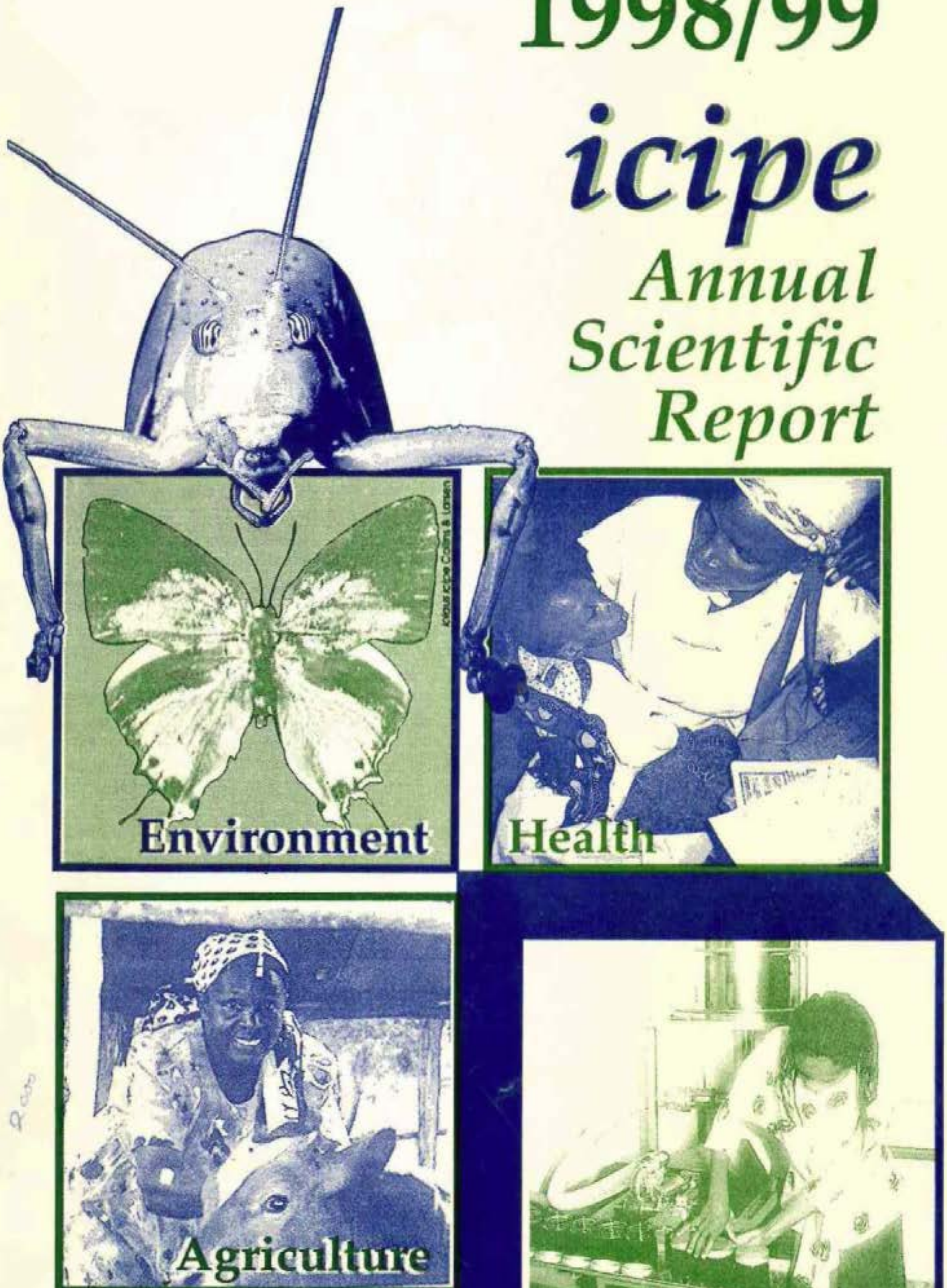
1998/99

icipe

Annual Scientific Report



International Centre of Insect Physiology and Ecology

Tropical Insect Science for Development

1998/99 *icipe* Annual Scientific Report

The International Centre of Insect Physiology and Ecology (ICIPE)
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Cover photographs, clockwise from upper right:
Woman and child suffering with malaria, Coast Province, Kenya;
packaging processed honey in ICIPE's Apiculture Quality Control Laboratory;
woman farmer from Suba District, Kenya with new calf fed on *Desmodium* forage;
Iolaus icipe Collins & Larsen;
Original photograph of katydid by Antony Bannister of Gallo Images, SA.

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Foreword

Five years have passed since I took over the helm as ICIPE's second Director General in September 1994. In this half-decade in the run-up to the second millenium, developments in science have sped ahead with bullet-like speed, but if the truth be said, much if not most of it is irrelevant to the majority of the world's population living in the tropical developing countries. The basic reasons for the creation of ICIPE back in 1970 remain the same today, almost 30 years later: to serve as a centre of excellence in performing advanced research on the most pressing development issues of the Third World—insufficient food and poor nutrition, debilitating and deadly tropical diseases, poverty, degredation of natural resources and the agricultural production base, and lack of individual and institutional capacity to bring about the necessary changes and improvements in the quality of life. Many of these problems can be directly or indirectly linked to arthropods, those small creatures such as insects, spiders, ticks and mites that outnumber all other forms of life on earth. ICIPE is still continuing with its original mandate, which has now been reworked and molded into its updated "4-H" paradigm: to improve human, animal, plant, and environmental health, through basic strategic research and its application in technologies that are relevant, cost-effective and sustainable for the tropics' smallscale farmers and urban folk, most of whom earn less than a dollar a day.

Two of the new programme areas which were consolidated and strengthened over the last five years have now come of age and have demonstrated their worth, as can be seen in this Report. These are the Commercial Insects and the Arthropod Biodiversity and Conservation Programmes. When I arrived at ICIPE, the Sericulture and Apiculture activities were in a nascent stage of development, supported in the very beginning by seed money donated by our own staff out of their personal belief that these were two very promising income- and employment-generating activities which had long been neglected in Africa and which required scientific input if they were to compete as modern cottage industries to supply high-quality products for the world's (and local) markets. The enthusiastic response of the more than 5000 farmers and women's groups introduced to and trained in these technologies are witness to the foresight of our staff. Now in Phase II, the Programme is being requested to extend its activities from Eastern Africa to the South and North of the continent.

The Biodiversity and Conservation Programme was introduced to fill the alarming gap in the knowledge about Africa's insect life, how much of it there is, where it is found, what it does and therefore how it impacts on human life. As a centre of expertise in insect science in the region, and drawing on the elements of our numerous insect biodiversity surveys—an inherent component of almost all of our projects— ICIPE was the logical institution to catalyse and consolidate this vital knowledge base. As reported in the biodiversity and agroecology studies and information/IT projects, many of these gaps are now being filled with prolific amounts of data that are being processed and saved electronically for use by planners, agriculturalists and conservationists. Studies on the role arthropods play in mediating essential environmental processes such as pollination and soil fertility maintenance are in progress.The basic foundational activities laid in 1998 and 1999 will support future management decisions.

The close link between agriculture and human health cannot be overlooked, especially where cultivation takes place in environments where the abundant arthropod life serves as vectors of disease. Examples of this are irrigation schemes, where high malaria incidence is a constraint to productive, energetic human activity, and tsetse-infested zones where both humans and livestock are at risk of contracting trypanosomosis infections. ICIPE's Malaria Mosquitoes Research Programme has had a rebirth over the past 2-3 years, and is now raising the funding it deserves to continue with the cutting edge research on the mosquito vectors' biology and behavioural and chemical ecology, about which surprisingly few hard facts are known on which to develop rational control programmes. The recent shift of most of the malaria research activities to the Mbita Point Field Station bases the programme squarely in one of the most serious endemic malaria zones in Africa.

The rapid development of the Horticultural Crop Pests programme is another example of how ICIPE has responded to an unmet demand for solutions to the problems facing the region's farmers. At the request of the industry in Kenya—one of the fastest growing and most vigorous of any African country—ICIPE is working to develop pesticide-avoiding methods of growing fruits, vegetables and cut flowers that will allow this fresh produce to meet the stringent requirements of the EU and other importing countries, as well as protecting the farm workers and environment from the injurious side effects of chemical usage.

Maize and sorghum are two of the most important staple food crops in the region, and control of cereal stemborers and the parastic weed striga are being tackled though systematic research on what attracts and kills the pests, or repels them from ever attacking in the first place. The introduction of a small wasp (*Cotesia flavipes*) to control the exotic aggressive spotted stemborer (*Chilo partellus*) was first done by ICIPE in Kenya 6 years ago, and in 1998/99, the introductions were extended into 7 other countries. There is evidence that this small natural enemy is likely to bring this borer eventually under classical biological control, all done at no cost to the farmer. In another approach to controlling the borers, a system of using grasses and other plants to repel the pests away from the main crop and pull them into unfavourable sites where they are not a risk to the cereal crop is being introduced to over 400 enthusiastic farmers in Kenya's breadbasket of Trans Nzoia. The 'push-pull' strategy has had unexpected spin-offs other than pest control: it provides animal fodder, soil enrichment and cash income for women farmers who are selling the seeds.

The Tsetse Research Programme, one of the Centre's oldest, has in the past 5 years expanded its basic and applied research on the flies and how to trap them, into development of several other new potential management technologies. These include an effective repellent to prevent the flies from biting, an oviposition pheromone that attracts the gravid flies to sites in the countryside where they can be controlled, and new odour baits for the riverine flies, a group that carries human sleeping sickness and that has proved refractory to other baits; the potential use of tsetse pathogens is also being explored. This phase of basic tsetse research ended in 1999 with the completion of a 5-year grant, and funds are now being sought to do the large-scale field testing of some of the new control options. ICIPE will remain a centre of expertise in tsetse research in the region, and will actively offer its services to the planned EC-FITCA projects (Farming in Tsetse Control Areas).

Ticks are another devastating pest of livestock (and some wildlife), as the vectors of East Coast fever, heartwater and several other fatal diseases. Research in this area is now being temporarily curtailed due to cutbacks in funding, but as this Report shows, there are several non-chemical control methods ripe for larger-scale field testing. Total integrated animal health management is the goal, as the same animal often suffers from both vectors—tsetse and ticks—simultaneously, and the interactions between the two are still virtually unknown.

Another one of ICIPE's well-known research programmes is now moving away from strictly fundamental research—so necessary to provide the knowledge base for later steps—into the field. The Locusts and Migratory Pests Programme has made major advances over the past 5 years in understanding the desert locusts' chemical communication signals and environmental factors that cause the solitary insects to transform into the swarming masses that wreak such destruction over vast regions of Africa and the Middle East. Some of these semiochemicals have shown promise in disrupting hopper bands in tests near ICIPE's field site in the Red Sea area of Sudan, and are now ready for large-scale testing. The methods being developed for control of the desert locust represent a model for other migratory pests, such as the Madagascar migratory locust, the locusts found in central Asia (Kazakhistan) and the Red Locust of Southern Africa.

Underlying all of ICIPE's activities is the premise that the Centre must build the individual and institutional capacity in each country to eventually take over its own R&D work. ICIPE has now trained over 140 senior African scientists at PhD level, and another 7000 persons, including 1000 extension agents, in short courses and training sessions. ICIPE offers its research facilities as a centre of excellence in the region by collaborating with 25 African universities for the PhD programme and another four for MSc-level training, through the ARPPIS programme, as well as hosting visiting scientists and scholars from other countries. Special services which are on offer to collaborators and the region's scientific community include spectral analysis (using the GC-MS and LC-MS); bloodmeal analysis of haematophagous arthropods; animal rearing and quarantine; biosystematics and identifications; a germplasm centre for pathogens; library, printing and graphics services; and information technology.

Gender equity and consideration is of special concern in Africa, where women provide the majority of agricultural labour. ICIPE's Social Sciences Department provided gender analysis of several important projects over the last two years, including women's roles in implementing the habitat management strategy; in banana cultivation and pest control; and in community-based tsetse control programmes. Farmers' perceptions of their own problems and of the ICIPE technologies they are being encouraged to implement were sought for several projects, including ones on red spider mite control (for vegetables); on IPM for vegetable pest control; and on banana pests and diseases.

In order to improve the Centre's ability to coordinate research and capacity building activities, ICIPE has established a Research and Capacity Building Committee (R&CBC) for democratic and inclusive decision-making. The new R&CBC acts as a scientific steering forum to discuss all research and capacity building issues in order to ensure effective research management. The R&CBC committee is composed of Heads of Divisions and Departments, the Coordinator of Research and Research Support Units, the Head of Capacity and Institution Building and Manager of the R&CB office. Other committees that fall directly within the ambit of the R&CBC include the Board of Postgraduate Studies, Institutional Health and Safety Committee , Publications Committee, and Intellectual Property Commiittee. Among its many responsibilities, the R&CBC has been important in putting together internal review mechanisms such as the Annual Research Review and Planning weeks.

Collaboration with a wide consortium of partners at research level (universities worldwide, CGIAR centres, national, regional and international research centres) has expanded dramatically over the past 5 years, as can be seen from the comprehensive listings under each project. Just as essential are all of the partnerships ICIPE has made with the farmers' and womens' groups, NGOs and national research and extension systems that help us move from the laboratory into the fields and farms.

As funding continues to decline for agricultural research, famine and daily under-nourishment are still the lot of the majority of the world's population. Turning the corner into the new Millenium, ICIPE will continue to evolve to meet the challenges on the long road to development. We thank our donors for their continued support along the way, with special kudos to our core donors—Switzerland, Sweden, Norway and Demark—for their steady maintenance of Centre operations and core competencies.

Hans R. Herren
Director General

Editors note: The tables and figures in this document bear the section number of the text in which they are first cited

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MALARIA

Effective and sustainable malaria control in most parts of the tropics cannot realistically be accomplished without new tools and approaches for fighting both the parasites and mosquito vectors. Vector control and treatment methods 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 malaria control.

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 where treated bednets (and also residual spraying of insecticides) kill mosquitoes effectively, the overall impact on human infection is not sufficient. Thus, there is need for the development of new control methods that can supplement the mosquito-killing measures.

Lack of adequate knowledge on the ecology and behaviour of Afrotropical anopheline vectors hampers the control efforts. The re-establishment of malaria research at ICIPE in 1996 seeks to address this anomaly. Attention is being focused on changes in malaria trends due to global warming, insecticide resistance and land use changes, among other factors. In view of the WHO's renewed efforts to control malaria under the 'Roll Back Malaria' initiative, the integration of ICIPE's project with national research systems is expected to have an impact on malaria transmission in Africa, the continent most seriously affected by this debilitating and deadly disease.

The overall aim of this Programme is to contribute towards improved human health through the development of sustainable management strategies for malaria vectors. The focus is on mosquito ecology, behaviour and malaria transmission, with an emphasis on developing new tools for integrated malaria control that go beyond bednets and traditional insecticide-based approaches.

Human Health Division

MALARIA VECTORS PROGRAMME

Integrated Vector Management for Malaria Control in Africa

Background, approach and objectives

This project involves three inter-related study areas, namely: eco-epidemiology, vector ecology and behaviour, and community-based intervention studies. Research on malaria vectors and parasites (projects 1 and 2), will facilitate the development and testing of new strategies for community-based malaria control (project 3).

The objectives are to:

- identify environmental and climate-driven factors affecting larval ecology and malaria transmission;
- identify biotic and abiotic factors that influence the natural process of malaria parasite development in *Anopheles* mosquitoes;
- identify and field test semiochemicals that are integral to the process of mosquito host-seeking, mating, oviposition and feeding behaviour;
- conduct bioprospecting studies to identify natural mosquito repellents and larvicides from plants;
- develop an agroecosystem approach for minimising malaria risks in irrigation schemes;
- evaluate through community-based field trials, the efficacy of larval and adult mosquito control that could lead to improved integrated approaches for malaria control;
- assess the efficacy of a mosquito-proof house design and community-based malaria control interventions in the Ethiopia Bio-Village Initiative.

The activities undertaken in 1998/99 include:

- developing GIS-based approaches for mapping the distribution of mosquito vectors in Suba District, western Kenya and the coast of Kenya;
- determining species composition, sporozoite rates and spatial/temporal dynamics of mosquito populations;
- developing and testing mosquito repellents and larvicidals from plants;
- undertaking larval ecology studies, including mechanisms for dry season survival in the egg stages;
- evaluating farmer-based water management strategies with potential for minimising vector breeding in rice irrigation schemes.

A. ECOLOGY OF ANOPHELINE MOSQUITOES AT THE COAST OF KENYA

Background, approach and objectives

There is little background information on the biology of anopheline populations and malaria transmission along the Indian Ocean coast. The only information available is for Kilifi District; data accumulated since 1990 indicate that vector densities are very low. The design involved entomological studies in 30 ecologically different sites.

Participating scientists: *C. Mbogo, J. Beier, J. Githure, C. Mutero, G. Yan, J. Shililu*

Assistants: *P. Seda, M. Wanjiru, B. Njiru, B. Yana, P. Baraza*

Donors: *ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark) through DANIDA and OPEC*

Collaborators: *• Kenya Medical Research Institute (KEMRI) • Division of Vector Borne Diseases, Ministry of Health, Kenya • Jomo Kenyatta University of Agriculture and Technology • Medical Research and Training Centre, Bamako, Mali • Tulane University, USA*

Work in progress

1. SPATIAL AND TEMPORAL DISTRIBUTION PATTERNS OF ANOPHELINE MOSQUITO POPULATIONS AND *PLASMODIUM FALCIPARUM* TRANSMISSION AT 30 SITES ALONG THE KENYAN COAST

Mosquito collections were done in each site once every two months to make sure that each site was sampled six times per year. Mosquito sampling techniques include pyrethrum spray sheet collection (PSC). Specimens were identified and tested by

Plasmodium falciparum sporozoite ELISA. Additionally, blood-fed anophelines were tested by bloodmeal ELISA, and ovaries from half-gravid *Anopheles gambiae* were stored for species identification by cytogenetic techniques.

The transmission of *P. falciparum* was studied for one year at 30 sites located in three districts (Kwale, Kilifi, Malindi) along the Kenyan coast. A total of 10 houses were selected in each site, following informed consent from the head of each household. Information for each household and the surrounding environment was obtained. A reference primary school was the focal point for each sampling site. Anopheline mosquitoes sampling was done between June 1997 to May 1998, to define the species composition of vector populations, and their patterns of abundance and sporozoite rates. The study design also included components to evaluate malaria prevalence rates among school-going children in primary schools distributed in each of the 30 sites.

