Essuman S. (1997) The impact of *Ixodiphagus hookeri*, a tick parasitoid of *Amblyomma variegatum* (Acari: Ixodidae) in a field trial in Kenya. *Experimental and Applied Acarology* 21, 117–126. 97-1388

Mwangi E. N., Hassanali A., Essuman S., Nyandat E., Moreka L. and Kimondo M. (1995) Repellent and acaricidal properties of *Ocimum suave* against *Rhipicephalus appendiculatus* ticks. *Experimental and Applied Acarology* 19, 11–18. 95-1222

Mwangi E. N., Kaaya G. P., Essuman S. and Kimondo M. (1995) Experimental and natural infections of the tick *Rhipicephalus appendiculatus* with entomogenous fungi *Beauveria bassiana* and *Metarhizium anisopliae*. *Journal of African Zoology* 109, 151–160.

Ndiege I. O., Budenberg W. J., Otieno D. O. and Hassanali A. (1996a) 1,8-cineole: An attractant for the banana weevil, *Cosmopolites sordidus*. *Phytochemistry* 42, 369–371. 96-1307

Ndiege I. O., Budenburg W. J., Otieno D. O. and Hassanali A. (1996b) The distribution of monoterpene hydrocarbons in airborne volatiles from pseudostem of eight cultivated banana cultivars in East Africa. *Bulletin of the Chemical Society of Ethiopia* 10 (1), 43–46. 96-1421

Ndungu M., Lwande W., Hassanali A., Moreka L. and Chhabra S. C. (1995) *Cleome monophylla* essential oil and its constituents as tick *(Rhipicephalus appendiculatus)* and maize weevil *(Sitophilus zeamais)* repellents. *Entomologia Experimentalis et Applicata* 76, 217–222. 95-1268

Ngi-Song A. J. and Overholt W. A. (1997) Host location and acceptance by *Cotesia flavipes* Cameron and *C. sesamiae* (Cameron) (Hymenoptera: Braconidae) parasitoids of African gramineous stemborers: Role of frass and other host cues. *Biological Control Theory and Application in Pest Management* 9, 136–142. 97-1402

Ngi-Song A. J., Overholt W. A. and Ayertey J. N. (1995) Suitability of African gramineous stemborers for development of *Cotesia flavipes* and *Cotesia sesamiae* (Hymenoptera: Braconidae). *Environmental Entomology* 24(4) 978–984. 95-1248

Ngi-Song A. J., Overholt W. A., Njagi P. G. N., Dicke M., Ayertey J. N. and Lwande W. (1996) Volatile infochemicals used in host and host habitat location by *Cotesia flavipes* Cameron and *Cotesia sesamiae* (Cameron) (Hymenoptera: Braconidae), larval parasitoids of stemborers on graminae. *Journal of Chemical Ecology* 22, 307–324. 96-1285

Nguu E. K., Osir E. O., Imbuga M. O. and Olembo N. K. (1996) The effect of host blood in the *in vitro* transformation of bloodstream trypanosomes by tsetse midgut homogenates. *Medical and Veterinary Entomology* 10, 317–322. 96-1323

Njagi P. G. N. and Torto B. (1996) Responses of nymphs of desert locust, *Schistocerca gregaria* to volatiles of plants used as rearing diet. *Chemoecology* 7, 172–178. (Publication released in Dec. 1997). 96-1400

Njagi P. G. N., Torto B., Obeng-Ofori D. and Hassanali A. (1996) Phase-independent responses to phase-specific aggregation pheromone in adult desert locusts, *Schistocerca gregaria* (Orthoptera: Acrididae). *Physiological Entomology* 21, 131–137. 96-1302

Nour A. M. (1995) Phenotypic stability of sorghum hybrids for resistance to the spotted stemborer, *Chilo partellus* (Swinhoe). *Insect Science and Its Application* 16 (3/4), 279–282. 95-1394

Nyindo M., Essuman S., Chesang' R. and Muteria P. (1996) Immunity induced by vaccination with *Rhipicephalus appendiculatus* salivary gland antigens does not augment immunity acquired naturally by exposing rabbits to adult ticks. *Journal of Medical Entomology* 33, 559–565. 96-1303

Obeng-Ofori D. (1995) Plant oils as grain protectants against infestations of *Cryptolestes pusillus* and *Rhyzopertha dominica* in stored grain. *Entomologia Experimentalis et Applicata* 77, 133–139. 95-1277

Obeng-Ofori D., Reichmuth Ch., Bekele J. and Hassanali A. (1997) Biological activity of 1, 8-cineole, a major component of essential oil of *Ocimum kenyense* (Ayobangira) against stored product beetles. *Journal of Applied Entomology* 121, 237–243. 97-1366

Odulaja A. (1996) Modifications to the evaluation of intercropping advantage. *Tropical Agriculture* 73, 231–233. (Publication released in 1997). 96-1391

Odulaja A. and Abu-Zinid I. M. (1997) The relative efficiencies of latin square and randomised complete block designs for insect trapping experiments: An investigation using field data on tsetse flies. *Ecological Entomology* 22, 184–188. 97-1309

Odulaja A. and Kiros F. G. (1996) Modelling agricultural production of small-scale farmers in sub-Saharan Africa: A case study in western Kenya. *Agricultural Economics* 14, 85–91. 96-1320

Odulaja A. and Madubunyi L. C. (1997) A sampling bias model for odour-baited traps in relation to tsetse hunger cycle and population suppression. *Ecological Modelling* 104, 165–173. 97-1413

Odulaja A. and Mohamed-Ahmed M. M. (1997) Estimation of the efficiency of the biconical trap for *Glossina fuscipes fuscipes* Newstead along the Lake Victoria shore, Kenya. *Entomologia Experimentalis et Applicata* 82, 19–24. 97-1345

Odulaja A. and Nokoe S. (1995) A serial correlation analysis of experimental field scores. *Discovery and Innovation* 7(1), 6–10. 95-1278

Odulaja A. and Nokoe S. (1997) Conversion of yield data from experimental plot to larger plot units. *Discovery and Innovation* 9, 137–141.