Six anopheline species were identified along the coast: *Anopheles gambiae s.l., An. funestus, An. coustani, An. nili, An. squamosus* and *An. pharoensis* (Table 1). Overall, *Plasmodium falciparum* sporozoite rates were 3.3% (37/1119), 7.7% (77/1005), and 2.4% (78/3263) for *An. gambiae s.l.* for Kilifi, Kwale and Malindi Districts, respectively. The proportion of *An. funestus* with *P. falciparum* sporozoite infections was 3.1% (25/798) in Kilifi, 2.8% (63/2227) in Kwale, and 0.0% (0/191) in Malindi. No infections were detected in other anophelines.

Table 1. Summary of anopheline mosquito collections and *P. falciparum* sporozoite ELISA results combined for 30 sites (June 1997 to May 1998)

	No. tested	*Plasmodium falciparum* sporozoite ELISA (% positive)
An. gambiae s.l.	5387	3.6
An. funestus	3216	2.7
An. nili	56	0.0
An. coustani	125	0.0
An. pharoensis	42	0.0
An. squamosus	16	0.0

Human IgG was detected in over 95% of the 474 *An. gambiae s.l.* and from 78% of the 232 *An. funestus* tested. *Plasmodium falciparum* sporozoites were identified in 9.3% (44) of blood-fed *An. gambiae s.l.* and in 2.6% (6) of *An. funestus*. All these sporozoite-positive vectors had fed on humans. This indicated that the malaria vectors were highly anthropophilic and therefore efficient transmitters of *P. falciparum*.

Annual entomological inoculation rates (EIRs) for the 30 sites ranged between 0 and 200 infective bites. The risk of human exposure to bites of infective mosquitoes, and hence *P. falciparum* transmission, was highly variable. Spatial and temporal patterns were associated with EIRs, which in turn vary with vector species. These are in turn influenced by environmental factors, indicating a marked heterogeneity in the distribution of malaria vectors. The presence of permanent water sources for mosquito breeding at some of the sites in the three districts is one of the important environmental factors that would enhance malaria transmission.

This study demonstrates extremely variable levels of *P. falciparum* transmission at 30 sites along the coast. *Anopheles gambiae s.l.* was the predominant vector in Malindi and Kilifi and *An. funestus* in Kwale. They occurred throughout the year, with peaks of abundance coinciding with seasonal rains in May to July and November to January (Figure 1).

Latitudes and longitudes for each site were determined using a geographic positioning system (GPS). A spatial analysis will be performed to determine the risks of exposure to infective mosquitoes and show how vector populations are distributed throughout the study area.

1.1 SPECIES COMPOSITION OF THE *ANOPHELES GAMBIAE* COMPLEX

The ovaries of 535 half-gravid female *An. gambiae* complex were evaluated by Dr Sekou Traore (Medical Research and Training Centre, Bamako, Mali) in March 1998. Cytogenetic identifications show the presence of *An. gambiae s.s., An. arabiensis* and *An. merus* (Table 1.1). This is consistent with previous information from coastal Kenya. Chromosomal polymorphism was simple as compared to those found in West Africa. The absence of inversion 2Rb in *An. gambiae* is remarkable in that it would be possible to understand more precisely the influence of inversion 2La on malariometric parameters. These results indicate that the inversion polymorphism of *An. gambiae s.s.* and *An. arabiensis* is more 'simplified' than that observed in the Kisumu area by other workers. However, the presence of *An. merus* is remarkable and it would be interesting to know the participation of this species to the vectorial system, especially in sites where animals are few and scattered. Analysis of another 630 samples of *An. gambiae s.l.* by the PCR technique confirmed the presence of the 3 species of *An. gambiae* complex (Table 1.1).

Table 1.1. Cytogenetics and PCR identification of *An. gambiae* species complex collected along the coast of Kenya

	No. tested	*An. gambiae s.s.* (%)	*An. arabiensis* (%)	*An. merus* (%)
Cytogenetics	535	82.0	13.0	5.0
PCR	630	83.2	12.9	3.9

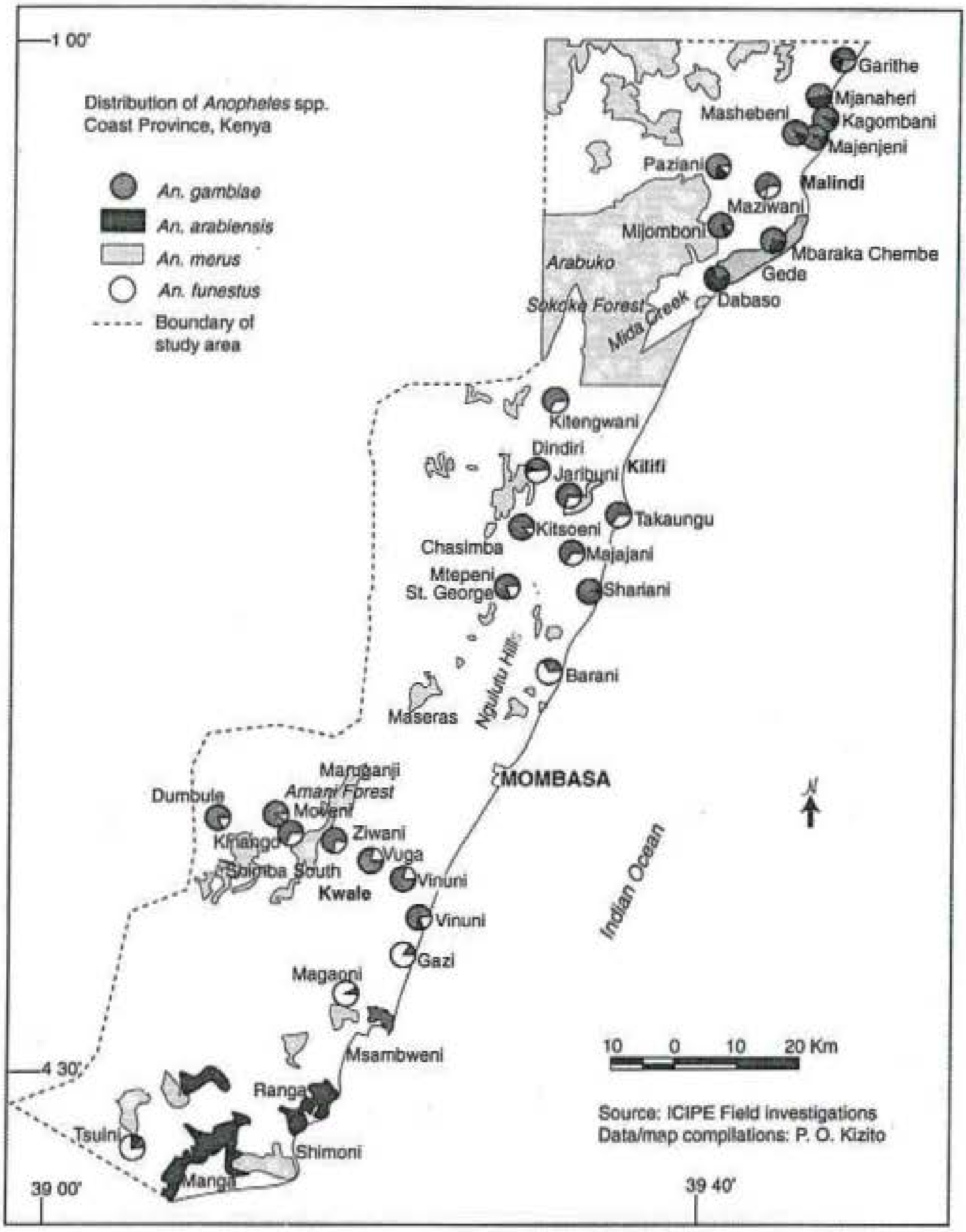

Figure 1. Anopheline mosquito occurrence along the Kenya Coast, June 1997–May 1998

1.2 ASSOCIATIONS BETWEEN MALARIA PREVALENCE IN CHILDREN, VECTOR DENSITIES AND *PLASMODIUM FALCIPARUM* TRANSMISSION

A cross-sectional survey to examine malaria prevalence in school-going children from the 30 study sites was conducted. A total of 3000 children was sampled for the presence of malaria parasites by finger prick. One hundred children aged between 6 and 12 years were randomly selected from each of the 30 primary schools. These children showed no clinical symptoms of malaria. Preliminary data on malaria prevalence rates were 58, 60, and 52% for Malindi, Kilifi and Kwale, respectively. Overall, *P. falciparum* was the predominant species followed by *P. malariae* and *P. ovale*. The blood slides are now being re-examined to determine densities of asexual and gametocyte stages. This study will provide information on relationships between vector densities in houses, malaria infections and parasite densities.

B. ECOLOGY OF ANOPHELINE MOSQUITOES IN SUBA DISTRICT, WESTERN KENYA

Background, approach and objectives

Sampling of anopheline mosquitoes conducted twice in Suba District in 1997 was repeated at 30 different sites in June 1998. Schoolchildren were examined for malaria parasites at primary schools closest to the various study sites. During the same period, *An. gambiae s.l.* samples from 1997 were processed for studies including PCR-based identification of sibling species and ELISA analysis for determination of sporozoite infection rates.

Participating scientists: *C. Mutero, J. Githure, C. Mbogo, G. Yan, B. Knols, J. Shililu, J. Beier, N. Minakawa*

Assistants: *P. Seda, M. Wanjiru, B. Njiru, B. Yana, P. Baraza*

Donors: *ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark) through DANIDA and OPEC*

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Work in progress

2. ENTOMOLOGICAL EVALUATION

Compared to 1997, a general increase in the density of daytime indoor resting mosquitoes was observed in most of the 30 sites. Thus, the average number of anopheline mosquitoes collected in a bedroom ranged between 2–9 in June and August 1997, while the average for June 1998 was 11 mosquitoes per house. The range of mosquitoes collected in a house from 30 sites during the three occasions varied from 0–17 in August 1997 to 0–118 in June 1998. The higher mosquito densities in 1998 were attributed to an unusual expansion of suitable breeding sites occasioned by the El Niño weather phenomenon.

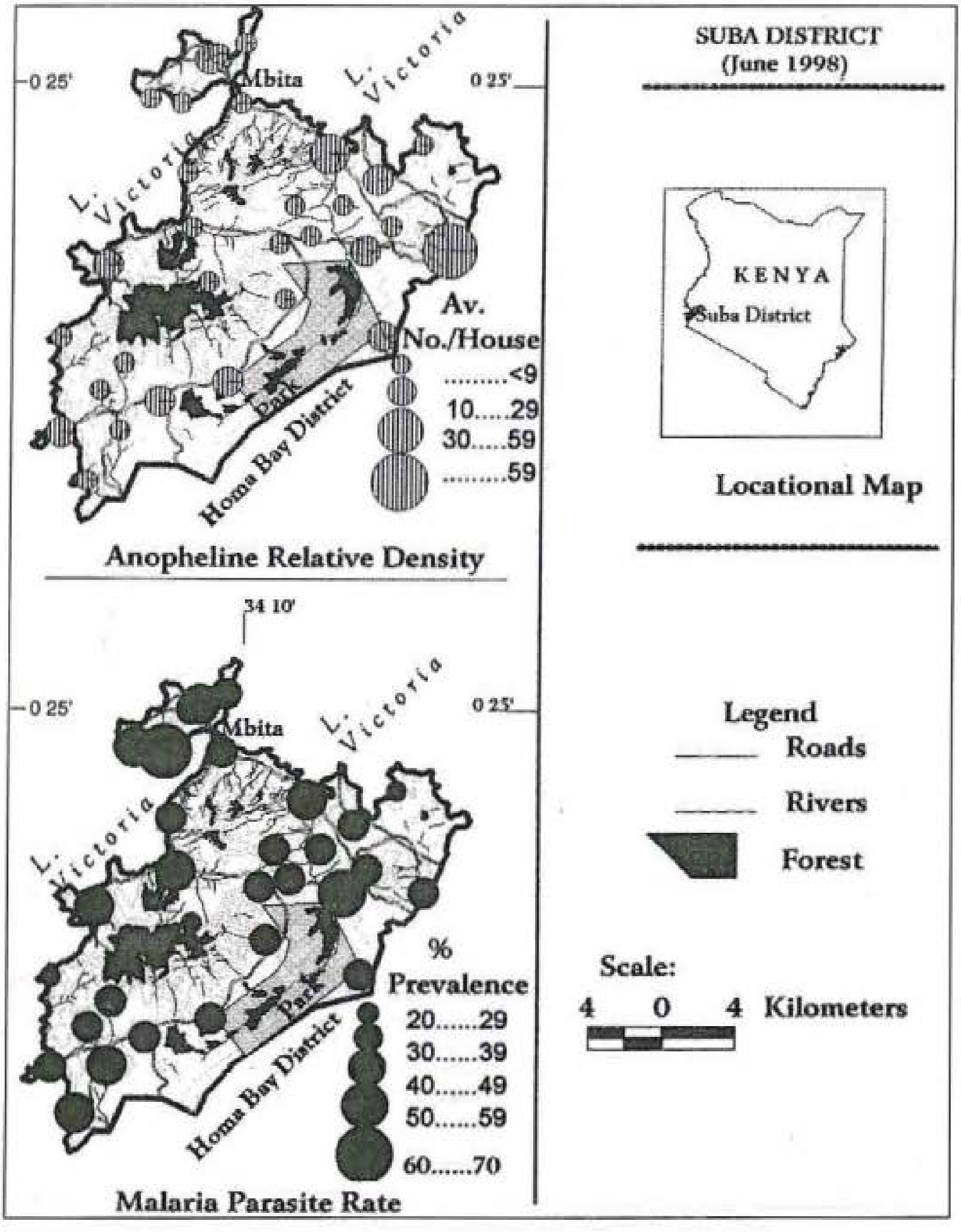

Figure 2. Anopheline relative density and malaria parasite rate in Suba District, Kenya (June 1998)

Out of 946 *An. gambiae s.l.* collected in 1997 and identified by PCR methods during the reporting period, the relative proportions of *An. gambiae s.s.* and *An. arabiensis* were 61.2 and 38.8%, respectively. Generally higher densities of anopheline mosquitoes were recorded in sites lying in the northern part of Suba District, along the Homa Bay–Mbita road (Figure 2).

3. MALARIA PREVALENCE

Malaria parasite rate among 2944 primary schoolchildren examined in Suba District in June 1998 ranged between 26–61%. More than 98% of the children examined had no symptoms of malaria. The highest concentration of malaria cases was on Rusinga Island. Parasite rates generally appeared to be positively correlated with mosquito densities in a northwesterly direction along the Homa Bay–Mbita road. Further GIS analysis is underway to facilitate spatial analysis of mosquito and malaria distribution in relation to various environmental parameters.

4. MOIST SOIL AS AN OVIPOSITION SITE OF THE MALARIA VECTORS

Ovipositional site selection by females initially determines the distribution of mosquito larvae. Muirhead-Thomson (1945) observed that *An. gambiae* complex oviposits in water without dense emergent vegetation. Habitats without dense emergent vegetation are usually small temporary waters. Other workers have observed that larvae of the *An. gambiae* complex are often found in temporary water such as tyre tracks and animal footprints.

It is suspected that viable eggs remaining in soil of temporary habitats are responsible for the sharp increase of vectors at the beginning of the rainy season. In this study, we hypothesised that *An. gambiae s. s.* oviposits in moist soil, in particular when surface water is not available.

The oviposition behaviour of *An. gambiae s. s.* was studied with different oviposition media. *Anopheles gambiae s. s.* oviposited significantly more eggs in flooded soil than in moist soil, water without soil and dry soil. The differences in mean egg numbers was not significant between moist soil and water without soil. When mosquitoes were given the choice of moist soil and dry soil, they oviposited almost always (99.9%) in moist soil. The results from this study support the notion that *An. gambiae s. s.* oviposits in moist soil, particularly when surface water is not available.

C. CHEMICAL AND BEHAVIOURAL ECOLOGY

Background, approach and objectives

Local plants have been used for centuries to repel mosquitoes from homesteads. They have been used in different ways, for instance, through drying and subsequent burning inside houses, or simply by smearing fresh plant material on the walls. ICIPE scientists have undertaken surveys to identify such plants and have compiled a list and their uses (*see ICIPE 1995–1997 Annual Scientific Report*). In 1998 a two-way approach was followed: (1) the identification of active principles from those plants, and (2) studies on the use of entire plants and/or parts thereof for optimal local use. Research in 1998 mainly focused on evaluating the repellent effect of a group of selected plants against Africa's main malaria vector, *An. gambiae*. These studies encompassed bioassay tests on volunteers' forearms, detailed chemical analyses of the essential oils of these plants (by using GC and GC-MS), and electroantennography studies (EAG).

Participating scientists: *B. Knols, B. Frei, A. Hassanali, W. Lwande, C. Mutero J. Githure, J. Beier*

Assistants: *M. Wanjiru, B. Njiru*

Donors: *ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark) through DANIDA, OPEC, WHO/TDR*

Collaborators: • *Ifakara Health Research and Development Centre, Tanzania* • *National Institute for Medical Research, Tanzania* • *University of Wageningen, the Netherlands*

Work in progress

5. IDENTIFICATION OF CHEMICALS PRESENT IN EAST AFRICAN PLANTS TRADITIONALLY USED TO REPEL MOSQUITOES

Following the social survey undertaken by Dr C. Mutero on the shores of Lake Victoria on the indigenous plants used as mosquito repellents, a number of plants were selected for further study. This was done on a chemotaxonomic basis (i.e. plants that belong to a taxon of plants known to repel insects were selected) and on a purely ad-hoc basis. About 19 different plant species were collected (minimum 5 kg per plant) and subjected to hydro-steam distillation to obtain the essential oils. These oils were dissolved in acetone and 5 different concentrations were then tested against *An. gambiae* (0.01, 0.1, 1, 10 and 50%). This was done by introducing a forearm into a 50 x 50 x 50 cm cage that contained 100 hungry females. Every hour the left forearm (treated with the solvent only) was introduced in the cage and the number of females landing within 30 seconds scored. Immediately afterwards, the treated arm (with oil in solvent) was introduced. Every subsequent hour the treatments were repeated with higher concentrations of the oil.

The protective efficacy (PE) was calculated using PE = ([T/Cx100]-100) whereby:

C= number of bites on the control arm
T= number of bites on the treated arm

Thus, if an equal number of bites were received on the control as on the treated arm, the PE was 0. In case of full protection, the PE was 100.

The average PE was calculated from exposing six different test persons to the same oil concentration. Subsequently, the overall mean PE was calculated by averaging the results for all 5 different concentrations. The 19 plants were finally ranked according to their overall mean PE.