Oghiakhe S. (1995) Progress and future prospects in utilisation of host plant resistance in the control of insect pests of cowpea, *Vigna unguiculata* in Africa. *Insect Science and Its Application* 16, 123–143. 95-1349

Ogoyi D. O., Osir E. O. and Olembo N. K. (1995) Lipophorin and apolipophorin-III in solitary and gregarious phases of *Schistocerca gregaria*. *Comparative Biochemical Physiology* 112B(3), 441–449. 95-1242

Ogoyi D. O., Osir E. O. and Olembo N. K. (1996) Effect of phase status on responses to AKH I in the desert locust, *Schistocerca gregaria gregaria*. *Archives of Insect Biochemistry and Physiology* 32, 173–185. 96-1304

Okech S. H. O., Neukermans L. M. N. R. and Chinsembu K. C. (1994) Agroecological distribution of major stalk borers of maize in Zambia. *Insect Science and Its Application* 15(2), 167–172. 94-1398

Okech S. H. O. and Overholt W. A. (1996) Comparative biology of *Cotesia chilonis* (Hymenoptera: Braconidae) on selected African gramineous stemborers. *Biocontrol Science and Technology* 6, 595–602. 96-1326

Omolo E. O., James M. D., Osir E. O. and Thomson J. A. (1997) Cloning and expression of a *Bacillus thuringiensis* (L1-2) gene encoding a crystal protein active against *Glossina morsitans morsitans* and *Chilo partellus*. *Current Microbiology* 34, 118–121. 97-1344

Omwega C. O. and Overholt W. A. (1996) Genetic changes occurring during laboratory rearing of *Cotesia flavipes* Cameron (Hymenoptera: Braconidae), an imported parasitoid for the control of gramineous stem borers in Africa. *African Entomology* 4, 231–237. 96-1321

Omwega C. O. and Overholt W. A. (1997) Progeny production and sex ratios of field populations of *Cotesia flavipes* and *Cotesia sesamiae* reared from gramineous stemborers in coastal Kenya. *Insect Science and Its Application* 17, 137–142. 97-1407

Omwega C. O., Kimani S. W., Overholt W. A. and Ogol C. K. P. O. (1995) Evidence of the establishment of *Cotesia flavipes* (Hymenoptera: Braconidae) in continental Africa. *Bulletin of Entomological Research* 85, 525–530. 95-1256

Omwega C. O., Overholt W. A., Mbapila J. C. and Kimani-Njogu S. W. (1997) Establishment and dispersal of *Cotesia flavipes* (Cameron) (Hymenoptera: Braconidae), an exotic endoparasitoid of *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) in northern Tanzania. *African Entomology* 5, 71–75. 97-1355

Onyido A. E. and Mutinga M. J. (1995a) Ecology of *Sergentomyia garnhami*, (Diptera: Psychodidae) in a kala-azar endemic area of Tseikuru, Kitui District, Kenya. I: The breeding sites. *East African Medical Journal* 72(2), 83–88. 95-1228

Onyido A. E. and Mutinga M. J. (1995b) Ecology of *Sergentomyia garnhami*, (Diptera: Psychodidae) in a kala-azar endemic area of Tseikuru, Kitui District, Kenya. II: Day resting sites. *East African Medical Journal* 72(2), 89–93. 95-1229

Osir E. O., Abubakar L. and Imbuga M. O. (1995) Purification and characterization of a midgut lectin-trypsin complex from the tsetse fly *Glossina longipennis*. *Parasitology Research* 81, 276–281. 95-1230

Osir E. O. and Gould F. (1994) The future role of biotechnology in integrated pest management. *Insect Science and Its Application* 15, 621–631. (Published in 1996). 94-1329

Overholt W. A., Ngi-Song A. J., Omwega C. O., Kimani-Njogu S. W., Mbapila J., Sallam M. N. and Ofomata V. (1997) A review of the introduction and establishment of *Cotesia flavipes* Cameron in East Africa for biological control of cereal stemborers. *Insect Science and Its Application* 17, 79–88. 97-1420

Potting R. P. J., Overholt W. A., Danso F. O. and Takasu K. (1997) Foraging behaviour and life history of the stemborer parasitoid, *Cotesia flavipes*. *Journal of Insect Behaviour* 10, 13–29. 97-1393

Potting R. P. J., Vet L. E. M. and Overholt W. A. (1997) Geographic variation in host selection behaviour and reproductive success in the stemborer parasitoid *Cotesia flavipes* (Hymenoptera: Braconidae). *Bulletin of Entomological Research* 87, 515–524. 97-1376

Prasad J. S., Seshu Reddy K. V. and Sikora R. A. (1995) Hosts of the banana root-lesion nematode, *Pratylenchus goodeyi* in East Africa. *Nematologia Mediterranea* 23, 253–254. 95-1287

Rai M. M., Hassanali A., Saini R. K., Odongo H. and Kahoro H. (1997) Identification of components of the oviposition aggregation pheromone of the gregarious desert locust, *Schistocerca gregaria* (Forskal). *Journal of Insect Physiology* 43, 83–87. 97-1353

Raina S. K., Das S., Rai M. M. and Khurad A. M. (1995) Transovarial transmission of *Nosema locustae* (Microsporida: Nosematidae) in the migratory locust *Locusta migratoria migratorioides*. *Parasitology Research* 81, 38–44. 95-1216

Saini R. K., Hassanali A., Andoke J., Ahuya P. and Ouma W. P. (1996) Identification of the major components of larviposition pheromone from larvae of tsetse flies *Glossina morsitans morsitans* Westwood and *Glossina morsitans centralis* Machado. *Journal of Chemical Ecology* 22, 1211–1220. 96-1306

Saini R. K., Rai M. M., Hassanali A., Wawiye J. and Odongo H. (1995) Semiochemicals from froth of egg pods attract ovipositing females *Schistocerca gregaria*. *Journal of Insect Physiology* 41, 711–716.