Candidate oils (i.e. those with a high overall mean PE) were converted to base formulation in order to test the longevity of protection. These oils were directly compared with existing products (e.g. DEET and eucalyptus oil). The best plant (MOS2, 10% oil in the base formulation), had a PE of 96.3% after 7 hours, compared to only 63.5% for a 10% DEET lotion and 75.4% for a commercial eucalyptus formulation (the latter figure depicts the PE after 6 rather than 7 hours).

The advantage of MOS2 is that it has a very pleasant smell that was referred to by an outside donor as 'perfume'. So far there have been no indications of any side effects of using the oil, even at a high dose of 50%. MOS2 can grow easily and occurs naturally as a woody shrub. The plant can be harvested without destroying it, making subsequent harvests possible.

Current research now focuses on testing MOS2 under semi-field conditions at ICIPE's Mbita Point Field Station. ICIPE scientists, in collaboration with ICIPE management, have developed a business plan for product development.

6. IDENTIFICATION OF VOLATILES FROM *ANOPHELES GAMBIAE* BREEDING SITES RESPONSIBLE FOR THE ATTRACTION OF GRAVID FEMALES

The behaviour of malaria vectors still remains poorly understood. Yet, if the semiochemicals mediating the behaviour of these insects are known, novel methods to reduce contact between humans and vectors may be developed. One of the least understood processes in a mosquito's life-history is the oviposition behaviour. The factors which govern the behaviour of a gravid female mosquito when searching for a suitable breeding site remain completely unknown. ICIPE scientists have embarked on a project to identify the possible infochemicals mediating this behaviour with the ultimate aim of developing so-called ovitraps for monitoring vector populations.

Simple dual choice experiments were started in collaboration with Dr Leonard Mboera of the National Institute for Medical Research (NIMR) in Tanzania. Various oviposition choices were offered to gravid females of *An. gambiae* in 30 x 30 x 30 cm cages. It was established that gravid females preferred to lay eggs on oviposition cups with soil from known breeding sites, compared to cups containing distilled water. When the soil from a breeding site was sun-dried and subsequently autoclaved and compared to untreated sun-dried soil, there was a highly significant preference for the cup containing the untreated soil. Soil treated with an antibiotic (oxytetracycline 5%) gave a similar effect and clearly demonstrated the role of soil micro-organisms in the production of compounds that attract gravid females. Volatiles were collected from the various soil samples that were either treated with antibiotics or autoclaved and compared with those from untreated soil. These are currently being analysed and compared using GC-MS. Ongoing studies will incorporate electroantennography to identify compounds active at the sensory physiological level.

7. USING SPERM MOTILITY INSIDE FEMALE *ANOPHELES GAMBIAE* SPERMATHECAE AS AN AGE-GRADING TOOL

Knowledge of the age of field-collected specimens of malaria mosquitoes is important in understanding the transmission potential of a given population. Currently, a simple method determines whether a female is nulliparous (i.e. she has never laid eggs) or parous (the female has laid at least one batch of eggs). However, it is more interesting to determine the number of egg batches a female has laid and thus determine her age on the understanding that one gonotrophic cycle on average takes 3 days. Ovarian age-grading can establish this, but this method is rather complex and only practised by a few scientists in the world. Thus, any simple additional method to determine the age of females is highly desirable. Sperm stored in the spermatheca of female mosquitoes has been found to rotate after contact with a saline solution. This study aimed at identifying whether sperm rotation is age-related and may thus be used to age-grade females.

Female mosquitoes were left for 24 hours with aged males and subsequently kept for a specified number of days to determine sperm motility upon aging. It was found that very young females (<48 hours after mating) never show a rotating sperm mass in the spermatheca. The frequency of sperm motility subsequently increases and is at its peak on day 6 after mating. Thereafter, it rapidly declines and is very low in mosquitoes greater than 8 days of age. In practical terms, this means that mosquitoes can now be age-graded into three categories rather than two: nulliparous mosquitoes (no motility, younger than 2 days), parous mosquitoes (motility, age 3–8 days), parous (no motility, greater than 8 days).

D. BIOLOGICAL CONTROL

8. BIOLOGICAL CONTROL OF ADULT *ANOPHELES GAMBIAE* USING *METARHIZIUM ANISOPLIAE*

Biological control of *Anopheles* mosquitoes has been developed (for instance by using *B.t.*), but there are no examples for adult mosquitoes. It was decided to study the effects of *Metarhizium* fungus on adult *An. gambiae*.

A device for infecting mosquitoes was developed by E. J. Scholte, a student from Wageningen Agricultural University in the Netherlands. Conidia were placed on a hair roller which was fixed over the normal sugarfeeding bottle to give a very effective infecting method. The cumulative mortality of groups of 50 male *An.gambiae* were compared after contact with either an infected or untreated hair roller. The greatest increase in mortality occurred 4 days after infection, when within a 24 hour period some 50% of all mosquitoes succumbed to infection with the fungus. The Kolmogorov-Smirnov tests were highly significant ($P < 0.0001$).

A project proposal was subsequently submitted to the Netherlands Organisation for the Advancement of Tropical Research and the Project has recently commenced. Experiments for killing adult malaria mosquitoes are currently underway with female *An. gambiae* and both male and female *Culex quinquefasciatus*. The potential of using this system to suppress adult vector populations is being explored.

E. STRATEGIES FOR MALARIA CONTROL, WATER CONSERVATION AND INCREASED FOOD SECURITY IN IRRIGATION SCHEMES

Background, approach and objectives

In Kenya and other African countries, only a small fraction of the potential area has been developed for irrigation. The demand for rice is growing rapidly and it is likely that the total area under rice cultivation will increase. Rice fields generally constitute an important source of vector mosquitoes. The provision of mosquito breeding sites associated with irrigation for rice has often resulted in a corresponding increase in prevalence of malaria and other vector- and water-borne diseases. With increasing drug resistance of *P. falciparum* against chloroquine in Kenya, effective drugs for treating malaria are unaffordable by the majority of the population in the rural areas. Hence, new malaria control interventions, including efforts to reduce vector abundance, are urgently needed to supplement the drug-based curative approach. Arguably, the most important approaches are those involving an integration of complementary environmental management methods, as nearly 90% of the malaria burden is thought to be due to environmental factors.

In rice production systems, environmental management approaches that have had demonstrable impact on malaria in different parts of the world include intermittent irrigation. However, intermittent irrigation has not been widely evaluated or used in Africa, despite the method's potential for malaria control.

The main objective of this study is to test whether intermittent irrigation could reduce vector breeding without negatively affecting rice yields. This study is the first of several that have been planned for the evaluation of environmental management approaches for vector control in rice irrigation schemes.

Participating scientists: *C. M. Mutero, H. Blank, J. Githure, W. van der Hoek, F. Konradsen*

Research assistant: *P. Ng'ang'a*

Technician: *P. Wekoyela*

Donors: *ADB through IWMI; International Development Research Centre (IDRC); World Health Organisation (WHO/PEEM)*

Collaborators: *• IWMI • IDRC • University of Nairobi• National Irrigation Board • KEMRI • Division of Vector Borne Diseases, Ministry of Health (DVBD)*

Work in progress

9. WATER MANAGEMENT FOR THE CONTROL OF *ANOPHELES* IN RICE IRRIGATION SCHEMES

The impact of intermittent irrigation on *Anopheles* larval populations, rice yields and water use was assessed in the Mwea Rice Irrigation Scheme (Figure 9a) during the review period. Four water regimes including intermittent irrigation were tested in a complete randomised block experimental design. Intermittent irrigation was carried out on a weekly

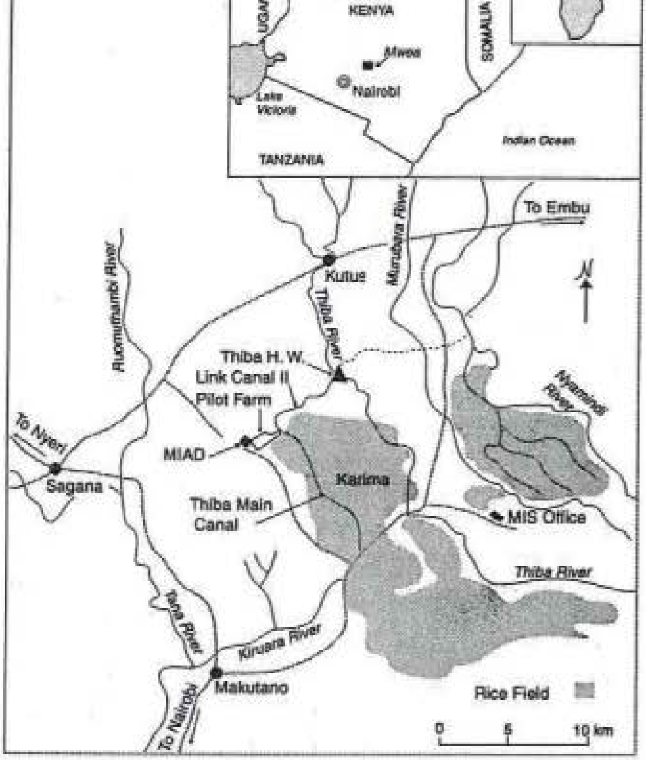

Figure 9a. Locational map of Mwea Rice Irrigation Scheme

schedule, with flooded conditions from Saturday through Tuesday morning. Larval sampling at each plot was conducted every Monday and prior to draining of intermittently irrigated subplots on Tuesday.

All the adult anopheline mosquitoes emerging from larvae collected in the experimental plots were *An. arabiensis*. The highest numbers of *An. arabiensis* 1st instar larvae were found in the intermittently irrigated subplots, indicating that the water regime provided the most attractive environment for egg laying (Table 9). However, the ratio between the 4th to 1st instar larvae in the subplots was only 0.08, indicating very low survival rates. In contrast, the 4th to 1st instar ratio for subplots with other water management regimes ranged between 0.27 and 0.68, suggesting a correspondingly higher survival than observed with intermittent irrigation. The total number of 4th instars was nevertheless almost the same in the intermittently irrigated subplots and the irrigation system normally practised by the farmers. The failure to eliminate larval development up to the 4th instar in the former method was attributed to residual pools of water.

Larval abundance fluctuated throughout a 12-week sampling period (Figure 9b). The highest larval densities were recorded in the 3 weeks after transplanting the rice seedlings. Afterwards, larval numbers dropped dramatically as the height of rice plants increased.

Rice yields at harvest did not show statistically significant differences among subplots with different water regimes. The average yield per hectare ranged from 4.8 – 5.3 metric tonnes. The average daily water percolation/seepage rate was 3.6 mm and did not significantly differ among different water management regimes.

Further research will be conducted to determine whether rice yields could be increased by having flooded and drained intervals that were different

Table 9. Number (percentage) of *An. arabiensis* larvae collected from experimental fields with different water management regimes in the Mwea Rice Irrigation Scheme, Kenya

	Water management method								
Larval stage	A[1]		B[2]		C[3]		D[4]		Total
1st instar	172	(40)	340	(41)	238	(31)	3528	(82)	4278
2nd instar	172	(40)	286	(35)	234	(30)	581	(13)	1273
3rd instar	73	(17)	105	(13)	141	(18)	112	(3)	431
4th instar	8	(2)	93	(11)	162	(21)	85	(2)	348
Total	425	(100)	824	(100)	775	(100)	4306	(100)	6330

[1] Continuously flooded, no rice planted.
[2] Rice transplanted under drained conditions; flooded after transplanting.
[3] Rice transplanted under flooded conditions; flooded after transplanting.
[4] Rice transplanted under dry conditions; intermittent irrigation after transplanting.

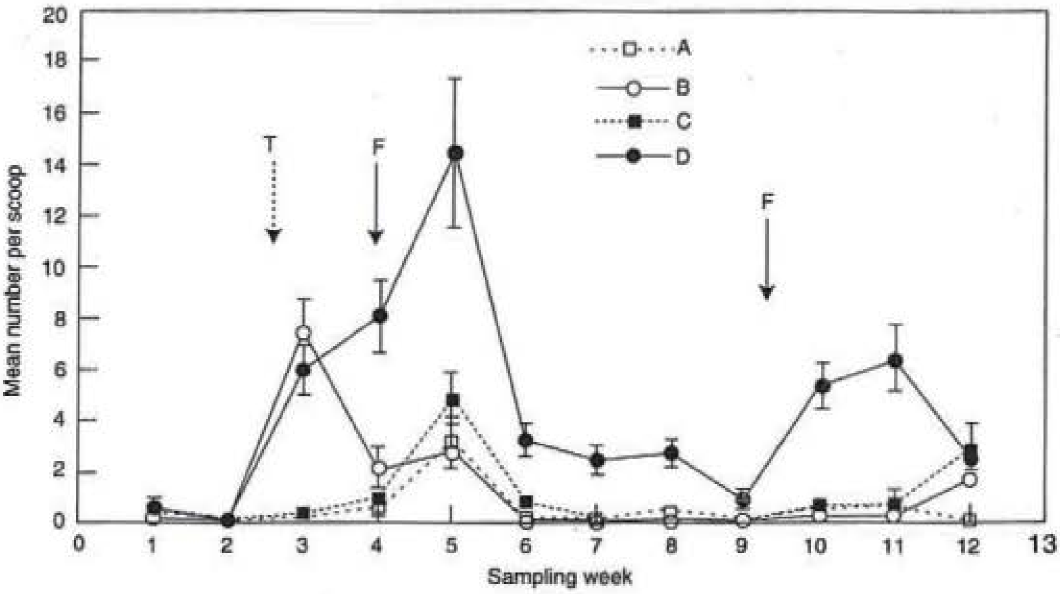

Figure 9b. Weekly fluctuations in *An. arabiensis* relative density from 7 September (1st sampling week) to 24 November (12th sampling week) 1998. Vertical bars represent standard errors of the means. A–D refer to the four water regimes described in the text. Activities: T=Transplanting; F=Fertiliser application

from those used in the previous study. The feasibility of implementing intermittent irrigation with respect to farmer acceptance and required changes in irrigation system design and management will also be assessed.

10. LIVESTOCK MANAGEMENT AND MALARIA PREVENTION IN RICE IRRIGATION SCHEMES

Background, approach and objectives

Livestock, especially cattle, can play a part in malaria transmission since they serve as alternate hosts to certain mosquito species. However, there are two schools of thought regarding their actual role. On the one hand, reduced feeding on people by mosquitoes due to availability of cattle could lead to reduced malaria transmission. Conversely, increased transmission could occur due to an expanded vector population resulting from an unlimited access to bloodmeals.

Conflicting observations and opinions on the role of livestock in malaria transmission leave no clear policies on whether or not livestock keeping should be encouraged for zooprophylaxis, particularly in Africa. It has been found rather difficult to predict possible changes that might arise from integration of livestock, partly due to ecological complexities, which make it difficult to extrapolate the events arising from one situation to another. However, some simulation models have tried to deal with interactions of livestock, vectors and diseases. Some of the models suggest that if introduced livestock are readily fed upon by mosquitoes, then populations of the latter might increase, leading to greater biting on people and raised infection rates. Other simulation models on zooprophylaxis for malaria control have supported the conclusion that the extent of human risks is determined by the relative abundance, attractiveness and accessibility of livestock compared to that of human hosts. The various models are important in assessing whether a given situation provides the right conditions for zooprophylaxis to be a useful method. The models would be applicable in the African context, if they are validated with actual field data.

The objective of the study is to quantify the role of livestock in relation to malaria transmission, taking into account various contributing factors including vector host preferences, and densities, cattle to man ratios, meteorological conditions, topography and location of livestock in relation to human settlements and breeding sites.

A consultation for the development of a consortium research proposal to assess options for livestock management for the reduction of malaria transmission risks in East African irrigation schemes was held at ICIPE in February 1999, with the specific objectives to:

- carry out a critical technical review of a research proposal previously drafted by ICIPE and the Kilimanjaro Christian Medical Centre (KCMC), Tanzania;
- formulate detailed recommendations for improvement and completion of the proposal;
- identify opportunities for capacity building that could be built into the proposal;
- review and comment on the institutional arrangements between the consortium partners;
- advise on a resource mobilisation strategy for the proposed research.

Networking among the workshop participants and also with other researchers on environmental management for vector control was unanimously endorsed. The report of the meeting was published in an international journal in order to publicise the livestock/malaria proposal among potential donors and other research groups.

Output

Publications

Anjili C.O., Ngichae C.K., Mbati P.A., Lugalia R.M., Wamwayi H.M. and Githure J.I. (1998) Experimental infection of domestic sheep with culture-derived *Leishmania donovani* promastigotes. *Veterinary Parasitology* 74, 315–318.

Beier J.C., Killeen G.F. and Githure J.I. (1999) Entomologic inoculation rates and *Plasmodium falciparum* malaria prevalence in Africa. *American Journal of Tropical Medicine & Hygiene* 61, 109–113.

Boelaert M., Al Safi S., Mousa H., Githure J.I., Mbati P., Gurubacharya V., Shrestha J., Jacquet D., DeMuynck A., LeRay D. and Van der Stuyft P. (1999) Multicentre evaluation of repeatability and reproducibility of the direct agglutination test for visceral leishmaniasis. *Tropical Medicine and International Health* 4, 31–37.

Braks M.A.H., Anderson R. and Knols B.G.J. (1999) Infochemicals in mosquito host selection: Human skin microflora and *Plasmodium* parasites. *Parasitology Today* 15, 409–413.

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Knols B.G.J., Mboera L.E.G., Kihonda J. and Braks M.A.H. (1998) Trapping of *Anopheles gambiae s.s.* and *Culex quinquefasciatus* with CDC light traps next to bednets: Effects of trap position. *Proceedings of the 19th African Health Sciences Congress/16th Annual Joint Scientific Conference, NIMR* (in press).

Knols B.G.J., Mboera L.E.G. and Takken W. (1998) Electric nets for studying odour-mediated host-seeking behaviour of mosquitoes. *Medical and Veterinary Entomology* 12, 116–120.

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Mboera L.E.G., Kihonda J., Braks M.A.H. and Knols B.G.J. (1998) Influence of Centers for Disease Control light trap position, relative to a human-baited bednet, on catches of *Anopheles gambiae* and *Culex quinquefasciatus* in Tanzania. *American Journal of Tropical Medicine and Hygiene* 59, 595–596.

Mboera L.E.G., Knols B.G.J., Takken W. and Huisman P.W.T. (1998) Olfactory responses of female *Culex quinquefasciatus* Say (Diptera: Culicidae) in a dual-choice olfactometer. *Journal of Vector Ecology* 23, 107–113.