Saxena R. C. and Kidiavai E. L. (1997) Neem seed extract spray applications as low-cost inputs for management of the flower thrips in the cowpea crop. *Phytoparasitica* 25, 99–110. 97-1348

Seshu Reddy K. V., Prasad J. S., Ngode L. and Sikora R. A. (1995) Influence of trapping of the banana weevil, *Cosmopolites sordidus* (Germar 1824) on the root-lesion nematode, *Pratylenchns goodeyi* (Sher and Allen 1953) population densities and subsequent banana yield. *Acta Oecologica* 16(5), 593–598. 95-1289

Solomon G. and Kaaya G. P. (1996) Comparison of resistance in three breeds of cattle against African ixodid ticks. *Experimental and Applied Acarology* 20, 223–230. 96-1298

Ssennyonga J. W., Goodell G., Lako G. T. and Tedla S. (1994) Social and economic aspects of integrated pest management in the tropics. *Insect Science and Its Application* 15, 633–648. (Published in 1996). 94-1330

Takasu K. and Overholt W. A. (1996) Oviposition behaviour of *Cotesia flavipes* and *Goniozus indicus*, larval parasitoids of the lepidopteran stemborer, *Chilo partellus*. *Japan Journal of Applied Entomology and Zoology* 40, 308–310.

Takasu K. and Overholt W. A. (1997) Aggressive behaviour of *Chilo partellus* larvae against the larval parasitoid *Cotesia flavipes*. *Insect Science and Its Application* 17, 131–135. 97-1410

Tawfik A. I., Mat'hova A., Sehnal F. and Ismail S. H. (1996) Haemolymph ecdysteroids in the solitary and gregarious larvae of *Schistocerca gregaria*. *Archives of Insect Biochemistry and Physiology* 31, 427–438. 96-1311

Tawfik A. I., Osir E. O., Hassanali A. and Ismail S. H. (1997) Effects of juvenile hormone treatment on phase changes and pheromone production in the desert locust, *Schistocerca gregaria* (Forskal) (Orthoptera : Acrididae). *Journal of Insect Physiology* 43, 1177–1182. 97-1397

Tawfik A. I., Vedrova A., Li W., Sehnal F. and Obeng-Ofori D. (1997) Haemolymph ecdysteroids and the prothoracic glands in the solitary and gregarious adults of *Schistocerca gregaria*. *Journal of Insect Physiology* 43, 485–493. 97-1347

Torto B., Bentley M. D., Cole B. J. W., Hassanali A., Huang F., Gelbaum L. and Vanderveer D. G. (1995) Limonoids from *Turraea floribunda*. *Phytochemistry* 40(1), 239–243. 95-1258

Torto B., Hassanali A., Nyandat E. and Bentley M. D. (1996) A limonoid from *Turraea floribunda*. *Phytochemistry* 42, 1235–1237. 96-1314

Torto B., Njagi P. G. N., Hassanali A. and Amiani H. (1996) Aggregation pheromone system of nymphal gregarious desert locust, *Schistocerca gregaria* (Forskal). *Journal of Chemical Ecology* 22, 2273–2281. 96-1327

Van Emden H. F. and Dabrowski Z. T. (1994) Biodiversity and habitat modification in pest management. *Insect Science and Its Application* 15, 605–620. (Published in 1996). 94-1338

Van Lenteren J. C. and Overholt W. A. (1994) Ecology and integrated pest management. *Insect Science and Its Application* 15, 557–582. (Published in 1996). 94-1331

Wamunyokoli F. W. and Osir E. O. (1995) Characterisation of *Bacillus thuringiensis* variety *israelensis* delta-endotoxin. *Insect Science and Its Application* 16(3/4), 343–349. 95-1395

Zdarek J. and Denlinger D. L. (1995) Changes in temperature, not photoperiod, control the pattern of adult eclosion in the tsetse, *Glossina morsitans*. *Physiological Entomology* 20, 362–366. 95-1270

Zdarek J. and Denlinger D. L. (1997) Species variation in the response of tsetse flies (*Glossina* spp., Diptera: Glossinidae) to parturition hormone. *European Journal of Entomology* 94, 381–383. 97-1362

Reprints of articles with a call number at the end of the citation can be ordered from the Documentalist, ICIPE.

B. MISCELLANEOUS PUBLICATIONS

(Includes papers in published conference proceedings, books, chapters in books, articles in newsletters, books about ICIPE, review articles and electronic-journal articles)

Bob M. A., Sithanantham S. and Nono Womdim R. (1997) Whitefly problems in Africa: Known importance and research needs, pp. 859–866. In *Proceedings of ANPP-Fourth International Conference on Pests in Agriculture* 7–9 Jan. 1997, Montpellier, France, Volume 3. Association Nationale de Protection des Plantes, Paris. 97-1392

Chiliswa P., Khan Z. R., Loxdale H. D. and Brookes C. P. (1997) Allozyme variation in tropical cereal stemborers with particular reference to *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) and *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae), pp. 89–102. In *Focus on Agricultural Research for Sustainable Development in a Changing Economic Environment*. Proceedings of the 5th KARI Scientific Conference, 14–16 October 1996, Nairobi, Kenya. 97-1426

Hailu G., Sithanantham S. and Rao M. R. (1997) Incidence of aphids and their predators in sole and intercropped beans with different hedgerow species, pp. 615–622. In *Proceedings of ANPP-Fourth International Conference on Pests in Agriculture* 7–9 January 1997, Montpellier, France. Association Nationale de Protection des Plantes, Paris.

Jordan A. M. (1995) *A Review of the Tsetse Research Programme of the International Centre of Insect Physiology and Ecology, 1971–1994*. Wageningen Agricultural University, Wageningen, The Netherlands. 70 pp.

Kaaya G. P. and Mwangi E. N. (1995) Control of livestock ticks in Africa: Possibilities of biological control using the entomogenous fungi *Beauveria bassiana* and *Metarhizium anisopliae*, pp. 5–16. In *International Conference on Tick-Borne Pathogens*. Proceedings of the 2nd International Conference on Tick-Borne Pathogens at the Host-Vector Interface, Kruger National Park, South Africa, 28 August – 1 September, 1995. 95-1403

Khan Z. R. (1997) A review of entomological techniques and methods used to determine mechanisms and bases of stem borer resistance in maize, pp. 62–67. In *Insect Resistant Maize: Recent Advances and Utilisation* (Edited by J. A. Mihm). Proceedings of an International Symposium held at the International Maize and Wheat Improvement Centre (CIMMYT), 27 November–3 December 1994 at CIMMYT, Mexico, D.F.

Kiarie M. and Saxena R. C. (1996) Exploratory evaluation of neem extract sprays on maize for control of stalk borers in coastal Kenya, pp. 571–573. In *Neem and Environment*, Vol. 1 (Edited by R. P. Singh, M. S. Chari, A. K. Raheja and W. Kraus). Proceedings of the World Neem Conference, India, 1993. Oxford & IBH, New Delhi.

Kiros F. G. (1996) The silent violence of insect pests and disease vectors in sub-Saharan Africa: Facing up to the challenge. *Bulletin of African Insect Science*, Vol. 16, pp. 1–3.

Lux S. A. and Gaggl K. (1995) Ethological analysis of medfly courtship: Potential for quality control, pp. 425–432. In *Fruit Fly Pests: A World Assessment of Their Biology and Management* (Edited by B. A. McPheron and G. J. Steck). St Lucia Press, Delray Beach, Florida.

Mengech A. N., Saxena K. N. and Gopalan H. N. B. (Eds) (1995) *Integrated Pest Management in the Tropics: Current Status and Future Prospects*. John Wiley & Sons, Chichester, New York, Brisbane, Toronto, Singapore. 171 pp.

Mihok S. (1997) Tsetse and trypanosomiasis and wildlife/livestock interactions, pp. 165–172. In *Proceedings of the East Africa Livestock Assessment Workshop*. University of California, Small Ruminant CRSP, Davis, California.

Mihok S., Kock R. and Masake R. (1996) Health implications of translocations of endangered species in Africa: Trypanosomiasis in rhinoceros, pp. 423–424. In *Proceedings of the Joint Conference of AAZV/WDA/AAWV*. Michigan, USA. (Publication released in 1997).

Ngi-Song A. J. and Overholt W. A. (1997) Host selection by *Cotesia flavipes* and *Cotesia sesamiae* (Hymenoptera: Braconidae): An example of a tritrophic relationship in a grass–stem borer parasitoid system, pp. 173–181. In *Integrating Biological Control and Host Plant Resistance*. Proceedings of a CTA/IAR/IIBC Seminar, Addis Ababa, Ethiopia, 9–14 October 1995. CTA Publication.

Odindo M. O., Nour A. M., Ajala S. O., Kiros F. G., Chitere P. O., Ampong-Nyarko K., Mohamed Ali M. A. and Ngalo Z. O. (1997) Integration of *Bacillus thuringiensis* with elite sorghum and maize genotypes to enhance productivity of small-scale farms in the coastal region of Kenya, pp. 144–153. In *Integrating Biological Control and Host Plant Resistance*. Proceedings of a CTA/IAR/IIBC Seminar, Addis Ababa, Ethiopia, 9–14 October 1995. CTA Publication. ISBN 92 9081 1625. 97-1351

Odulaja A. (1995) A modelling study of agricultural production of African small scale farmers, pp. 132–139. In *Proceedings of the Fourth Meeting of the East, Central and Southern African Network of the International Biometric Society*, Stellenbosch, Republic of South Africa. 5–7 December, 1995. University of Stellenbosch, South Africa.

Odulaja A. (1997) Detecting significant differences in comparative experiments, pp. 85–88. In *Proceedings of the Fifth Scientific Conference of the East, Central and Southern African Network of the International Biometric Society*, 22–25 September 1997 Mombasa, Kenya. (Edited by C. Duchateau and H.G. Mwambi). ILRI, Addis Ababa, Ethiopia. ISBN 92 9146 026 5.

Olando C. N., Seshu Reddy K. V. and Sum K. (1997) Spatial distribution and sampling plans of cereal stemborer, *Chilo partellus*, pp. 94–98. In *Proceedings of the Fifth Scientific Conference of East, Central and Southern African Network of the International Biometric Society*, 22–25 September 1997 Mombasa, Kenya (Edited by L. Duchateau and H.G. Mwambi). ILRI, Addis Ababa. ISBN 92 9146 026 5.

Omolo E. O., Ssennyonga J. W., Ngugi A., Kiros F. G. and Okali C. (1995) Community mapping exercises: An evaluation. *Agricultural Administration (Research and Extension) Network Paper 52*. Overseas Development Institute, London.

Overholt W. A. (1995) The rearing of *Cotesia flavipes* for classical biological control of *Chilo partellus*, pp. 331–345. In *Techniques of Insect Rearing for the Development of Integrated Pest and Vector Management Strategies*, Vol. 2. (Edited by J. P. R. Ochieng-Odero). Proceedings of the International Group Training Course on Techniques of Insect Rearing for the Development of Integrated Pest and Vector Management Strategies. 16 March–3 April 1992, ICIPE, Nairobi. ICIPE Science Press, Nairobi.

Overholt W. A., Ngi-Song A. J., Omwega C. O., Kimani-Njogu S. W., Mbapila J., Sallam M. N. and Ofomata V. (1996) An ecological approach to biological control of gramineous stemborers in Africa: The introduction and establishment of *Cotesia flavipes* Cameron (Hymenoptera: Braconidae). In E. B. Radcliffe and W. D. Hutchison (eds), *Ted Radcliffe's Gopher State IPM Site*, URL:http: / / www.ent.agri.umn.edu/academics/classes/ipm/ipmsite.htm.Univ. of Minnesota, St Paul, MN.

Raguraman S., Jayaraj S. and Saxena R. C. (1996) Effect of neem extracts on brown planthopper, *Nilaparvata lugens* and its symbionts, pp. 375–380. In *Neem and Environment*, Vol. 1 (Edited by R. P. Singh, M. S. Chari, A. K. Raheja and W. Kraus). Proceedings of the World Neem Conference, India, 1993. Oxford & IBH, New Delhi.

Saxena R. C. (1995a) Biological effects of neem and their modes of action. Homoptera: Leaf- and planthoppers, aphids, psyllids, whiteflies and scale insects, pp. 268–286. In *The Neem Tree* Azadirachta indica *A. Juss. and Other Meliaceous Plants: Sources of Unique Natural Products for Integrated Pest Management, Medicine, Industry and Other Purposes* (Edited by H. Schmutterer). VCH, Weinheim.

Saxena R. C. (1995b) Neem products for integrated pest management: Pests of stored products, pp. 418–432. In *The Neem Tree* Azadirachta indica *A. Juss. and Other Meliaceous Plants: Sources of Unique Natural Products for Integrated Pest Management, Medicine, Industry and Other Purposes* (Edited by H. Schmutterer). VCH, Weinheim.