Mbogo C.N.M., Kabiru E.W., Glass G.E., Foster D., Snow R.W., Khamala C.P.M., Ouma J.H., Githure J.I., Marsh K. and Beier J.C. (1999) Vector-related case-control study of severe malaria in Kilifi District, Kenya. *American Journal of Tropical Medicine & Hygiene* 60, 781–785.

Minakawa N., Mutero C., Githure J., Beier J. and Yan G. (1999) Spatial distribution and habitat characterization of anopheline mosquito larvae in western Kenya. *American Journal of Tropical Medicine & Hygiene* 61, 1010–1016.

Mutero C.M., Mosha F., Odulaja A., Knols B.G.J. and Bos R. (1999) Livestock management and malaria prevention in irrigation schemes. *Parasitology Today* 15, 394–395.

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Takken W. and Knols B.G.J. (1999) Odor-mediated behavior of Afrotropical malaria mosquitoes. *Annual Review of Entomology* 44, 131–157.

Wahinya D.N., Mbati P.A., Jomo P.M. and Githure J.I. (1998) Relationship between parasite load and immune responses in early stages of *Leishmania donovani* infection in inbred Balb/c mice. *East African Medical Journal* 74, 156–159.

Poster presentations

Knols B.G.J., Githure J.I., Beier, J.C. and Hassanali A. (1998) Mosquito-host interactions in a multipartite context: The role of skin micro-organisms and *Plasmodium* parasites. Presented during the Governing Council meeting in April.

Knols B.G.J., Githure J.I., Beier J.C. and Hassanali A. (1998) Presented at the 4th International Congress on Dipterology in Oxford, UK between 1–6 September.

Frei B., Knols B.G.J., Mutero C.M, Van Schayk I., Lwande W. and Hassanali A. (1998) An ethnobotanical phytochemical search for mosquito repellent African plants to reduce malaria transmission in rural communities. Presented during the Governing Council meeting in April.

Publicity

Newspaper articles

Centre tackles malaria threat in *Daily Nation*, 1 October, 1998, Nairobi.

Kudos to ICIPE for mosquito trap invention in *Kenya Times*, 23 July, 1998.

Mosquito traps to help curb malaria – ICIPE in *Kenya Times*, 22 July, 1998.

ICIPE researching on mosquito repellent plants in *East African Standard*, 22 July, 1998.

Interview by Stefan Lovgren for *US News & World Report*, November, about the ICIPE Malaria Vectors Programme.

Radio interviews

Radio interview for AGFAX Africa by Anne Pickstock (Wren media, UK) in December 1999 on the research activities at ICIPE concerning malaria vectors.

Radio interview for Swedish Broadcasting Corporation (Sveriges Radio P3) by Bobbo Krul, in November 1999, on ongoing research on mosquito repellent plants at ICIPE.

Other publications

'Health Chat' on malaria and malaria mosquitoes for the Nairobi based health insurance company, Health Management Solutions (HMS) by invitation from the Editor, Mrs Fran Piggott.

Conferences/Workshops attended

Workshop on development of human protocols for trials of transmission blocking vaccines, held in Bamako, Mali on 23–31 March 1998.

19th African Health Sciences Congress and 16th Annual Joint Scientific Conference of the National Institute for Medical Research held in Arusha between 14–18 April. Paper presented, 'Positioning of CDC light traps in relation to occupied bednets affects catch size and parity rates of malaria and filariasis vectors'.

WHO-sponsored international workshop titled: 'Practical approaches to the population genetics of African malaria vectors', which was held at ICIPE between 7–13 June.

Participated in the 3rd Pan African Malaria Conference, held at Safari Park Hotel, Nairobi between 21–26 June.

Participated in the international workshop titled: 'Networking on bioprospecting for anti-malarial, mosquito repellent and insecticidal plants', sponsored by WHO/MIM, and held at ICIPE between 20–22 July.

International Congress on Ecosystem Health. 15–20 August, 1999. Sacramento, USA. Paper presented, 'Integrated vector management for malaria control—an African perspective'.

AMREF/USAID/MOH Conference on Insecticide Treated Materials (ITMs), 12–13 July, 1999. Paper presented, 'Integrated malaria vector control'.

Workshops organised

International workshop on 'Practical Approaches to Population Genetics of African Malaria Vectors and Planning Their Control' sponsored by WHO/TDR and held in Nairobi on 7–13 June 1998.

International workshop titled 'Networking on Bioprospecting for Anti-Malarial, Mosquito Repellent and Insecticidal Plants', sponsored by WHO/MIM, and held at ICIPE between 20–22 July.

International Training Workshop on 'Use of Radioisotopes for the Control of Communicable Diseases in Africa', sponsored by IAEA held in Nairobi from 12–21 August.

WHO (PEEM)/ICIPE technical consultation on a proposal for a consortium research project on 'The Assessment of Options of Livestock Management for the Reduction of Malaria Transmission Risks in East African Irrigation Schemes', 15–18 February 1999, ICIPE, Nairobi.

Project proposals submitted and funding

A number of proposals have been written jointly with national and international research institutions and submitted for funding to various donors. Funding has so far been received from the folowing donors:

1. Core (DANIDA and OPEC, $700,000 for 3 years),
2. WHO/MIM 1999–2000, $ 145,360 for mosquito repellent and larvicidal plants.
3. WHO/TDR 1999–2000, $ 38,200 for bednets studies
4. WHO/TDR 1999–2000, $ 20,000 for human odour studies
5. IWMI 1999, $27,000 for water management and malaria transmission
6. IDRC 1999, $5070 for proposal development on livestock management for malaria control
7. NIH, ICIDR 1999–2004, $ 1.86 million for African malaria vectors.

Capacity building

The following students received training within the ongoing research:

ARPPIS PhD students

Richard Mukabana: Characterisation of human odours as attractants for mosquito vectors. (University of Nairobi)

Evan Mathenge: Development of bednet traps for afrotropical mosquitos. (University of Nairobi).

Lucy Kamau: The role of skin bacteria in the production of volatiles that attract malaria mosquitoes. (Kenyatta University)

Mary Wambui Ndungu: Isolation characterisation of antimosquito compounds from selected E. African Meliaceae plants. (JKUAT)

Benard Okech: Vector competence of malaria vectors (Kenyatta University)

DRIP scholars

Ernst-Jan Scholte: Sugar feeding behaviour of anopheline mosquitoes. (MSc student, Wageningen Agricultural University, The Netherlands)

Maina Gichuhi: Bloodmeal analysis of mosquito vectors. (MSc student, Kenyatta University)

Students on attachment

Gladys Kariuki, Kisumu Polytechnic College

Stephen Barassa, Kenyatta University

Susan Waweru, Egerton University

Eunice Njeri, graduate

Rose Mumbi, Nairobi Technical.

Impact

Throughout Africa, a need exists to elucidate the environmental basis of both malaria transmission pressure and infection/disease incidence in different eco-epidemiological settings. Indeed, the WHO has launched a new concept, 'malaria stratification', a new paradigm of appropriate integrated control strategies based on specific ecozones, irrigated agriculture, desert zones, urban areas, etc. The driving force is the realisation that public health programmes need to be more selective in utilisation of limited resources for site-specific epidemiological situations.

Through our collaborative linkages with the national systems, we shall contribute to stratification of malaria endemicity, which will in turn lead to formulation of appropriate policy for vector control in the East African region. Vector control tools and products developed in this project will be promoted in the communities and at household level for effective malaria control.

Our close linkage with the Kenya Medical Research Institute (which has the national mandate to research on health sciences) and the Ministry of Health, which is in charge of disease control, will ensure that any technology jointly developed with ICIPE will be incorporated in the national health care delivery system. The other pathway will involve transfer of developed technology directly to communities through non-governmental and community and farmer-based organisations.

(See also the reports of the Biodiversity and Conservation Programme, the Behavioural and Chemical Ecology Department, Molecular Biology and Biochemistry Unit and the Capacity Building (ARPPIS) programme.)

ANIMAL HEALTH RESEARCH

ANIMAL HEALTH MANAGEMENT

TSETSE

African animal trypanosomosis, carried by the tsetse fly (*Glossina* spp.), remains a major constraint to food security in areas of Africa that hold the continent's greatest potential for expanded agricultural production. The flies also carry the parasites responsible for human sleeping sickness.

The most direct economic impact of tsetse-borne diseases is on cattle, with over 3 million of the continent's herds succumbing yearly. Food security is undermined as sick animals produce less milk and meat, and reproduce less. In all, direct monetary losses of animal protein amount to about US$ 1 billion annually; the effects on human nutrition are immeasurable. About 94% of Africa's cattle living at the fringes of the tsetse belt are at risk. Other valuable livestock, such as camels, also suffer from trypanosomosis. With the scourge of human sleeping sickness making a comeback, human health is also at risk, particularly in regions experiencing large-scale migrations and inadequate medical care, such as in southern Sudan, Zaire and Angola. This frightening disease, so expensive to treat, is believed to affect 500,000 people.

Crop production also suffers, as fear of contracting sleeping sickness makes farmers avoid tsetse-infested areas. In the absence of cattle, there is less draft power for ploughing, less manure for use as fertiliser and fewer crop residues for animal feed. Better control of the fly vectors of the often-fatal and debilitating trypanosomal diseases will result in increased agricultural productivity through better land use.

Current wisdom favours control strategies that are adapted to the diverse local conditions and are tailored to the many different tsetse species involved. Experience has taught that vector control and disease management strategies need to be integrated for sustainable tsetse control.

ICIPE's Tsetse Research Programme concentrates on environmentally safe methods of controlling trypanosomosis by targeting the fly vector. Over the many years of programme activity, a large fund of knowledge has been built about the flies' basic biology, ecology and behaviour, as well as the relationship of the flies with their hosts and the trypanosome parasites they carry.

Truly sustainable tsetse control has proved difficult to achieve, partly because of the flies' ability to reinvade cleared areas and make a population comeback, and partly because of the local communities' inability to manage control programmes without constant external input. Recognising this, ICIPE works closely with social scientists to help communities plan, participate and evaluate their own tsetse management programmes. Capacity building at all levels, from farmers to PhD students is an integral part of all tsetse projects and helps ensure long-term sustainability. ICIPE will soon extend its capacity building activities to the field training of a cadre of vector entomoligists specialised in the new integrated technologies and products.

Animal Health Division

TSETSE

Interactive Development and Application of Sustainable Tsetse Management Technologies for Agropastoral Communities in Africa

Background, approach and objectives

The main objectives of this five year project which ended in 1999 were to:

1. Develop improved control methodologies for tsetse;
2. Develop strategies for maintaining cleared areas from re-invasion by tsetse;
3. Monitor adoption of control methodologies by local communities to achieve sustainability;
4. Improve sustainability of tsetse control through training across all levels of society.

All the activities as related to objectives 2, 3 and 4 were completed by June 1998, while the rest were completed by January 1999.

Donor: *European Commission*

Summary of achievements

1. POTENT REPELLENT IDENTIFIED FOR SAVANNA TSETSE

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

Assistants: *J. Andoke, E. Mpanga, J. Mbayi, P. Musa*

A potent analogue of a natural repellent for *Glossina pallidipes* and *Glossina morsitans morsitans* has been identified. On the recommendation of the European Union, a patent (Saini and Hassanali, 2000) has been filed. The repellent significantly reduces the tsetse challenge. Trap catches and even catches with cattle odour are reduced by more than 80%. Feeding efficiency of the flies on cattle is also significantly reduced. This repellent and others currently being identified from wild animals refractory to tsetse provide a set of new weapons in the arsenal for use in conjunction with other tsetse and trypanosomosis control tactics to protect livestock.

2. REPELLENTS FROM UNPREFERRED HOSTS (WATERBUCK)

Participating scientists: *N. Gikonyo, A. Hassanali, P. Njagi, R. K. Saini*

The existence of allomones in waterbuck volatiles and sebum have been demonstrated. GC-EADs have shown different activity profiles for *G. pallidipes* and *G. morsitans morsitans*. 11 GC-EAD active components have been found in volatile collections from waterbuck, of which 8 have been fully characterised. The sebum compounds are less volatile and so far two electrophysiologically active compounds have been detected. Micro-preparative GC and bioassay-led fractionation are now being deployed to isolate the other active compounds for characterisation.

3. IDENTIFICATION OF KAIROMONE ATTRACTANTS FOR *GLOSSINA FUSCIPES FUSCIPES*

Participating scientists: *A. Hassanali, R. K. Saini, M. Girma, P. Njagi*

Assistants: *J. Andoke, E. Mpanga, J. Mbayi, P. Ahuya, W. Ouma*

Work at ICIPE has clearly shown that more than 90% of the bloodmeals of *G. f. fuscipes* in Kenya come from monitor lizards. Hence, considerable effort has been put in identifying and evaluating candidate compounds from these preferred reptilian hosts, both in the laboratory and under field conditions. 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 *G. f. fuscipes* flies.

Field tests in Keto Valley, Ethiopia with blends of these aldehydes doubled overall *G. f. fuscipes* catches. In fact, catches of females were increased 3 times. However, in Rusinga Island in Kenya, inconsistent results (varying from no increase to twofold increase) were attained. These variable results in Kenya could be attributed to very low densities of flies present in the experimental sites. In addition, it is possible that additional attractants may 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.

Thus far, GC-EAD and GC-MS analyses of 10 different collections of monitor lizard urine have been undertaken. EAG-active compounds, 1-octen-3-ol, phenol and 4-cresol were identified in some (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 *G. f. fuscipes*. A mixture of the identified aldehydes and phenols was also not effective.

Our field experiments also indicate that *G. f. 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.

4. RESPONSES OF *GLOSSINA FUSCIPES FUSCIPES* TO LIVE LIZARDS

Participating scientist: *M. M. Mohamed Ahmed*

Assistants: *J. Muchiri, S. Mokaya, P. Ongele*

Field experiments clearly show that *G. f. fuscipes* feeds almost exclusively on monitor lizards in the presence of humans and other mammals monitored, and that olfactory and visual cues are important in host location by this species. However, experiments with live lizards gave inconsistent results because of different thermoregulatory and metabolic cycles of the captured lizards.

To overcome these problems, we attempted in 1997 to create as natural an environment as possible for lizards during experiments. This was done by constructing a cage or a house (2.5 m^3) inside the tsetse-infested forest at Ungoye Research Site, ICIPE. The house was provided with a small living tree, sandy floor, burrows and a water pool. Grass mats were appended to the walls to conceal lizards confined within. Half of the roof was left uncovered to admit sunlight and warmth. Experimental lizards (usually six) were fed on boiled fresh eggs during experiments.

Two experiments were conducted using this improvised house to test the responses of flies to the lizards. A control treatment (empty house) was always run first to curtail effects of lizard residues (urine and faeces). The latter arrangement allowed us to monitor the change in catches immediately after introduction of the lizard treatment. Each treatment consisted of a 3-day run: one with lizards and another without. In each experiment, four consecutive runs (12 days) were performed, two with lizards and two without in the following order: control, lizard, lizard and finally control. Clean air or odour of lizards was evacuated using a 6-m PVC pipe (diameter 0.15 m). Flies were caught at the odour outlet using a wall of two 1.5 x 1.5 m electric nets. No visual target was used.

In both experiments, in the absence of visual cues, lizard odour increased catches of females significantly (2 times); male catches were not similarly affected. However, in earlier experiments using three different sites, each with a similar wall of electric nets, neither carbon dioxide at 5 l/ min nor odour of two cows improved the catches of any one sex significantly.

It should be noted that recent experiments with warthog in Zimbabwe and black rhino in Kenya failed to find novel chemical baits for tsetse, other than those already identified from bovids. These hosts bovines (cattle and buffalo) are large herbivorous mammals, which vary in form and physiology from the small carnivorous monitor lizard. Lizard metabolic wastes must, therefore, differ substantially from those of mammals in both chemical composition (urine) and in quantity of wastes (carbon dioxide). Identification of the attractive components of lizard odour may thus culminate in novel tsetse kairomones.

5. LARVIPOSITION PHEROMONES

Participating scientists: *R. K. Saini, A. Hassanali, P. Njagi*

Assistants: *J. Andoke, E. Mpanga, J. Mbayi, P. Ahuya, W. Ouma*

Collaborator: *Regional Tsetse and Trypanosomiasis Control Programme (RTTCP), Zimbabwe*

The presence of pheromones produced by larvae of *G. m. morsitans* and *G. m. centralis*, respectively, which attract gravid females and result in aggregation of pupae, is confirmed. Behavioural experiments indicated that females preferred to larviposit over moist sand conditioned by previously allowing larvae to pupariate in it. Similar results were obtained with filter papers contaminated with the prepupariation excretions of larvae and with volatiles collected from larvae prior to pupariation. *n*-Pentadecane and *n*-dodecane were identified as the dominant electrophysiologically active components of the larviposition pheromones of *G. m. morsitans* and *G. m. centralis*, respectively, by GC-EAD and GC-MS analysis of the trapped larval volatiles. Both identified compounds were shown to significantly attract gravid females to larviposition sites in laboratory behavioral assays.

The potential of candidate compounds to attract gravid females to artificially developed larviposition sites was evaluated in Zimbabwe in collaboration with RTTCP. Field demonstrations of the larviposition effect of *G. m. morsitans* pheromone (*n*-pentadecane) in collaboration with RTTCP in Zimbabwe indicate promising results in attracting gravid females. However, further tests with the existing experimental design may need to take into account the effects of pheromone doses and fly densities on the behaviour of gravid females.

Field experiments in Nguruman with artificially constructed burrows (similar to those used in Zimbabwe) thus far indicate no evidence of their being used by gravid *G. pallidipes* females for larviposition.

Three GC-EAD active peaks from volatiles collected from *G. pallidipes* larvae have been identified and characterised. However, further identification work has been frustrated by variability among samples and the fact that the olfactory system of laboratory-reared *G. pallidipes* appears to be insensitive to semiochemicals, including larval volatiles.

The current work clearly points to the need for further investigations in this new area of research. Can larviposition behaviour patterns be exploited to specifically attract gravid females for control? If so, this will open up the exciting possibility of manipulating larviposition behaviour and controlling tsetse at its most crucial stages of its life cycle.

The visual and olfactory ecology of larvipositing females needs to be better understood in order to develop artificial larviposition sites/targets. This work also needs to be extended to other species, especially riverine species which are known to aggregate pupae.