Saxena R. C. (1996) Sustainable development—Beyond 2000. *Global Neem Update* 1(2), 3–5, and 11–12.

Sithanantham S., Olubayo F. M., Seshu Reddy K. V. and Nyarko K. A. (1997) Collaborative research for understanding and managing the insect pest problem among indigenous (leafy) vegetable crops in Kenya, pp. 74–77. In *Proceedings of the National Seminar on Horticultural Research and Development in Kenya* 29–31 January 1997, Nairobi. Jomo Kenyatta University of Agriculture and Technology (JKUAT), Nairobi.

Sithanantham S., Otieno Z. and Nyarko K. A. (1997) Preliminary observations on effects of neem sprays on some non-target arthropods in cowpea ecosystems, pp. 643–648. In *Proceedings of ANPP-Fourth International Conference on Pests in Agriculture* 7–9 January 1997, Montpellier, France. Association Nationale de Protection des Plantes, Paris.

Ssennyonga J. W. (1996) Community-based tsetse control, pp. 99–107. In *Partnerships for Sustainable Agriculture* (Edited by L. A. Thrupp). World Resources Institute, Washington DC.

Ssennyonga J. W., Mohamed-Ahmed M. M. and Kiros F. G. (1996) The development and validation of a model for community-managed tsetse trapping technology in Lambwe, Kenya. *Research Methodology Paper No. 20*, May 1996. SSD, ICIPE.

Wambugu E. N., Farrel G. and Sithanantham S. (1996) Evaluation of susceptibility of grains of some stalk borer tolerant maize and sorghum genotypes to maize weevil and larger grain borer, pp. 88–93. In *Crop Protection for*

Resource-Poor Farmers in Kenya. Proceedings of KARI/ ODA Crop Protection Conference, Nairobi, Kenya, 27–28 March 1996. KARI/ODA.

Zweygarth E., Mihok S., Majiwa P. A. O. and Kaminsky R. (1995) A new *Nannomonas*-type trypanosome; isolation, *in vitro* cultivation and partial characterisation, pp. 188–190. In *First International Congress of Parasitology and Tropical Medicine* (Edited by B. Sinnah). Malaysian Society of Parasitology and Tropical Medicine, Kuala Lumpur.

C. PUBLICATIONS BY ICIPE SCIENCE PRESS

- *1994 ICIPE Annual Report Highlights.* Edited by A. Ng'eny-Mengech. ISBN 92 9064 091 X. 48 pp. October 1995.
- *1994 ICIPE Annual Scientific Report.* Edited by A. Ng'eny-Mengech and M. F. B. Chaudhury. ISBN 92 9064 092 8. 199 pp. November 1995.
- *1995 ICIPE Annual Report.* Edited by A. Ngeny-Mengech. ISBN 92 9064 098 7. 72 pp. October 1996.
- *1996/97 Annual Report Highlights.* Edited by A. Ng'eny-Mengech. ISBN 92 9064 112 6. 56 pp. September 1997.
- *Directory of Neem Workers in Eastern and Southern Africa.* Edited by R. C. Saxena. ISBN 92 9064 107 X. 30 pp. April 1997.
- Financial and Administrative Management of Research Projects in Eastern and Southern Africa (FAMESA) Management Manuals:
  - *Productive R&D Strategic and Project Planning and Budgeting.* ISBN 92 9064 075 8, 323 pp.
  - *Productive R&D Institute Facilities and Materials Management.* ISBN 92 9064 076 6, 284 pp.
  - *Productive R&D Project Planning, Monitoring and Evaluation.* ISBN 92 9064 072 3, 262 pp.
  - *Productive R&D Scientific, Technical and Management Information Systems.* ISBN 92 9064 074 X, 259 pp.
- *ICIPE 5-Year Plan: Research and Capacity Building Plan for the Period 1996–2000* (temporary cover). ISBN 92 9064 104 5. 132 pp. December 1996.
- *ICIPE. 25 Years of Research in Tropical Insect Science.* Edited by A. Ng'eny-Mengech. ISBN 9064 086 3.
- *Improved Insect Pest Management for Maize, Sorghum and Cowpea Production in Coastal Kenya. Technology Handbook for Extensionists.* Compiled by S. Sithanantham, G. M. Kamau, E. Wekesa and K. Mwangi. ICIPE Science Press, Nairobi for the Kenya Agricultural Research Institute. ISBN 92 9064 106 1. 12 pp. December 1996.
- Insect Science and Its Application *(The International Journal of Tropical Insect Science). Founded by Thomas R. Odhiambo. ISSN 0191-9040*
  - –Volume 15 (1994). Editor-in-Chief, K. N. Saxena.
  - –Volume 16 (1995). Editor-in-Chief, H. R. Herren.
  - –Volume 17 (1997). Editor-in-Chief, H. R. Herren.
  - *(Also available as electronic version.)*
- *IPM Technologies for Stemborer Control on Maize in Coastal Kenya. A Guide for Extension Staff.* Social Sciences Department. ISBN 92 9064 110 X. 12 pp. September 1997.
- *Techniques of Insect Rearing for the Development of Integrated Pest and Vector Management Strategies* (Vol. 2). Edited by J. P. R. Ochieng'-Odero. Proceedings of the International Group Training Course on Techniques of Insect Rearing for the Development of Integrated Pest and Vector Management Strategies. 16 March–3 April 1992, ICIPE, Nairobi, Kenya. ISBN 92 9064 065 X. 252 pp.
- *Vision and Strategic Framework towards 2020.* ISBN 92 9064 111 8. 74 pp. September 1997.

D. OTHER PUBLICATIONS BY ICIPE STAFF

(Includes papers and books published about work not conducted at ICIPE)

Buffoni G., Di Cola G., Baumgärtner J. and Maurer V. (1997) The local dynamics of acarine predator-prey (*Cheyletus eruditus-Dermanyssus gallinae*) populations: Identification of a lumped parameter model. *Mitt. Schweiz. Ent. Ges.* 70, 345–359.

Herren H. R. (1996) Cassava and cowpea in Africa. *Biotechnology and Integrated Pest Management* (Series Editor—G. J. Persley). 15, 136–149. CABI, Wallingford, UK. 96-1405

Mahamat H., Olaho-Mukani W. and Mboloi M. M. (1997) Pregnancy diagnosis in the dromedary camel (*Camelus dromedarius*) based on a competitive progesterone enzyme linked immunosorbent assay (ELISA). *Journal of Camel Practice and Research* 4(2), 203–205. 97-1425

Maitima J. M. (1995) Late Holocene human activities and their impacts on biological diversity, pp. 9–12. In *Conservation of Biodiversity in Africa: Local Initiatives and Institutional Rites* (Edited by L. A. Bennun, R. A. Aman and S. A. Crafter). Proceedings of International Conference held at the National Museums of Kenya, 30 August–3 September 1992. National Museums of Kenya, Nairobi, Kenya.

Maitima J. M. (1997) Prehistoric fires and land cover change in western Kenya: Evidence from pollen, charcoal, grass cuticles and grass phytoliths. *The Holocene* 7, (4) 409–417.

Maitima J. M., Adhikary S., Guisan A., Holten J., Innes J. and Tessier L. (Principal Lead Authors). Benston M., Fox D. (Convening Lead Authors) (1996) Impacts of climate change on mountain regions. In *Climate Change 1995—Impacts, Adaptations and Mitigation of Climate Change: Scientific–Technical Analyses* (Edited by R.T. Watson, M. C. Zinowera and R. H. Moss). Contributions of Working Group II to the Second Assessment Report (SAR) IPCC-WMO-UNEP. Cambridge University Press, 880 pp.

Meikle W. G., Gutierrez A. P. and Herren H. R. (1996) Decision-making by smallholder farmers in an oil-palm-based economy in southern Benin, West Africa. *Tropical Agriculture (Trinidad)* 17 (3), 217–225. 96-1401

Muhigwa Bahananga J.-B., Diamani B. and Kabungo K. (1996) Physico-chemical preferences of the zooplankton and notes on the predominance of a carnivorous copepod in Lake Tanganyika. *African Journal of Ecology: (E.A. Wildlife Society)* 34, 86–89. 96-1301

Raina S. K. and Overholt W. (Eds) (1996) *Conservation of Hymenopteran Parasitoids for Management of the Citrus Blackfly in Oranges.* Printed at ICIPE Science Press. 78 pp.

Stäubli Dreyer B., Neuenschwander P., Baumgärtner J. and Dorn S. (1997a) Functional response of two *Hyperaspis notata* strains to their prey, the cassava mealybug *Phenacoccus manihoti. Mitt. Schweiz. Ent. Ges.* 70, 18–21.

Stäubli Dreyer B., Neuenschwander P., Baumgärtner J. and Dorn S. (1997b) Trophic influences on survival, development, and reproduction of *Hyperaspis notata* (Coleoptera: Coccinellidae). *Z. Ang. Ent.* 121, 249–256.

Yan G., Christensen B. M. and Severson D. W. (1997a) Comparisons of genetic variability and genome structure among mosquito strains selected for refractoriness to a malaria parasite. *Journal of Heredity* 88, 187–194.

Yan G., Severson D. W. and Christensen B. M. (1997b) Costs and benefits of mosquito refractoriness to malaria parasites: Implication for genetic diversity of mosquitoes and genetic control of malaria. *Evolution* 51, 441–450.

Reprints of articles with a call number at the end of the citation can be ordered from the Documentalist, ICIPE.

E. DOCTORAL AND MASTERS THESES BY GRADUATES OF ICIPE'S POSTGRADUATE TRAINING PROGRAMMES

PhD theses of graduates of the African Regional Postgraduate Programme in Insect Science (ARPPIS)

Adgeh B.J. (1995) Effects and use of some *Ocimum* plant species and their essential oils on some storage insect pests. University of Nairobi, Kenya.

Assad Y.O.H. (1995) The role of host plants in maturation of the desert locust *Schistocerca gregaria* (Forskal)(Orthoptera: Acrididae). University of Gezira, Sudan.

Bengally S. (1996) Studies on cellular and humoral immune responses of *Amblyomma variegatum* and *Rhipicephalus appendiculatus* to infection by pathogens and parasitoids. University of Ghana, Ghana.

Deng A.L. (1995) Studies on the factors that influence phase dynamics of the desert locust *Schistocerca gregaria.* University of Khartoum, Sudan.

Dossa K. (1997) Studies on acquisition of tick resistance against *Amblyomma variegatum* in cattle and on the effects of parasitism (trypanosomiasis and babesiosis) on tick resistance. University of Ghana, Accra.

Epidi T.T. (1997) Mechanisms of resistance in selected sorghum genotypes to the spotted stem borer, *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae). Rivers State University of Science and Technology, Nigeria.

Kamara S.I. (1996) Effect of host semiochemicals on the behaviour of *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae). University of Sierra Leone, Fourah Bay.

Kambona K. (1996) Biocontrol potential of the fungus *Beauveria bassiana* (Balsamo) against the desert locust, *Schistocerca gregaria* (Forskal). Moi University, Kenya.

Kenya E.U. (1995) The mode of action of some isolates of *Bacillus thuringiensis.* Rivers State University of Science and Technology, Nigeria.

Kimani S.W. (1995) Morphological and biochemical systematics of the *Cotesia* parasitoid complex (Hym. Braconidae). University of Nairobi, Kenya.

Kutua S.F. (1997) Behavioural responses of *Rhipicephalus appendiculatus* Neumann 1901 to host and non-host semiochemicals. Kenyatta University, Kenya.

Masaninga F. (1997) Adaptation of *Trypanosoma congolense* types to different hosts and transmission by *Glossina* species. University of Zambia, Lusaka.

Mohammed H.A.F. (1996) Comparison of two isolated populations of the desert locust *Schistocerca gregaria gregaria* Forskal and *Schistocerca gregaria flaviventris* Burmeister with particular reference to pheromone communication system (Orthoptera: Acrididae). Ain Shams University, Egypt.

Mohammed M.A. (1995) Interaction between *Bacillus thuringiensis* (Berliner), enhancing agents and sorghum genotypes for control of the spotted stemborer, *Chilo partellus.* University of Gezira, Sudan.

Mutinda C.J. (1997) Genetic variability and responses to selection for *Chilo partellus* (Swinhoe) resistance in a maize *(Zea mays* L.*)* population. University of Nairobi, Kenya.