6. DEVELOPMENT OF TRAPPING TECHNOLOGIES FOR *GLOSSINA MORSITANS SUBMORSITANS*

Participating scientists: *S. Mihok, P. Ndegwa*

Assistants: *E. N. Munyoki, S. O. Maramba, D. K. Mungai*

Collaborators: *• Tropical Pesticides Research Institute (TPRI), Arusha • Ethiopian Science and Technology Commission*

Work was initiated in Western Wollega, Oromia, Ethiopia to develop trapping technologies for *G. m. submorsitans.* Triangular blue and black trap formats such as the NG2G, NZI and Epsilon were shown to be the best formats for sampling this species. However, initial behavioural experiments suggest that even the best traps operate at only 3% efficiency for *G. m. submorsitans* as opposed to 30% efficiency for *G. pallidipes*. Hence, considerable effort will be required for the development of a new generation of innovative traps for the control of *G. m. submorsitans.*

7. A NEW TRAP FOR BITING FLIES

Participating scientists: *S. Mihok, P. Ndegwa*

Assistants: *E. N. Munyoki, S. O. Maramba, D. K. Mungai*

The project scientists have developed a new effective trap (the NZI trap) for these nuisance flies. This trap is a modification of the NGU trap previously developed by ICIPE, but attracts more biting flies.

8. DEVELOPMENT OF A SUSTAINABLE BARRIER SYSTEM FOR CLEARED AREAS

Participating scientist: *R. Copeland*

Assistants: *J. Kilu, S. Pukare, J. Tanchu, J. Kobaai*

The project has done much to contribute to the basic knowledge required to develop sustainable barrier systems to prevent flies from immigrating from uncleared areas into cleared areas. Using the basic knowledge on tsetse behaviour and ecology previously acquired through the Project research, improved barrier systems are now possible.

A new approach was tested, the 'push-pull' strategy, in which repellents push the flies into a region where there are traps/targets baited with attractants (pull).

9. DEVELOPMENT OF AN ELISA SYSTEM TO IDENTIFY BLOOD MEALS FROM TSETSE

Participating scientists: *S. Mihok, E. Osir*

Assistants: *J. Kabii, E. N. Munyoki, S.O. Maramba*

Collaborator: *University of Nairobi*

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. Little or no information is available on host preferences, precluding the formulation of appropriate control strategies for some disease vectors.

ICIPE has consolidated past efforts to develop an ELISA system for the identification of bloodmeal residues in the guts of tsetse flies under this project. The system developed at ICIPE is capable of identifying up to 50 wild and domestic animal hosts and is currently offered as a paid service to collaborators and researchers worldwide.

10. SOCIOECONOMIC ACTIVITIES AT NGURUMAN AND ETHIOPIA

Participating scientists: *G. T. Lako, G. Tikubet*

Assistants: *R. Emongor, D. K. Kahuria, P. Muasa*

Collaborators: *• Doeke C. Faber • Netherlands Institute of Cooperative Entrepreneurship, Nijenrode University, Netherlands*

10.1 CONDITIONS FOR SUCCESSFUL ADOPTION OF TSETSE MANAGEMENT TECHNOLOGIES

It has been shown that the application of tsetse management methods (technologies) can be successfully adopted and sustained, if and when implemented under appropriate conditions. The necessary, but not sufficient, conditions have been found to be:

- problem identification and definition by the recipients
- demand-driven approach, ownership and commitment by recipients
- bottom-up participatory approach
- enabling environment, government policy and services
- clearly defined objectives and verifiable outputs
- benefits to be made visible to community
- short-term successes and long-term benefits
- appropriate environmental and cultural conditions
- strong community leadership.

Tsetse suppression and control methods and techniques have proved to be appropriate under various and widely different conditions. Production, maintenance, deployment and checking of tsetse fly traps have been adopted and materials used are locally available.

Project implementation has been more sustainable in situations where better economic alternatives were not available.

Development of 'benchmark' data provides a useful tool to do comparative studies between the 'before' and 'after' situations in the project area. The impacts of interventions can thus be measured and analysed. Such information can also be used for monitoring, evaluation and management of project.

Projects must, in their implementation, give due regard to institutional requirements to ensure sustainability of activities.

10.2 LESSONS LEARNED FROM SOCIOECONOMIC ACTIVITIES

The activities related to adoption of sustainable tsetse management technologies are considered to have been successful in one location (Ethiopia) and unsuccessful in another (Kenya). The activities in the two locations (Ethiopia and Kenya), have been implemented under very different circumstances, the difference being the starting conditions prevailing in the two locations. In Ethiopia, there was: (i) involvement and ownership of the communities; (ii) a recipient- driven approach; (iii) bottom-up approach; and (iv) government interest and involvement at both national and regional level. In Kenya, there was: (i) no ownership of the problem and activities; (ii) a donor-driven approach; (iii) a top-down approach, and (iv) no interest or support by government or national systems.

Proposals that are multidisciplinary in nature should be developed by a multidisciplinary team. The proposal should be developed with the assistance of important actors and stakeholders, in order to ensure ownership and commitment at all levels. A bottom-up and participatory, recipient-driven approach should become a standard.

Development of a socioeconomic component as an appendix to an already completed 'technical' proposal, will be sub-optimal in its implementation and results. ICIPE's Social Sciences department needs to be strengthened to play a role in the development and implementation of complex multidisciplinary projects.

The development of questionnaires and socioeconomic surveys will only be effective and useful, if *a-priori* it is decided what questions need to be answered, what relationships are to be tested and what other information is needed that may add to the knowledge and insight into the problems that the project attempts to tackle. Collecting information on a large number of variables is of no use in itself.

10.3 ELEMENTS OF AN EXTENSION PACKAGE

Based on past experience and taking into account the lessons learned, ICIPE has described a generic package that can be used for purposes of developing and implementing similar activities elsewhere, under roughly similar circumstances. The package is not meant to be a blueprint, but rather a guideline for developing like-oriented activities. There must be an expressed need to solve an identified problem that falls within the expertise or competence of ICIPE in order for it to become involved as follows:

- Actors and stakeholders are to be identified.
- ICIPE will establish, verify, and analyse the problem and provide advice on possible courses of action. The most preferable course of action will be developed into a project proposal.
- Development of a benchmark study should be done in the community or area where the project will be implemented. The idea of a benchmark study is to take a 'snapshot' of the socioeconomic and/or agricultural situation at the moment that an intervention will take place. A second snapshot will be taken ex-post, allowing a comparison between the two situations and providing a set of reference points which may be used to analyse what impact the intervention has had on the area or community, depending of course on the objectives and expected output as defined by the project.

It is therefore not possible to provide a 'fixed' set of variables which should be included in the snapshot survey; rather, they should be deduced from the type of intervention to take place.

In the case of adoption of tsetse management practices, one will need to design a survey in which the variables that are related to or influenced by those practices will be measured, e.g. for an intervention to take place in a community, participants in the project may ultimately want to see their well-being and welfare increased. This can be measured through income, number of days ill, money in savings account and investments made. If animal health is at stake, milk yield, calving rate, maturity, weight, health treatments, etc. will be considered. In short, one needs to develop a number of relationships, in the form of y = f (x,z,a,b,c), and collect data on each of these variables, in order to use these later in the impact analysis.

It is paramount, that the data is sampled and collected to allow for statistical analysis. It should also be noted that the length of time between snapshots for most socioeconomic surveys should not be less than 3 years, if longitudinal and cross sectional data can be combined.

Implementation of the proposal by ICIPE is based on the approach and involvement of community, project staff and others through:

- general awareness-raising sessions in order to mobilise communities
- training sessions with community leaders and facilitators
- trapping activities implemented including trap making, deployment, maintenance and siting
- transfer and adoption of trapping activities through community-oriented and commitment-oriented activities
- development of integrated community development activities, such as development of income-generating agricultural or non-agricultural activities, in order to enhance sustainability of the project
- sustainability of the technology ensured through activities based on extension and income generation:
  - (i) monitoring and evaluation of ongoing tsetse suppression and control activities
  - (ii) providing advice on new methods and techniques
  - (iii) refresher training courses and workshops to exchange knowhow and lessons of best practice.

11. NEW INSIGHTS INTO THE ANALYSIS OF TSETSE DATA

Participating scientists: *A. Odulaja, S. Mihok, M.M. Mohammed, I. M. Abu-Zinid*

Assistants: *J. Muchiri, S. E. Mokaya, P. Ongele*

The current method of estimating efficiency of tsetse traps was developed and employed for *G. f. fuscipes*. Methods of accounting for flies that avoid or fly over the electric nets were spelt out. These give more reliable estimates of trap efficiency, and therefore, better planning of trap optimisation and deployment for tsetse suppression, than previously used methods.

The relative efficiency of the Latin square design for tsetse trapping experiments was quantified for the first time. The conditions, in terms of number of sites and days under which the design 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 essential for efficient design and interpretation of results from tsetse trapping experiments.

The importance of spatial and temporal interaction effect in tsetse trap catches was quantified. This issue has never been addressed empirically by tsetse researchers. Such information is important in determining the most appropriate sampling method for tsetse.

The spatial and temporal dynamics of the tsetse population at Nguruman was investigated in detail using a 2200 trap-days data set. The relationships of these dynamics with weather data were also investigated. The results give a new insight into the focal point for the spread of tsetse at Nguruman, and serve as a guide to strategic location of traps for cost-effective tsetse control in this area.

Patterns of association between vegetation type, distance of a trap from the vegetation edge and sex composition of trap catches with respect to the trappability of *G. f. fuscipes* were ascertained using appropriate models. The models enabled the estimation of optimum trapping distances from the different vegetation types for *G. f. fuscipes*. A simulation technique was used to estimate the radius of attraction of the unbaited biconical trap for the fly, taking the efficiency of the trap into consideration.

12. REGIONAL COLLABORATION

During the life of the Project, regional collaboration was strengthened and linkages with the following institutions/government departments established:

- Centre International de Recherché -Development sur l'Elevage en Zone sub-Humids, Burkina Faso (CIRDES)
- International Trypanotolerance Centre, Banjul, the Gambia (ITC)
- Regional Tsetse and Trypanosomiasis Control Programme (RTTCP)
- Coordinating Office for the Control of Trypanosomosis in Uganda (COCTU)
- Uganda Trypanosomosis Control Council (UTCC)
- Ethiopia Science and Technology Commission (ESTC)
- Governments of Ethiopia, Rwanda and Mozambique
- Association for Strengthening Agriculture Research in East and Central Africa (ASARECA)
- Kenya national partners:
  - (i) Kenya Trypanosomiasis Research Institute (KETRI)
  - (ii) Department of Veterinary Services, Ministry of Agriculture, Livestock Development and Marketing
  - (iii) Kenya Wildlife Services (KWS).

Output

Publications

Project output includes one patent and 38 publications. Only 1998–1999 publications are listed below:

Mohamed-Ahmed M. M. and Wynholds Y. (1999) Effects of vegetation and weather on trap catches of *Glossina fuscipes fuscipes* near Lake Victoria, Kenya. *Entomologia Experimentalis et Applicata* (in press).

Mohamed-Ahmed M. M. (1998) Olfactory responses of *Glossina fuscipes fuscipes* (Diptera: Glossinidae) to the monitor lizard, *Varanus niloticus niloticus*. *Bulletin of Entomological Research* 98, 1440.

Muhigwa J. B. B., Saini R. K. and Hassanali A. (1999) Response of *Glossina fuscipes* Newstead 1910 (Diptera: Glossinidae) to the Nile monitor lizard, *Varanus niloticus*. *Journal of African Zoology* (in press).

Muhigwa J. B. B., Saini R. K. and Hassanali A. (1998) Effects of fly abundance on the catch index of traps for *Glossina fuscipes fuscipes* (Diptera: Glossinidae). *Journal of Medical Entomology* 98,1430.

Njagu Z., Mihok S., Kokwaro E. and Verloo D. (1999) Isolation of *Trypanosoma brucei* from the monitor lizard, *Varanus niloticus* in an endemic focus of rhodensian sleeping sickness in Kenya. *Acta Tropica* 72, 137–148.

Odulaja A., Mihok S. and Abu-Zinid I. M. (1998) The magnitude of site and time interaction effect in tsetse fly (Diptera: Glossinidae) trap catches. *Bulletin of Entomological Research* 88, 59–64.

Saini R.K. and Hassanali A. (1999) A novel method for controlling tsetse flies and other related blood feeding insects (patent application).

Saini R. K. (Ed.) (1998) *Tropical Entomology — Proceedings of the Third International Conference on Tropical Entomology*. ICIPE Science Press, Nairobi. ISBN 92 9064 108 8, 409 pp.

Saini R.K. (1999) *Fighting Africa's Deadly Fly—New Ecofriendly Solutions for Tsetse Management: Accomplishments of the European Commission Funded Project 'Interactive Development and Application of Sustainable Tsetse Management Technologies for Agropastoral Communities in Africa'*. ICIPE Science Press, Nairobi. ISBN 92 9064 126 6, 12 pp.

Conference presentations

Saini R.K., Baumgartner J. and Cuisance J. (1999) 25th Jubilee Conference of the OAU/ISTRC, 27 September to 1 October, 1999. Plenary talk, 'In search of sustainable integrated vector control systems'.

Saini R.K. (1999) 25th Jubilee Conference of the OAU/ISCTRC, 27 September to 2 October, 1999. Mombasa, Kenya. Paper presented, 'A potent repellent identified for savannah tsetse—ecofriendly tools for integrated management of tsetse and trypanosomosis'.

Saini R.K. (1999) 15th East African Ministerial Coordination Meeting of Farming in Tsetse Control Areas of Eastern Africa (FITCA) and the launching of FITCA, 11–13 August, 1999, Busia, Kenya. Paper presented, 'Repellents for management of savannah tsetse and odour baits for *Glossina fuscipes fuscipes*'.

Saini R.K. (1998) 14th East African Coordination Meeting on Farming in Tsetse Control Areas (FITCA), 7–9 December, Arusha, Tanzania. Paper presented, 'Achievements of ICIPE's tsetse R&D activities and future projections'.

Saini R. K. (1998) 13th East African Coordination Meeting on Farming in Tsetse Control Areas of Eastern Africa, 7–8 May 1998, Kampala, Uganda. Paper presented, 'Achievements of the EU Funded tsetse project and future perspective with respect to ICIPE's role in the upcoming regional projects'.

Awards

R.K. Saini was awarded Silver Medal by the Secretary General of the OAU on behalf of 37 African countries affected by tsetse flies for making significant contributions to advances in the understanding and control of African trypanosomes and their vectors. The award was presented by the Vice President of the Republic of Kenya at the opening of the 25th Jubilee Conference of the ISCTRC on 27 September 1999.

Capacity building

PhD students supervised

Four PhD students from three countries who were sponsored by the Project completed their studies and were awarded their doctoral degrees:

- J. B. Muhigwa (University of Sudan): Visual and olfactory cues of *Glossina fuscipes fuscipes* (Supervisors: R. K. Saini and M. O. Bashir)
- Z. Njagu (Kenyatta University): Role of the monitor lizard, *Varanus niloticus* in the epidemiology of trypanosomosis along the shores of Lake Victoria. (Supervisors: Steve Mihok and E. D. Kokwaro)
- F. Masaninga (University of Zambia): Adaptation of *Trypanosoma (Nannomonas) congolense* Broden 1904 types to different hosts and transmission by *Glossina* spp. (Supervisors: Steve Mihok and K. Mbata)
- S. Akinyi (Kenyatta University): Factors affecting the reproductive performance and the effects of certain insect growth regulators on the reproduction of *Glossina fuscipes fuscipes*. (Supervisors: R. K. Saini and N. O. Oguge).

Training courses

A total of 66 technicians from East African countries have benefited from training courses organised by the Project. The courses (lectures/laboratory practicals) were held in Nairobi and at the coast in Shimba Hills National Reserve (field exercises). Forty-one resource staff participated from eight different organisations.

Training of farmers

During the Project period, more than 500 farmers were trained in Kenya and Ethiopia in basic biology and tsetse management of bait technologies.

Impact

ICIPE's main strength—development of integrated vector control technologies, experience in socioeconomic research in different agroecosystems with differing community organisations and capacity building at all levels of society—are exemplified in this Project, which also provides a good example of the integration of research, training and extension.

The potent repellent identified through a molecular optimisation process is a promising addition to the tsetse control arsenal. It opens the possibilities of integration with other tsetse and trypanosomosis control tactics, to develop new strategies to protect livestock and man. These strategies need to be evaluated. In addition, research and development already going on needs to be supported for identifying additional repellents from unpreferred hosts of savanna tsetse, to augment the effects of the existing one. Repellents also need to be developed for riverine tsetse.

Our work has clearly shown that contrary to commonly held opinion, *G. f. fuscipes* is attracted by a variety of host odours, and this is very encouraging for the development of effective control tactics for this important vector species. We also need to build on the Project's success in the identification of candidate kairomones for *G. f. fuscipes* and extend this work to the other *palpalis* group of flies in order to develop effective baits for riverine tsetse.

In the new regional project, *G. f. fuscipes* is one of the target species for control and ICIPE's bait technology can form the basis of such operations. The technology needs to be evaluated and optimised in collaboration with national partners in Uganda and Kenya.

The bloodmeal ELISA has a serum bank of about 50 species of host animals and 31 specific reagents covering major species of interest to tsetse biologists. Hence, ICIPE could provide a service for the identification of bloodmeals. Since bloodmeal ELISA is too expensive and labour-intensive, PCR techniques need to be developed and optimised.

Quantitative information generated by the Project on effects of trap siting, efficiency and sampling bias on population dynamics, will be important for guiding future tsetse suppression campaigns. The NZI trap developed for biting flies also promises to be a useful bait for the control of biting flies which are emerging as important pests of livestock in tropical Africa.

The socioeconomic insights provided by the Project have an important bearing on future tsetse control operations. The Extension Package developed could be useful in implementing similar community-based tsetse control activities elsewhere.

Capacity building, which has been one of ICIPE's strengths, was an integral part of the Project and has significantly contributed to enhancing the capability of target communities at farmer and extension level in tsetse control. In addition, the training at postgraduate level has contributed to the pool of indigenous high level manpower who are expected to impact tsetse R& D in the region. These gains need to be continuously augmented and the base broadened to ensure sustainability of tsetse and trypanosomosis management in the region.

ICIPE is cognisant of the fact that disease vectors and crop pests constitute only two facets of the problems that underline the vicious cycle of successful and sustainable development in Africa. Successful and sustainable development can be achieved not only through the transformation of vector control and pest management tactics into working strategies, but more importantly through a holistic development paradigm. ICIPE is but one player in such a venture and will work with its partners, the rural communities, national extension systems and international organisations.

(See also the reports of the Behavioural and Chemical Ecology Department, the Moelcular Biology and Biochemistry Unit, the Social Sciences Unit, the Biostatistics Unit and the Capacity Building Programme.)