Mwangi S.G. (1995) Inheritance and linkage studies using isoenzymes and morphological characters in arid-resistant cowpea cultivar. University of Nairobi, Kenya.

Nabasirye M. (1996) Statistical inferences on pest resistance indices: Implications for selection in crop plants. Makerere University, Uganda.

Ngi-Song A. (1997) Chemical ecology of host finding behaviour in *Cotesia flavipes* (Cameron) and *Cotesia sesamiae* (Cameron). University of Ghana, Accra.

Nguu E.K. (1997) Effect of host blood and its digestive products on trypanosome differentiation in tsetse fly *Glossina morsitans.* University of Nairobi, Kenya.

Niassy A. (1997) Studies on some factors mediating the interaction between *Schistocerca gregaria* (Forskal) and *Locusta migratoria migratorioides* (Reich & Fairmaire) in relation to phase polymorphism. University of Ghana, Accra.

Ogoyi D.O. (1996) Changes in lipophorin structure and function during phase transition in *Schistocerca gregaria* (Forskal) (Orthoptera: Acarididae). University of Nairobi, Kenya.

Omolo E.O. (1997) Cloning and sequence analysis of the genes that encode the delta endotoxin of novel *Bacillus thuringiensis* strains, effective against tsetse flies *(Glossina morsitans morsitans)* and armyworms *(Spodoptera exempta).* University of Nairobi, Kenya.

Oranga H. (1996) Modelling productivity of indigenous zebu cattle (*Bos indicus*) under the natural field conditions on Rusinga Island, Kenya. Moi University, Kenya.

Rapuoda B.A. (1996) Ecological and behavioural studies of mosquitoes in Mwea Tebere Irrigation Scheme, Kirinyaga District, Kenya with special reference to *Anopheles arabiensis* (Diptera: Culicidae). Kenyatta University, Kenya.

Randriamanoro J.J. (1996) Behavioural and physiological responses of the maize stalk borer *Busseola fusca* Fuller (Lepidoptera: Noctuidae) to selected cultivated and wild host plants. Rivers State University of Science and Technology, Nigeria.

Tawfic A.I. (1997) Interaction between pheromones and hormones in phase dynamics of the desert locust *Schistocerca gregaria* (Forskal). Assiut University, Egypt.

Tikubet G. (1996) Tsetse ecology and trypanosomiasis challenge in Southern Ethiopia. University of Sierra Leone, Fourah Bay.

PhD and MSc theses of students of the Dissertation Research Internship Programme (DRIP)

Amimo F.A. (1996) Ecology of phlebotomine flies in Marigat, Kenya. MSc Thesis. Kenyatta University, Kenya.

Hutter N.J. (1996) Insect–plant interaction. MSc Thesis. University of Newcastle-upon-Tyne, United Kingdom.

Kolsch G. (1996) Anaerobic respiration of submerged insects. PhD Thesis. University of Kiel, Germany.

Mohamud M.H. (1996) Suitability of different wild gramineous plants for the survival and development of the stemborer *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae). MSc Thesis. Kenyatta University, Kenya.

Manyara C.G. (1996) Assessing the impact of the tsetse fly on land use and human welfare: A case study of Lambwe Valley, Kenya. PhD Thesis. Michigan State University, USA.

Michalik S. (1996) Integrated pest management for French beans. PhD Thesis. University of Hannover, Germany.

Sumba A.L. (1996) Mechanical transmission of *Trypanosoma evansi* and *Trypanosoma congolense* by African *Stomoxys* flies. MSc Thesis. University of Nairobi, Kenya.

Acronyms and Abbreviations

AAAP attraction-aggregation-attachment pheromone
AAIS African Association of Insect Scientists
AAU Association of African Universities (Accra, Ghana)
ABESO Arumeru Beekeepers Society (Arusha, Tanzania)
ABLH Association for Better Land Husbandry (Kenya)
ACIAR Australian Centre for International Agricultural Research
ADC Austrian Development Cooperation
AGRIS Agricultural Information Service (FAO)
AINA Arthropod Information Network in Africa (ICIPE)
ARC Agricultural Research Corporation (Sudan)
ARI Agricultural Research Institute (Tanzania/Uganda)
ARPPIS African Regional Postgraduate Programme in Insect Science (ICIPE)
AVRDC Asian Vegetable Research and Development Centre (Taipei, Taiwan, China)
BARNESA Banana Research Network for Eastern and Southern Africa (Uganda)
BARS Bvumbwe Agricultural Research Station (Malawi)
BMZ Bundesministerium fur Wirtschaftliche und Entwicklung Zusammenarbeit (Bonn, Federal Republic of Germany)
Bt *Bacillus thuringiensis*
CAAS Chinese Academy of Agricultural Sciences
CASP Consortium of African Scholarly Publishers
CDC Centres for Disease Control (Atlanta, GA, USA)
CGIAR Consultative Group on International Agricultural Research (Washington DC, USA)
CIAT Centro Internacional de Agricultura Tropical (Colombia)
CIMMYT Centro Internacional de Mejoramiento de Maiz y Trigo (Mexico DF, Mexico)
CIRAD/FLHOR Centre de cooperation internationale en recherche agronomique pour le développement—Département des productions fruitères et horticoles (Réunion)
CIRDES Centre internationale de recherche et développement d'elevage en zone sub humide (Burkina Faso)
CRF Coffee Research Foundation (Kenya)
CSB Central Silk Board (India)
CSBR Centre of Sericulture and Biological Pest Management Research (India)
CSIRO Commonwealth Scientific and Industrial Research Organisation (Australia)
cv. cultivar
DAAD German Academic Exchange Service
DANIDA Danish International Development Agency (Copenhagen, Denmark)
DAT days after transplanting
DBM diamondback moth
DFID Department for International Development (UK) formerly ODA
DGIS Directorate General for International Cooperation (The Netherlands)
DRIP Dissertation Research Internship Programme (ICIPE)
DRSRS Department of Resource Survey and Remote Sensing (Kenya)
DVBD Division of Vector-Borne Diseases (Kenya)
EAG electroantennogram
ECOSUR El Colegio de la Frontera Sur (Tapachula, Mexico)
ENVIRONET Environmental Publishing Network (ICIPE Science Press project)
EPZ The Export Processing Zones Authority (Kenya)
ESARC Eastern and Southern African Centre for the Improvement of Cassava, Banana and Plantain (IITA, Uganda)
ESTC Ethiopian Science and Technology Commission
FAO Food and Agriculture Organisation of the United Nations
FBRCAF Federal Biological Research Centre for Agriculture and Forestry (Darmstadt, Germany)
FINIDA Finnish International Development Agency
FITCA Farming in Tsetse Controlled Areas (project countries—Kenya, Uganda, Tanzania and Ethiopia)
FPEAK Fresh Produce Exporters Association of Kenya
G gregarious phase (of migratory locusts)
GIS geographic information systems
GPS global positioning system
GTZ Gesellschaft für Technische Zusammenarbeit (Eschborn, Germany)
HCDA Horticultural Crops Development Authority (Kenya)
HIB Bergen High-Technology Centre Ltd
HMF hydroxymethylfurfural
HORTI Horticultural Research and Training Institute (Tanzania)
HUJ Hebrew University of Jerusalem
IACR Integrated Approach to Crop Research (Rothamstead, UK)
IAEA International Atomic Energy Agency (Vienna, Austria)
IAR Institute for Agricultural Research (Ethiopia)
IARCs international agricultural research centres
IBRA International Bee Research Association (UK)
ICRAF International Centre for Research in Agroforestry (Nairobi, Kenya)
ICRC International Committee of the Red Cross (Geneva, Switzerland)
ICRISAT International Crops Research Institute for the Semi-Arid Tropics (Hyderabad, India)
IDEA Investment for Development of Export Agriculture (Uganda)
IFAD International Fund for Agricultural Development (Rome, Italy)

IGR	insect growth regulator
IIE	International Institute of Entomology (UK)
IITA	International Institute of Tropical Agriculture (Ibadan, Nigeria and Cotonou, Benin)
ILRI	International Livestock Research Institute (Nairobi, Kenya and Addis Ababa, Ethiopia)
INIBAP	International Network for the Improvement of Banana and Plantain
IPER	ICIPE Periodic External Review
IPM	integrated pest management
IPVM	integrated pest and vector management
IRRI	International Rice Research Institute (Los Baños, Philippines)
ISAAA	International Service for the Acquisition of AgriBiotechnology Application
ISERIPM	Interactive Socioeconomic Research for Bio-Intensive Pest Management (ICIPE project)
ISP	ICIPE Science Press
ITC	International Trypanotolerance Centre (Banjul, The Gambia)
IVRP	Indian Vegetable Research Project
JIC	John Innes Centre (UK)
JIRCAS	Japan International Research Centre for Agricultural Sciences
JKUAT	Jomo Kenyatta University of Agriculture and Technology (Kenya)
JSPS	Japan Society for the Promotion of Science
KARI	Kenya Agricultural Research Institute
KEMRI	Kenya Medical Research Institute
KESSEFA	Kenya Small Scale Farmers' Association
KETRI	Kenya Trypanosomiasis Research Institute
KIOF	Kenya Institute of Organic Farming
KIRDI	Kenya Industrial Research and Development Institute
KWS	Kenya Wildlife Services
LAN	local area network
LIT	lethal insect technique
MES	stages of midgut evacuation
MIS	management information system
MOALDM	Ministry of Agriculture, Livestock Development and Marketing (Kenya)
MPFS	Mbita Point Field Station (ICIPE)
MSV	maize streak virus
NARES	national agricultural research and extension systems
NARL	National Agricultural Research Laboratories (Kenya)
NARO	National Agricultural Research Organisation (Uganda)
NARS	national agricultural research system
NB	neem bitters
NC	neem cake
NCP	neem cake powder
NGOs	nongovernmental organisations
NHM	Natural History Museum (UK)
NIH	National Institutes of Health (USA)
NKP	neem kernel powder
NMK	National Museums of Kenya
NO	neem oil
NRI	Natural Resources Institute (UK)
NSKE	neem seed kernel extract
NSP	neem shell powder
NSW	New South Wales (Australia)
OAU	Organisation of African Unity (Addis Ababa, Ethiopia)
ODA	Overseas Development Agency (UK)-now DFID
ODG/UEA	Overseas Development Group at the University of East Anglia (UK)
OLCV	okra leaf curl virus
PCPB	Pest Control Products Board (Kenya)
PDA	potato dextrose agar
PPI	Permaculture and Parasitology Institute (Ethiopia)
PPRI	Plant Protection Research Institute (South Africa)
R&D	research and development
RCSSMRS	Regional Centre for Services in Surveying, Mapping and Remote Sensing (Nairobi, Kenya)
RTTCP	Regional Tsetse and Trypanosomiasis Control Programme (Zimbabwe)
S	solitarious phase (of migratory pests)
SADC	Southern Africa Development Community (Gaborone, Botswana)
SAREC	Swedish Agency for Research Cooperation with Developing Countries (Stockholm, Sweden)
SGI	Sponsoring Group of the ICIPE
SHARE	Society for Hospital and Resources Exchange (Kenya)
SIT	sterile insect technique
SNNPRS	Southern Nations, Nationalities and Peoples Regional State of Ethiopia
SRI	Sericulture Research Institute (China)
T&TBDs	ticks and tick-borne diseases
TPRI	Tropical Pesticides Research Institute (Arusha, Tanzania)
TWAS	Third World Academy of Sciences
TYLCV	tomato yellow leaf curl virus
UNDP	United Nations Development Programme
UNECA/PADIS	United Nations Economic Commission for Africa/Pan African Development Information System (Addis Ababa)
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational Scientific and Cultural Organisation
UNHCR	United Nations High Commission for Refugees
UNU/INRA	United Nations University, Institute of Natural Resources in Africa
USAID	United States Agency for International Development (Washington DC, USA)
USAP	University Students' Attachment Programme (ISP project)
USDA	United States Department of Agriculture
WAN	worldwide area networks
WAU	Wageningen Agricultural University (The Netherlands)
WHO	World Health Organisation
WMCSV	watermelon chlorotic stunt virus
WOTRO	Netherlands Foundation for Tropical Science
WTVs	whitefly transmitted viruses (on tomato)

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