Participatory Testing and Validation of Sustainable Tsetse Control Technologies

Donor: IFAD

1. EVALUATION OF A COMMUNITY-BASED 'PUSH-PULL' PROTOTYPE FOR TSETSE CONTROL

Background, approach and objectives

Recent work at ICIPE has led to the identification of a potent repellent for *G. pallidipes* and *G. m. morsitans* (see previous report). This repellent significantly reduces the tsetse challenge. Trap catches and even catches with cattle odour are reduced by more than 80%. Feeding efficiency of the flies on cattle is also significantly reduced. This repellent provides a new weapon in the arsenal for use in conjunction with other tsetse and trypanosomosis control tactics to protect livestock. These tactics include the use of repellents with drugs, trypanotolerant breeds of cattle, integrated use of bait technologies and repellents in 'push–pull' strategies and use in barrier systems and for personal use to protect man.

The following activities were initiated under this project to:

- optimise the repellent dispenser.
- determine the optimum placement of repellent dispensers on cattle in order to maximise protection;
- demonstrate the level of protection of cattle in communal herds treated with repellent;

Participating scientists: *R.K. Saini, A. Hassanali*

Assistants: *J. Andoke, E. Mpanga, J. Mbayi, P. Muasa*

Work in progress

1.1 OPTIMISATION OF A DISPENSER FOR THE TSETSE REPELLENT

Figure 1.1 shows a schematic drawing of the prototype dispenser used to protect cattle. The dispenser was designed to provide a constant release rate of the repellent for over a month and to allow cattle to graze freely with the dispenser in place. The dispensers were prepared from 10-ml polypropylene pipette tips,

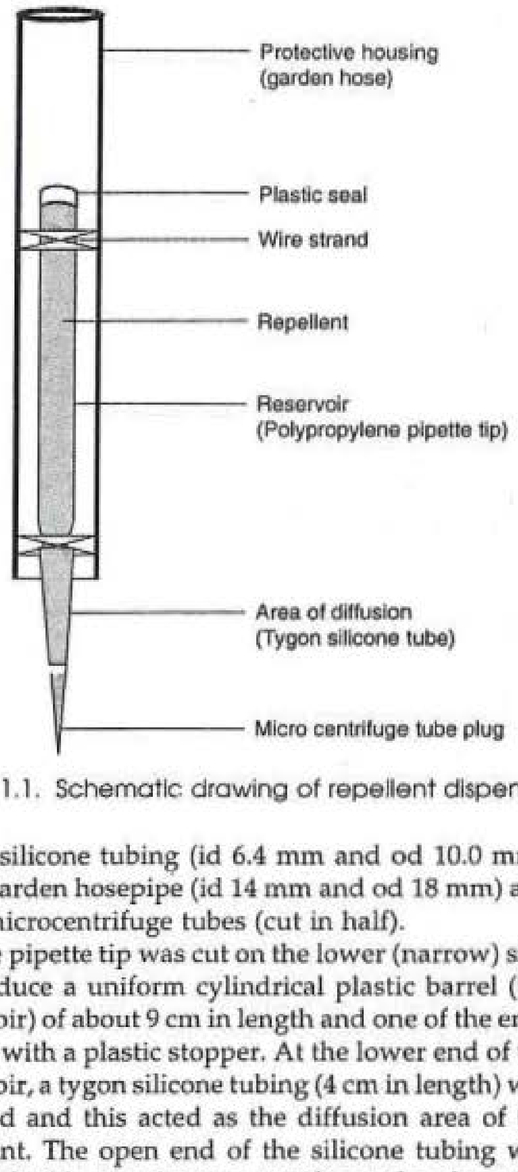

Figure 1.1. Schematic drawing of repellent dispenser

tygon silicone tubing (id 6.4 mm and od 10.0 mm), clear garden hosepipe (id 14 mm and od 18 mm) and 1-ml microcentrifuge tubes (cut in half).

The pipette tip was cut on the lower (narrow) side to produce a uniform cylindrical plastic barrel (the reservoir) of about 9 cm in length and one of the ends sealed with a plastic stopper. At the lower end of the reservoir, a tygon silicone tubing (4 cm in length) was inserted and this acted as the diffusion area of the repellent. The open end of the silicone tubing was plugged with a 1-ml microcentrifuge tube plug after the repellent was poured into the reservoir. The reservoir was then pushed into a clear garden hose (length about 12 cm), so that only the tygon silicone tube was exposed. The garden hose acts as a protective shield to the dispenser when the cattle are moving.

Such a dispenser is capable of releasing an average of 4.5 mg of the repellent per hour. Since previous field experiments indicated that 9 mg/hour of the repellent provides maximum protection to cattle, two such dispensers were used to protect each animal. The dispensers were tied around the neck of a cow with a belt, so that the tygon silicone tubing faced downwards and the dispensers were near the forelegs of the cattle.

1.2 PLACEMENT OF THE DISPENSERS ON THE BODY OF CATTLE

Several field experiments were undertaken to determine the optimum position for placement of the repellent dispenser on the cattle. In order to determine the feeding efficiency, an ox with or without the repellent was placed at the centre of an incomplete ring (8 m dia.) of 5 electric nets. The nets covered about 20% of the circumference of the circle. Flies were separated according to the side of the net on which they were caught and classified as fed or unfed, based on the presence of red blood, visible through the abdominal wall. The feeding efficiency was estimated as the number of fed tsetse caught on the inside of the ring of nets, expressed as a percentage of the total catch from the inside of the ring.

The rings were constructed at two different sites and the treatments, ox alone or ox with repellent dispenser placed on the neck, body (near the forelegs) or tail or at all the three sites, were compared using a randomised block design. The treatments were randomly assigned to the experimental sites. Since in the experimental sites most flies were caught in the

Table 1.2. Percentage feeding efficiency of *Glossina pallidipes* with repellent dispensers placed at various parts of the body of an ox

Treatment (placement of repellent dispenser)	Control (ox alone)	Treatment (ox + repellent)
Experiment 1		
Neck	2.0	0.5
Body	1.8	0.7 *
Tail	3.9	0.6 *
Neck+Body+Tail	2.3	1.1
Experiment 2		
Neck	4.8	3.6
Body	9.0	1.3 *
Tail	4.7	6.3
Neck+Body+Tail	4.3	3.8
Experiment 3		
Neck	0	2.8
Body	7.4	0.6 *
Tail	2.0	3.0
Neck+Body+Tail	3.4	0

Feeding efficiency is the total catch of fed flies inside the ring of screens expressed as a proportion of the total catch (fed + unfed flies).
Ox was enclosed with an incomplete ring of 5 electric screens.
* Significantly different at $P \leq 0.05$.

afternoon, the experiments were run for 3 hours from 1500 – 1800 hours daily.

The feeding efficiency was significantly reduced if the repellent dispensers were placed on the body near the forelegs (Table 1.2). The dispenser is now ready for large-scale field trials.

1.3 DEMONSTRATION OF THE LEVEL OF PROTECTION OF CATTLE IN COMMUNAL HERDS TREATED WITH THE REPELLENT

Field work in three different localities in Nguruman Location, SW Kenya was initiated from September 1999 to evaluate the efficacy of the community-based 'push-pull' tactic for tsetse control. The three localities selected are Konei in the North, Oloibortoto in the centre and Sampu in the South. Sampu area covers the known tsetse belt in Nguruman. Konei and Oloibortoto localities are mainly farming areas, where besides keeping livestock, the community also grow vegetables for export. The livestock owners in these areas graze their stock within the farms. This makes the stock movement rather confined, although during the dry seasons, they are known to move their livestock to graze in the neighbouring forests. Sampu area forms the main grazing area with open grassland spreading southwards towards Tanzania. Both livestock and wildlife graze here. This area also borders the Nguruman escarpment that is believed to be an important reservoir for tsetse in the area. The tsetse population in this area is quite high and the disease incidence may be expected to be comparatively high.

However, our monitoring showed that the disease incidence was higher in Konei and Oloibortoto than Sampu. This may be due to the fact that most herdsmen avoid grazing within the forest, which are tsetse and nagana hotspots, unless forced to do so by adverse climatic conditions. Our monitoring also showed that although the disease incidence was very high in Konei and Oloibortoto, in these areas the fly densities were low as compared to Sampu.

Five communal groups were randomly selected in the localities, based on their willingness to participate in the trials and commitment to provide cattle. In Konei location, two communal herds (Kisongoi and Tanchu) comprised of 28 and 16 cattle, respectively, were unprotected, i.e. had no repellent dispensers and served as controls. In Sampu, one of the communal herds (Ndetu) and 25% cattle (30 cattle) were protected with the repellent. In Oloibortoto, 50% (20 cattle) of the herd (Pukare) were protected with the repellent and in Sampu, the Musenya herd of 18 cattle were 100% protected. Each protected ox had 2 repellent dispensers (each releasing 4.5 mg/hour of the repellent), hung around the neck of the animal with a band.

The animals were allowed to graze freely within their respective pastures, the farmers themselves taking care of the animals.

In Sampu, an area of 6–7 sq km, 21 baited NG2G traps were also placed to serve as the 'pull' component of the 'push-pull' tactic.

Table 1.3a shows the mean densities of the flies in the three experimental locations. It is clear that most flies are caught in Sampu area and the least in Konei, but disease incidence was high in Konei (Table 1.3b).

The September 1999 data can be considered as the baseline data. September, October and November were spent sorting out technical problems with the dispensers until the new dispenser described earlier in 1.1 was deployed. These technical problems involved breakage of the twines used to tie the dispensers, damage by vegetation, sun, heat, and leakage of the dispensers, caused by the cracking of the dispenser tubing and loss of dispensers.

All these technical problems peaked in November, especially in Sampu and Oloibortoto localities, resulting in relatively high infection in all the sites. These technical problems have now been resolved and very little damage to dispensers was reported in December 1999. The preliminary results suggest that the repellent has managed to keep infection relatively low as compared to the controls. These experiments are continuing.

Table 1.3a. Mean catch/trap/day of *Glossina pallidipes*

Locality	August	Sept.	Oct	Nov.	Dec.
Sampu	257.5	89.56	319.48	241.12	83.48
Konei	0.48	0.08	0.48	1.24	0.48
Oloibortoto	12.04	5.28	50.88	136.4	38.6

Table 1.3b. Percentage infection in herds treated with the repellent

Farmer	Locality	Treatment	Sept.	Oct.	Nov.	Dec.
Kisongoi	Konei	None	23.0	11.3	14.3	39.3
Tanchu	Konei	None	12.5	12.5	18.7	6.25
Ndetu	Sampu	25%	6.7	6.7	20.0	3.3
Pukare	Oloibortoto	50%	15.0	15.0	10.0	10.0
Musenya	Sampu	100%	0	0	16.7	5.9

2. COLOUR PREFERENCES, HOST-FINDING STRATEGIES AND RESPONSIVENESS TO BAITS OF *GLOSSINA FUSCIPES FUSCIPES*

Background, approach and objectives

This study was conducted on *G. f. fuscipes*, a riverine species of central and eastern Africa. It focuses on: (i) colour preferences, (ii) landing and feeding behaviours on a host, the Nile monitor lizard and (iii) trapping in odour- and colour-baited traps. Colour preferences were studied using electric screens in the field. Colours that were found most attractive were combined to make traps. These traps were tested as visual baits and compared to the standard biconical trap of Challier-Laveissière. The performance of the most successful trap type was analysed in relation to fly sex and abundance. It was baited with zebu urine of varying age of storage to estimate an optimum age of urine for baiting *G.f fuscipes* traps in field conditions. Zebu urine was also tested in conjunction with acetone. Whole body odours and urine of the monitor lizard were also tested as attractants.

Participating scientists: *J. B. Muhigwa, R. K. Saini, A. Hassanali*

Royal blue attracted relatively more flies than the black colour (1.7 times). The peony purple-red colour stimulated landing significantly more than royal blue. The attractancy of the trap colours was a function of reflectance in the blue ($P<0.01$) and in the infrared ($P<0.05$) ranges of the spectrum. However, very bright colours performed weakly both for attraction and landing, suggesting that moderate chroma in the range 450–490 nm and in the near IR (750–1100 nm) largely determine the attraction of this fly.

A biconical trap with the purple-red component inside caught 1.4 times more males and 1.63 times more females ($P<0.03$; n=21), an increase of up to 3 times at low abundance sites (catch of maximum 10 flies/trap/day) was obtained. Such a trap may find use at low densities in routine trapping on farms and immediately after the initial fast depletion of tsetse numbers during extermination campaigns with conventional tools. A blue/red target is also proposed as a candidate for further evaluation in comparison with the usual black or blue targets.

More flies approached the biconical trap in the light region 1600–1700 $uE/m^2/s$; the response of the fly became photonegative when illumination was above 1700 $uE/m^2/s$. The number of males attracted was associated with the presence of bushes and that of females was very dependent on illumination rather than vegetation.

Glossina fuscipes fuscipes showed a significant preference for the neck of the monitor lizard for feeding ($P<0.05$). When the Nile monitor lizard was present in the odour chamber of a compartmentalised experimental cage, traversed by a wind flow, 61.5 to 67.5% of the flies performed an active upwind flight towards the next compartment where further search for the host occurred. Out of 100 flies that took off from the release chamber towards the lizard, approximately 50% did so by ranging upwind. In nature, flies tended to aggregate at sites where monitor lizards live ($r=0.67$; $P<0.05$ for females and $r=0.54$; $P<0.03$ for males).

When acetone and 5- to 6- week-old cow urine were used together as a bait on the standard biconical trap, the highest catch indices occurred at sites with low abundance of tsetse (average catch 0–10 flies/day), 1.7 times for males and 2.3 for females ($P<0.05$). At low abundance (0–10 flies/day), the catch index of colour or odour-baited traps was high. A strong point of inflection appeared at the abundance level of 7 flies/day, where the treatment was just as good as the control trap. At high abundance (>20 flies/day) the catch index was very low (ca 0.25).

3. FACTORS AFFECTING THE REPRODUCTIVE PERFORMANCE AND EFFECTS OF CERTAIN INSECT GROWTH REGULATORS ON REPRODUCTION IN *GLOSSINA FUSCIPES FUSCIPES*

Background, approach and objectives

The reproductive behaviour of *G. f. fuscipes* was studied with the aim of determining factors that influence its laboratory colonisation. Further work was designed to determine the effects of certain insect growth regulators (IGRs) on reproduction and metamorphosis, with a view to assessing the possibility of their use in managing tsetse populations.

***Participating scientists:** S. Akinyi, R.K. Saini*

Work in progress

Receptivity was highest (F=2.40, $P<0.05$, n=473) in young females aged 1 to 2 days, older females being less receptive. Males from 4 days of age inseminated females, but mating was more successful (F=4.55, $P<0.01$, n=246) in older ones (8 to 12 days). Fecundity of females from Rusinga Island, Kenya was low (F=143, $P<0.0001$, n=331), compared to that of an established laboratory population from Seibersdorf, Austria, which originated from the Central African Republic (CAR). Fecundity of females from the Rusinga population was affected by abortion, slow growth of follicles and egg retention in inseminated females. First filial generation females produced low weight pupae compared to those produced by parental females (F=136.9, $P<0.001$, n=397). Laboratory reproductive performance was also affected by low adult emergence rates (χ^2=70.02, $P<0.001$, df=1) of the F2 generation, compared to that of the F1. Other reproductive abnormalities, e.g. equality in size of the two most developed follicles, fusion of follicles and abortions, were observed both in laboratory and wild populations. Abortion rates were significantly higher in the Rusinga population (χ^2=104.2, $P<0.001$, n=1331) than in the CAR population.

Topical treatment of females with the insect growth regulators (IGRs) pyriproxifen, W-328 and precocene, had no effect on fecundity or pupariation. However, adult emergence was inhibited. Pupariation failed in 1.7% (n=235) of the larvae produced by ketoconazole-treated females. Juvenile hormone replacement in precocene-treated females resulted in some emergence in the first reproductive cycle in pyriproxifen-treated females, but not in W-328-treated ones. Treated males transferred sterilising effects of JH analogues to the females they mated with, resulting in inhibition of emergence. The frequency of adults without any tergites was higher (χ^2=8.70, $P<0.01$, n=360) in W-328 treated females than in pyriproxifen-treated ones. Treatment of puparia of varying developmental stages with the two JH analogues inhibited emergence in puparia below 5 days post-larviposition. Those over 5 days showed high emergence rates irrespective of dose. Where emergence was inhibited, histological studies indicated failure of formation of the adult abdominal cuticle.

Poor reproductive performance of the Rusinga population may be due to lack of adaptation to laboratory conditions and supplementation of existing colonies with wild females or puparia needs to be continued until a stable colony is attained. A small proportion of larvae produced by ketoconazole-treated females did not pupariate. However, some went through normal development, suggesting that ketoconazole may not be effective in inhibiting synthesis of ecdysteroids in *Glossina*. Since the JH analogues have been shown to disrupt development in this species, field studies which have shown promising results with the *morsitans* group need to be initiated for the *palpalis* group to determine their response in the field.

4. ROLE OF MONITOR LIZARDS, *VARANUS NILOTICUS* LAURENTI IN THE EPIDEMIOLOGY OF TRYPANOSOMOSIS

Background, approach and objectives

Trypanosomosis is one of the major factors that hinders development of rural economies in Africa. The disease is endemic in some of the most potentially productive lands of tropical Africa, where it severely constrains livestock production and human settlement. The Lake Victoria shores in Kenya and Uganda have been endemic foci for human sleeping sickness since the early 1900s. *Glossina fuscipes* has been responsible for these epidemics. Reptiles, especially the monitor lizard, are preferred food sources for *G. fuscipes*. Studies were carried out to determine the role played by the monitor lizard, *Varanus niloticus* in the natural transmission cycle of trypanosomosis between tsetse flies, livestock and man. The objective was to determine the natural occurrence of trypanosomes in lizards. This survey was further supplemented by experimental infections of lizards with *Trypanosoma brucei* and *Trypanosoma congolense*.

***Participating scientists:** Z. W. Njagu, S. Mihok*

Work in progress

A combination of diagnostic techniques was used to determine the natural occurrence of trypanosomes in monitor lizards in Busia and Rusinga Island, in Lake Victoria, Kenya. None of the lizards caught from Rusinga Island (n=27) was infected and 5.3% (n=19) of the lizards caught from Busia were infected with trypanosomes. The trypanosome parasite isolated from Busia was characterised as *Trypanosoma brucei* using the polymerase chain reaction (PCR) and the identity was confirmed by hybridisation using a *Trypanozoon*-specific probe. This is the first record of isolation of *T. brucei* from any reptile. The *T. brucei* parasite was infective to laboratory rats and to tsetse.

Experiments were carried out to infect lizards with *Trypanozoon* and *Nannomonas* trypanosomes by cyclic passage using tsetse. It was possible to infect monitor lizards with *T. brucei* parasites without showing any clinical symptoms of the disease. However, infection of monitor lizards with savanna and riverine *T. congolense* was unsuccessful. The *T. brucei* parasite was infective to *G. m. centralis* (19.4%) and to laboratory rodents. These results indicate that the monitor lizard facilitates the developmental cycle of *T. brucei* and forms an important link in the transmission cycle of the parasite between the tsetse vector and mammals.

Comparative studies were further carried out to determine the influence of monitor lizard, crocodile and goat blood on infections with *T. brucei* and *T. congolense* in six *Glossina* species. Goat blood supported high infections (52–78.4%) and monitor lizard and crocodile blood had depressive effects (18.4–39.9%) on infections in all tsetse. The *morsitans* group of tsetse (*G. m. centralis* and *G.m. morsitans*) was more susceptible to infections with *T. brucei* and *T. congolense* than the *palpalis* tsetse, *G. fuscipes*, *G. p. gambiensis* and *G. tachinoides*. *Palpalis* flies maintained totally on monitor lizard blood in the laboratory had low maturation rates (4.6–12.4%) of *T. brucei* organisms. On the other hand, flies maintained on interrupted feeds of goat and lizard, had higher maturation rates of *T. brucei* (8.4–16.3%). This could represent the natural situation where lizards harbour parasites that never reach maturation sites in flies utilising lizards solely as a food source. In the event of an occasional tsetse feed on a favourable host, e.g. goat, parasites acquired from lizards mature and can be transmitted to other hosts, marking the beginning of an epidemic.

Results of this study indicate that monitor lizards, *Varanus niloticus* act as reservoirs of *T. brucei* parasites as evidenced by the isolation of *T. brucei* from 5.3% of wild monitor lizards caught from Busia area. This was further supported by infectivity experiments which demonstrated that lizard blood is not toxic to *T. brucei*. In undisturbed areas, monitor lizards act as natural cryptic (hidden) reservoirs of trypanosomosis.

Along the shores of Lake Victoria, man has encroached on the natural habitat of monitor lizards and *G. fuscipes*. A close contact therefore exists between man, livestock, monitor lizards and *G. fuscipes* near water along the lake shores. Results of this study suggest that monitor lizards are an important link in the fly-livestock-man cycle of *T. brucei* parasites. These findings are important in the control of trypanosomosis. In the past, control efforts have not considered reptiles as important hosts in the disease cycle and yet these animals are prevalent in trypanosomosis-endemic foci. They could be important in the sporadic resurgence of trypanosomes after periods of quiescence at the Lake Victoria shores. This in part explains the inability to eradicate the disease from many endemic foci across tropical Africa.

5. INVESTIGATIONS ON TSETSE REPELLENTS FROM THE BODY SURFACE OF WATERBUCK, *KOBUS DEFASSA* RUPPEL

Background, approach and objectives

Surveys on feeding patterns of different species of tsetse, *Glossina* spp. based on bloodmeal analysis and direct observations have shown varying degrees of specialisation on different groups of vertebrate hosts. No relationship exists between the relative abundance of different vertebrates that are available in different habitats and the frequency with which they are fed on. *Glossina pallidipes*, *G. morsitans morsitans* and *G. m. submorsitans* consistently derive their bloodmeals from bushbuck, buffalo, bushpig, warthog, hippopotamus, cattle and elephant, but not from impala, waterbuck, reedbuck, hartebeest and zebra.

We speculated that the refractoriness of wild animals like waterbuck to tsetse could be due to the absence and/or presence of specific semiochemicals. That is, key kairomone components are absent or present in sub-optimal amounts, rendering the flies relatively indifferent to the animals. Or, allomones may be present that repel the flies from a distance and, when close to the animal, deter them from feeding.

Participating scientists: *N. K. Gikonyo, A. Hassanali, P. G. N. Njagi, R. K. Saini*

Work in progress

The behavioural responses of caged individual teneral *G. m. morsitans* on waterbuck and ox and on feeding membranes with and without smears of different doses of waterbuck sebum were compared. Flies that contacted the body of the waterbuck or areas of the membrane treated with different doses of sebum showed significant reluctance to feed, manifested by high proportions of flies escaping, changing probing sites and general delays in the initiation of feeding relative to the ox or untreated zone of the membrane, respectively (Table 5; Figures 5a and 5b). This is consistent with the presence of aversive constituents (allomones) in the waterbuck sebum of low volatility perceived through tarsal receptors or olfaction at very close range. Additionally, significant demonstration of similar elements of behaviour by 2-day unfed flies that landed on the control zones of treated membranes, compared with those on untreated (double control) membranes, also implicate a more volatile signal.

Examination of waterbuck sebum by gas chromatography linked to an electroantennographic detector (GC-EAD) has revealed the presence of two electrophysiologically active constituents of relatively high molecular weights (370–470), which may have a

Table 5. Behavioural responses of 2- and 3-day teneral *G. m. morsitans* females on: (a) live animals (waterbuck and ox); (b) membranes treated/untreated with waterbuck sebum

	N		% Escaped on initial landing/ probing		% Changing probing sites after initial/subsequent landing		Average number probing sites changed (±SE)		Probing time (minutes) for first 50% of flies to start feeding*	
	2-day	3-day	2-day	3-day	2-day	3-day	2-day	3-day	2-day	3-day
(a) Animals										
ox	-	35	-	0.0	-	11.4	-	0.11 ± 0.05	-	3.1
waterbuck	-	34	-	35.3***	-	88.2***	-	3.94 ± 0.79***	-	7.3*
(b) Waterbuck sebum										
Dose (mg cm⁻²)										
0.0 (double control)	46	35	0.0	2.9	10.9	20.0	0.17 ± 0.07	0.31 ± 0.14	1.4	1.4
0.7 treated	21	21	9.5	4.8	19.0	38.1	0.29 ± 0.10	0.38 ± 0.11	1.9	2.0
control	24	21	4.2	0.0	25.0	28.6	0.25 ± 0.09	0.29 ± 0.10	2.2†	2.3†
1.0 treated	38	44	34.2	34.1**	68.4***	50.0***	1.74 ± 0.24***	1.20 ± 0.19***	4.5*	5.1*
control	34	32	26.5†††	9.4	26.5†	15.6	0.59 ± 0.14††	0.25 ± 0.09	2.1†	1.6
1.4 treated	-	30	-	26.7**	-	46.7**	-	0.90 ± 0.24*	-	2.6*
control	-	28	-	3.6	-	17.9	-	0.39 ± 0.18	-	1.4

*,**,*** Indicates significant differences at ($P<0.05$, 0.01 or 0.001, respectively) between live animals or treated and control zones of the membrane.
†,††,††† Indicates significant differences (at $P<0.05$, 0.01 or 0.001, respectively) between control zones of the membrane and untreated (double control) membrane.
*Calculated from regression curves in plots of proportions of flies that started feeding against probing time.

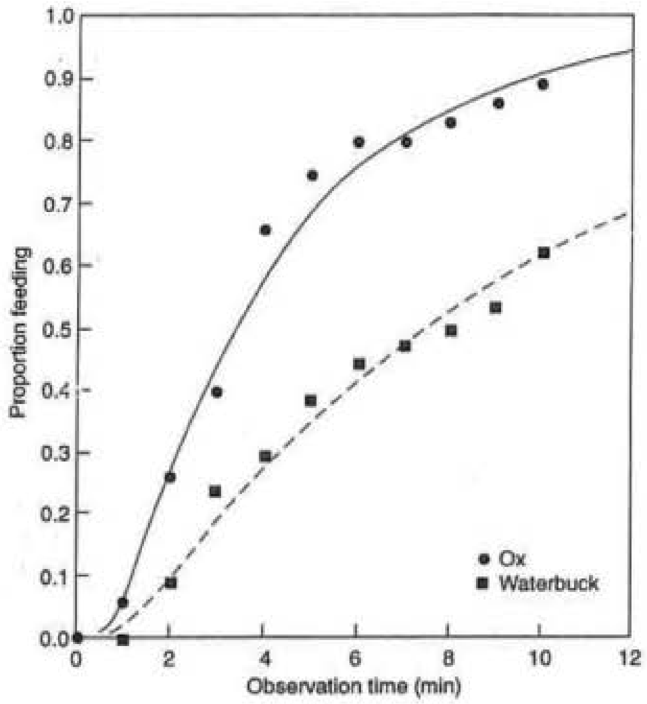

Figure 5a. Proportion of 3-day teneral *G. m. morsitans* females feeding on waterbuck and ox. Proportions feeding on waterbuck and ox differ significantly from the 2nd to 10th minute ($P<0.05$–$P<0.001$)

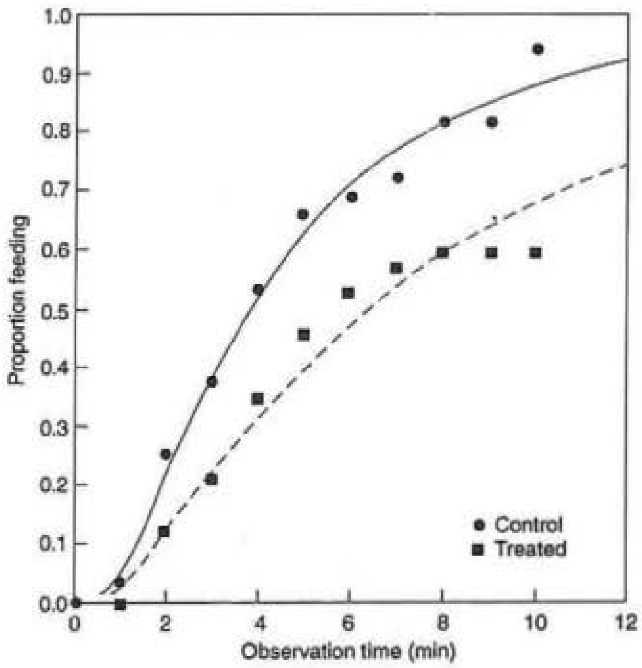

Figure 5b. Proportion of 3-day teneral *G. m. morsitans* females feeding through a membrane partly treated with 1.0 mg/cm² of waterbuck sebum. Proportions feeding on treated and control zones differ significantly from 3rd to 10th minute ($P<0.05$–$P<0.001$)

role in the close-range/contact effects observed in this study. Similar analysis of entrained volatile odours of waterbuck has shown the presence of a series of electrophysiologically active constituents not present in ox or buffalo odours and which may serve as long-range repellents of tsetse. Chemical characterisation and behavioural tests of these constituents is underway.

This study provides clear evidence that the relative refractoriness of waterbuck to attraction and feeding by tsetse is mediated by semiochemicals. Waterbuck may represent a group of wild game in Africa that may have successfully evolved a first line defence mechanism against tsetse (and the disease it transmits), based on secondary metabolism similar to what is commonly found in plants. This raises an intriguing possibility that allomones identified from these animals may constitute a basis of protecting cattle against tsetse attack.

Output

Publications

Gikonyo N.K., Hassanali A., Njagi P.N. and Saini R. Behaviour of *Glossina morsitans morsitans* Westwood (Diptera: Glossinidae) on waterbuck, *Kobus defassa* Ruppel and feeding membranes smeared with waterbuck sebum indicates the presence of allomones. *Acta Tropica*. (In press)

Conference attended

'Tsetse repellents from body surface of water buck *Kobus defassa* Ruppel (an unpreferred host of tsetse)' Poster presented at the 25th Meeting of the International Scientific Council for Trypanosomiasis Research and Control (ISCTRC), Mombasa, Kenya. 27 September 1999–1 October 1999.

(*See also the reports on the Behavioural and Chemical Ecology Department and the Biostatistics Unit.*)

Characterisation of Factors That Influence Vectorial Capacity in Tsetse Flies

Background, approach and objectives

An important step in the establishment of gut-adapted trypanosome infections in the tsetse vector involves their differentiation from bloodstream into procyclic (midgut) forms. This process is mediated by a complex interaction of a wide variety of factors, all of which are intrinsic to the tsetse and the host blood. Out of these factors, lectins, trypsin-like molecules and lysins have received the most attention. Subsequently, a lectin-trypsin complex was purified and partially characterised in our laboratory. It has been postulated that this molecule plays an important role in the differentiation of trypanosomes, but the actual mechanisms involved are still unknown. Apart from the lectin-trypsin complex, another midgut factor that is specifically involved in lysis of trypanosomes was identified. It was suggested that this molecule, trypanolysin, might account for the low midgut infection recorded in refractory flies. In order to gain insight into the involvement of these molecules in innate refractoriness of tsetse, we are continuing with the work that was reported earlier.

Participating scientist: *E. O. Osir*

Students: *L. Abubakar, L. Kiio, B. Ochieng*

Donors: *WHO (TDR) and ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark)*

Collaborators: • *Yale University (USA)* • *University of Nairobi (Kenya)* • *Jomo Kenyatta University of Agriculture and Technology* • *University of Bern (Switzerland)*

1. CHARACTERISATION OF THE TSETSE MIDGUT FACTORS INVOLVED IN DIFFERENTIATION AND LYSIS OF TRYPANOSOMES

Crude midgut homogenate was prepared from male tsetse flies (*Glossina morsitans morsitans* Westwood) that had been fed a bloodmeal 24 hours after emergence and then starved for 72 hours prior to dissection. The midgut factors involved in differentiation and lysis of trypanosomes were then isolated from the crude midgut homogenate by a combination of anion-exchange and affinity column chromatography. The purity of the lectin-trypsin complex and trypanolysin were assessed using polyacrylamide gel electrophoresis (PAGE).

Isolated trypanolysin was tested for its ability to lyse procylic form of *T.b. brucei*, *Leishmania major* and *Plasmodium falciparum*. Double serial dilution of trypanolysin was mixed with an equal volume of the respective parasite. After mixing, the plates were incubated (2 hours, 27° C) and lysis activity assessed.

Four main peaks were obtained by anion-exchange chromatography. Peak III fractions (eluted at 30% of NaCl gradient), gave the highest agglutination titre (128) and trypsin activity of 10.4×10^{-2} mmoles/min/ml (Figure 1a).

The affinity chromatography elution profile showed two peaks (Figure 1b). Samples from bound fractions (peak 2) agglutinated bloodstream trypanosomes at a titre of 64, with a corresponding trypsin activity of 1.78×10^{-2} mmoles/min/ml. Samples from unbound fractions (peak 1) had an agglutination titre of 4 and trypsin activity of 1.84×10^{-3} mmoles/min/ml.

Increasing the concentration of lectin-trypsin complex (from ~0.467 to ~0.827 mg protein/ml) resulted in higher transformation rate of bloodstream procyclics (Figure 1c). About 50% of the bloodstream trypanosomes transformed into procyclics after 6 hours incubation compared to about 35% of parasites transformed at the same time when a lower agglutinin concentration is used in the assay. The increase in lectin-trypsin complex concentration also resulted in higher parasite mortality such that no live parasites were observed in the assays with higher agglutinin concentrations after 14 hours. Comparatively, in the control, more than 95% of the parasites were still in the bloodstream form and viable after 18 hours.

Diethyl pyrocarbonate completely inhibited the trypanolysin activity (Table 1a). The same concentration of aprotinin reduced the trypanolysin activity by 50%. In contrast, Soybean Trypsin Inhibitor (STI), Tosyl-L-lysine chloromethyl ketone (TLCK), Phenyl methyl sulphonyl flouride (PMSF),

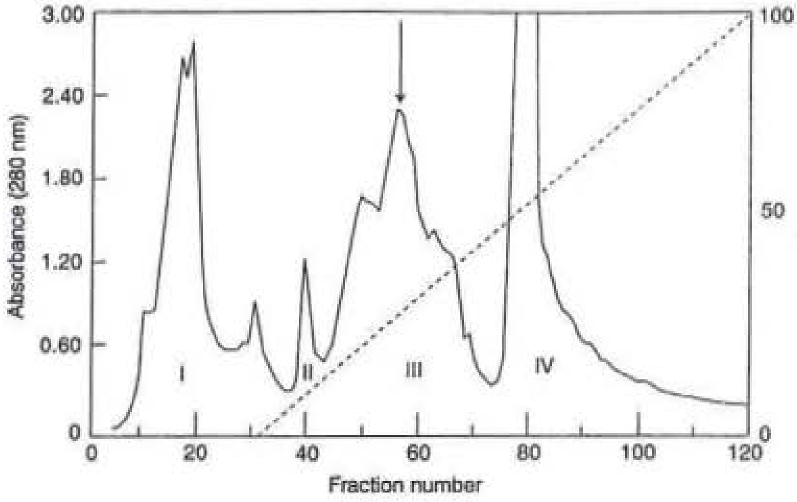

Figure 1a. Anion exchange chromatography. Crude midgut homogenate (85–100 mg protein) dissected from twice-fed tsetse was loaded onto a DEAE-Sepharose CL-6B column (1.6 x 20 cm). Unbound proteins (peak I) were eluted in 20 mM Tris-HCl, pH 8.0, while the bound fractions were eluted using a linear gradient of 0.0–0.5 M NaCl. Fractions (1.5 ml) were collected and absorbancies measured at 280nm. The arrow shows the peak with fractions with the highest agglutination and trypsin activities

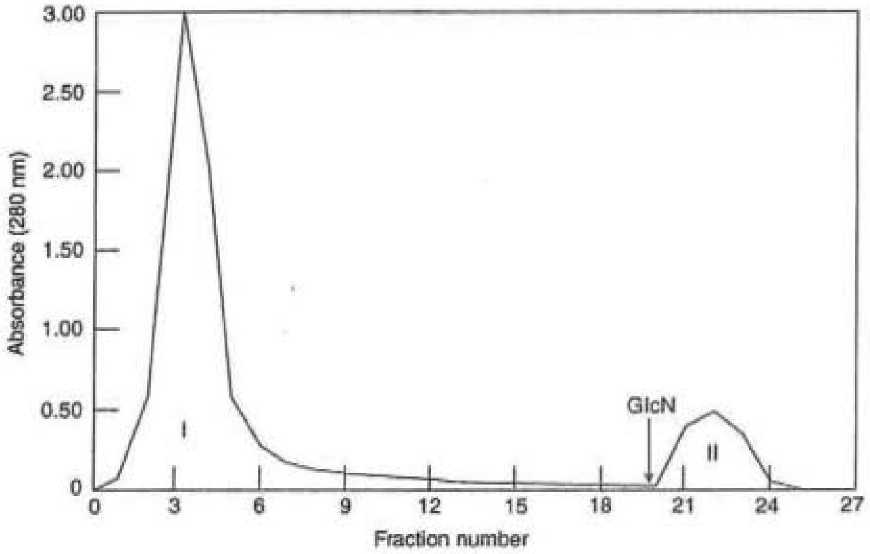

Figure 1b. Affinity chromatography. Peak III fractions from ion exchange chromatography step were loaded onto an affinity column (glucosamine-coupled epoxy-activated Sepharose 6B). Bound proteins were eluted using 0.2 M glucosamine. Fractions (1.5 ml) were collected and the absorbancies measured at 280 m

Diisopropylflourophosphate (DFP) and Tosylamide-2-phenylethyl chloromethyl ketone (TPCK) had no inhibitory effect even at a concentration of 1.0 mg/ml.

A sample of trypanolysin was tested for its ability to lyse *Trypanosoma brucei*, *Leishmania major* and *Plasmodium falciparum* parasites. The trypanosomes and *Leishmania* gave trypanolysin titres of 64 and 8, respectively (Table 1b). Thus, compared with trypanosomes, a higher concentration of trypanolysin was required to lyse the *Leishmania*. Conversely, the trypanolysin had no effect on the *Plasmodium*.

Lectins and proteases are the most prominent molecules in the midguts of most haematophagous insects. Earlier studies have reported the possible involvement of both lectins and trypsins in vector-parasite relationships in midguts of several haematophagous insects. In this study, a lectin with trypsin activity has been successfully purified from *G. fuscipes fuscipes* midgut homogenate using a two-step column chromatography procedure. The midgut lectin-trypsin complex purified in this study was able to induce *in vitro* transformation of trypanosomes. Increasing the concentration of the complex

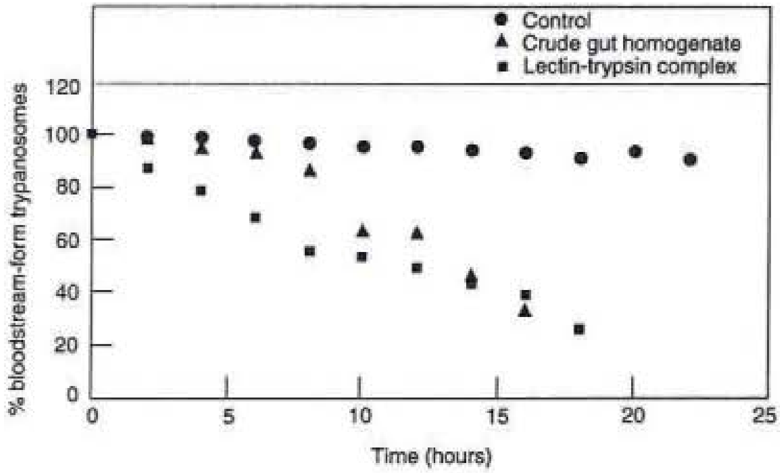

Figure 1c. EFFECT OF LECTIN-TRYPSIN COMPLEX ON TRYPANOSOME TRANSFORMATION. *Trypanosoma brucei brucei* (5x10⁶ parasites/ml) were incubated (27°C) with lectin-trypsin complex or crude midgut homogenate. The control consisted of a mixture of parasites and buffer. At 2 h intervals, aliquots were withdrawn from the incubation mixtures and tranformation of the trypanosomes from bloodstream forms to procyclics was assessed microscopically on the basis of position of kinetoplast relative to the nucleus, size of the trypanosome and extent of mitochondrial staining. Data points represent mean values ± SD (n=4).

Table 1a. Effect of protease inhibitors on trypanolysin activity

Inhibitor	Trypanolysin titre
Control	64
Soybean Trypsin Inhibitor (STI)	64
Tosyl-L-lysine chloromethyl ketone (TLCK)	64
Phenyl methl sulphonyl flouride (PMSF)	64
Diisopropylflourophosphate (DPF)	
Tosylamide-2-phenylethyl chloromethyl ketone (TPCK)	64
Diethyl pyrocarbonate	0
Aprotinin	32

Doubling serial dilutions of trypanolysin samples were pre-incubated with the various protease inhibitors for 30 min. Trypanolysin activities were determined as described above. The control consisted of reaction mixture in the absence of inhibitor.

subsequently resulted into higher transformation rates.

Another molecule, trypanolysin, that is involved in lysis of trypanosomes was also purified from the midguts of *G. f. fuscipes*. Earlier reports suggested that the trypanolysin molecule might be responsible for the low midgut infection rates recorded for *G. p. palpalis* in the field. The mode of action of trypanolysin does not involve trypsin, chymotrypsin or serine-195 residue. Since diethylpyrocarbonate is a histidine residue inhibitor, it is likely that the trypanolysin acts through a histidine residue.

Table 1b. Effect of trypanolysin on different parasites

Parasites	Trypanolysin titre
Bloodstream *T.b. brucei*	64
Procyclic *T.b. brucei*	8
Leishmania major	8
Plasmodium falciparum	0

Doubling serial dilutions of trypanolysin was incubated with the different parasites and lysis activity scored. Titres are expressed as reciprocals of the least dilution of trypanolysin that caused lysis of parasites.

Trypanolysin was highly specific for trypanosomes as plasmodium were not affected. Although lysis of leishmania was observed, a much higher concentration of trypanolysin was required compared to trypanosomes. These results confirm that trypanolysin does indeed play a role in the innate refractoriness of some tsetse.

The role of the lectin-trypsin complex in trypanosome differentiation will be further ascertained using the procyclin assay. The mode of action of the lectin-trypsin complex and the trypanolysin will be elucidated. Finally, expression of the molecules at different post-feeding time will be studied.

(*See also the report on the Molecular Biology and Biochemistry Unit.*)

Sustainable Management of Trypanosomosis and Tsetse Flies Through a New Concept: The Lethal Insect Technique (LIT)

Donor: Austrian Development Cooperation

Background, approach and objectives

The goal of the Austrian Development Cooperation (ADC)-funded project is to contribute to the improvement in the living standards of rural communities in Africa through sustainable management of tsetse flies and trypanosomosis, using a new, environmentally friendly concept: The lethal insect technique (LIT).

1. DEVELOPMENT OF AN IMPROVED AND COST-EFFECTIVE TSETSE MASS REARING SYSTEM

Participating scientist: D. J. Nadel (Project Leader)

Assistants: J. M. Kagoiya, J. A. Ojude, N. M. Mungula, R. O. Agan, J. Gitegi , J. M. Sindiga

Work in progress

1.1 INSTALLATION OF A COST-EFFECTIVE, SIMPLIFIED MASS REARING SYSTEM FOR TSETSE

The ICIPE's traditional tsetse rearing system was based on *in vivo* blood feeding on the ears of lop-eared rabbits, the flies being caged in lots of 20 to 30. This practice was gradually replaced by the *in vitro* membrane technique developed and refined by successive IAEA tsetse teams in Seibersdorf since the early 1970s. The ICIPE system change-over to membrane feeding was completed in December 1997.

The method of blood collection and its storage as developed in Seibersdorf, while dependable, is expensive and requires critical handling procedures throughout. In addition to the obligatory defribinisation, these include a sterilising treatment of a minimum 100 Krad using a costly high-capacity gamma radiation source installation. Blood is collected under septic slaughter-house conditions from cattle of unknown origin. Thereafter, apportioning and uninterrupted deep-freezing, transport and storage of the delicate product is a prerequisite. Additionally, an imported stimulant having a short shelf-life may also be required to induce a feeding response. In summary, it is a blood-diet system perhaps not best suited to large-scale tsetse production in Africa.

At ICIPE, blood is withdrawn on a strict rotation basis from selected, disease-free, donor livestock whose history is known. The fresh, still highly attractive product is delivered within minutes to the colonies, direct from the barn. Care is taken to ensure the health of donor animals; blood quality is evaluated by measuring packed-cell-volume (PCV) levels. A protocol to confirm diet safety for the flies is being developed.

A new system was introduced with the construction of a space- and labour-efficient three-component rearing system which employs, for the most part, locally produced, service-free and robust technology:

COMPONENT 1: THE CAGES (FIGURE 1a)

Light-weight aluminium cages were developed, having capacities of as little as 250 (for research purposes) to over 2500 female tsetse, each for mass-rearing. The larger cages are now being validated for fly productivity. By way of comparison, in 1997, standard PVC Seibersdorf production cages housed about 125 female flies each.

COMPONENT 2: THE LADDER CAGE-STORAGE UNIT (FIGURES 1b AND 1c):

Storage of production cages is achieved using a wall-mounted, book-shelf-type ladder system, which by simple adjustment of their intervals, converts the units to fit the desired cage size. A simple lever lowers the larvae collector trays to feeding position.

COMPONENT 3: THE MEMBRANE FEEDING TROLLEY (FIGURES 1d AND 1e):

A semi-automatic membrane feeding trolley is being validated. Designed for use by a single technician, the unit's capacity can be altered by adding or subtracting feeding trays. Blood-diet can be offered to a million or more flies over a single feeding period. The labour-

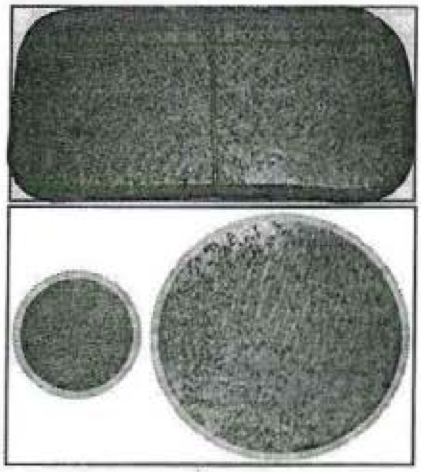

Figure 1a. Aluminium production cages with varying fly capacities

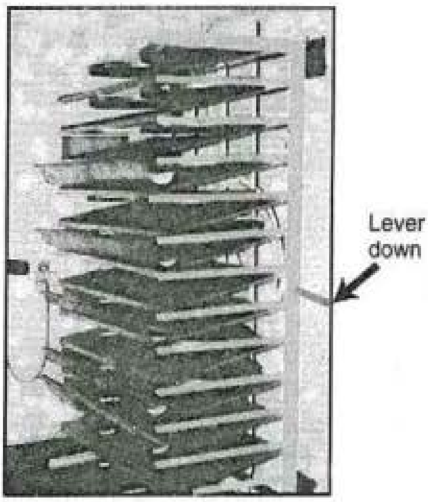

Figure 1b. The ladder system for supporting production cages (larval collecting trays in collection position

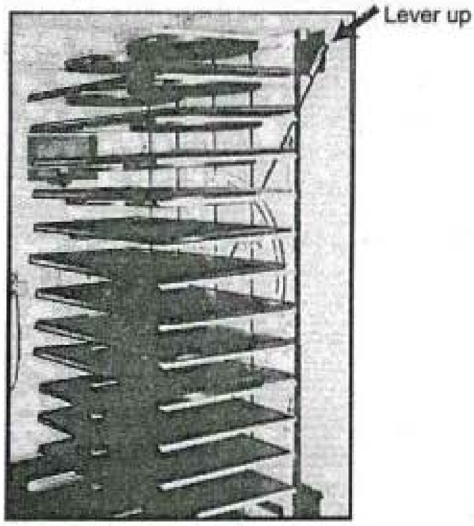

Figure 1c. The ladder system for supporting production cages (larval collecting trays in feeding position)

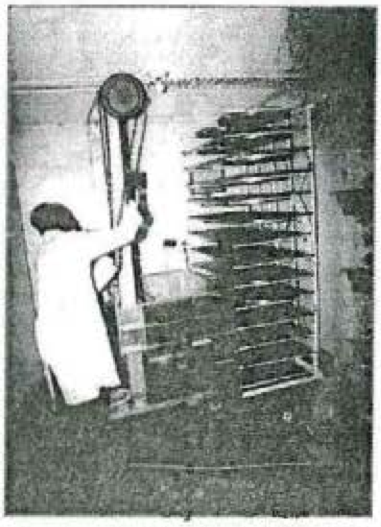

Figure 1d. The feeding trolley (height adjustment of membrane trays)

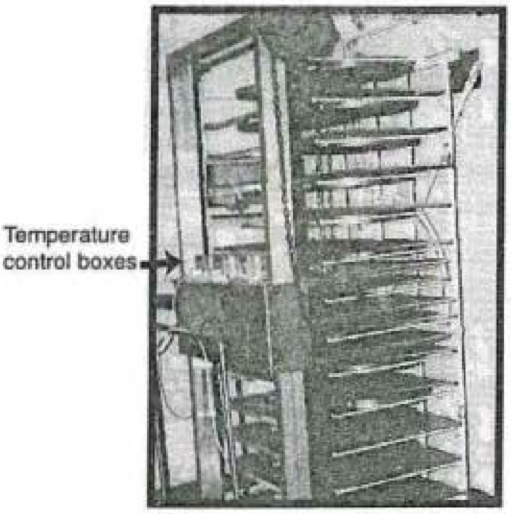

Figure 1e. The mobile trolley in feeding position. The small boxes on the left are the controls for heating the blood diet. This unit, serviced and operated by one technician, can be modified to simultaneously present blood to a large number of cages

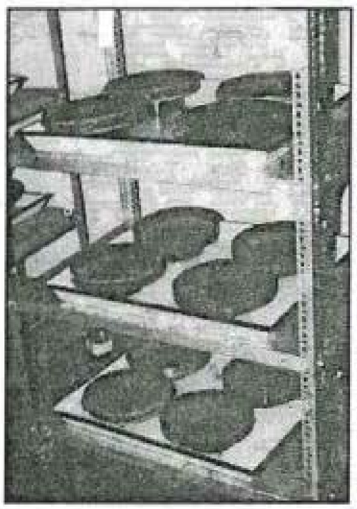

Figure 1f. A part of the tsetse self-sexing process. The females emerge first

and equipment-intensive Seibersdorf system involves transmitting multitudes of small production cages to numerous rows of stationary membrane feeding trays.

Daily average female mortality of less than 1.0% indicates a thriving, healthy colony. The laboratory-adapted Duduville *G. austeni* colony has experienced mortality ranging around the 0.5% mark. Colonies of *G. f. fuscipes*, *G. m. morsitans* and *G. m. centralis* are also maintained. Records show high performance of colonies in terms of longevity and pupal weight.

The cage cycle is 90 days, making 7 pupae per introduced female a possibility. Our colonies currently produce 4 pupae, while insemination rates exceed 90%, possibly as a result of abortions due to daily cage handling. Minor changes in the rearing protocol are being put in place to increase the birth-rate. With the introduction of the membrane trolley, a further productivity increase is anticipated for the entire 90-day cycle, since there will be no direct cage handling, following its initial placement on the ladder system. The flies will rest without disturbance, except for 5 to 10 minutes daily, or alternate-day, feeding opportunity. Seibersdorf rearing protocol requires cage turnover prior to, and following, feeding.

Other labour- and cost- saving procedures include using a weak solution of lithium carbonate at ICIPE, replacing the Seibersdorf system (batteries of energy-consuming washing machines, dryers and sterilisers). The well known asynchronous eclosion phenomenon of females followed by male flies over several days' period, has led to the development of a sexing technique used to 'self-load' in the breeding cages (Figure 1f). This places the Seibersdorf system which employs fly immobilisation by chilling for sexing and cage transfer purposes. This laborious technique takes most of the time of the rearing team. If not properly applied (e.g. over-exposure of flies to the cold or use of too-low temperature to effect quick knock-down), the chilling system, in addition to capital, energy and servicing costs, can often lead to mortality and/or sub-optimal flies.

Interruption in the supply of fresh blood could have a catastrophic effect on tsetse colonies and control programmes. A quality control test to compare the suitability of blood diet held for up to 7 days, stored under simple refrigeration conditions (+4°C) and deep frozen blood (stored at –20°C), gave the following results:

- In the event of a shortage of fresh blood, *Glossina austeni* colonies can be maintained, and experience some increase, when fed only on defibrinated porcine blood, stored at –20°C.
- Given a reliable source of fresh blood, the experiment indicates that, beyond defibrination, further treatment of the blood diet is not necessary.
- Additional evidence supports the concept of offering *G. austeni* a blood diet on alternate days as an acceptable labour and equipment saving procedure.
- In comparison with tsetse fed on diet stored at –20°C, pupae of flies fed blood stored at +4°C for a maximum of 7 days were heavier by an average of 2.32 mg.
- At day 90, female survival was 67% when fed blood diet stored at +4°C, whereas only 41% of females survived when fed blood stored at –20 °C.
- Under the range of holding room conditions, with chilled blood diet stored up to 7 days at +4°C, female tsetse could produce upto 5.8 pupae/female, which approaches their full potential over the 90-day test period under mass rearing conditions.

2. DEVELOPMENT, TESTING AND VALIDATION OF SYSTEMS TO CONTAMINATE TSETSE IN THE FIELD WITH BIOPESTICIDES FOR POPULATION SUPPRESSION

Participating scientists: *N. K. Maniania, D. J. Nadel, A. Odulaja, M. A. Okech*

Assistants: *J. Adino, E. Munyoki, J. Opere, R. O. Odhiambo and casual workers from Mfangano*

Collaborator: • *KETRI*

2.1 DEVELOPMENT OF AN OPTIMUM CONTAMINATION DEVICE (CD) FOR SELF-INFECTION OF TSETSE IN THE FIELD

An improved Cd was designed by Maniania and called the 'Maniania Cd'. The body of the device is constructed from inexpensive, locally available plastic water bottles. The bottles are divided on the long axis into two equal sections by placement of a tightly stretched nylon mosquito netting. The bottom of the lower section is lined with a velvet strip, thereby enhancing its conidia retaining properties, and a square hole (4 x 4 cm) is cut to connect the unit to the apex of the trap (Figure 2.1). A 2-cm-diameter hole made below the mouth of the bottle served as the fly exit. The underside position of the exit hole renders the design rainproof. The lower surface of the mosquito netting running the length of the bottle was also velvet-lined to enhance contamination of both the ventral and dorsal surfaces of the escaping flies.

The performance of the new Cds as protective repositories for the contaminant was tested at Rusinga Island in Lake Victoria for one month. Traps were exposed either directly to the sun or placed in shade. Dry conidiospores of *Metarhizium anisopliae* (1.3–1.6 g/Cd) were dusted on the surfaces of the velvet strips and the Cds afixed to the trap apex.

Dry conidiospores of *M. anisopliae* in the Cd exposed to the sun lost an average of 22% of their viability after 31 days, while those exposed under the shade lost an average of 40% of viability for the same period. The reason for this unexpected result warrants further investigation.

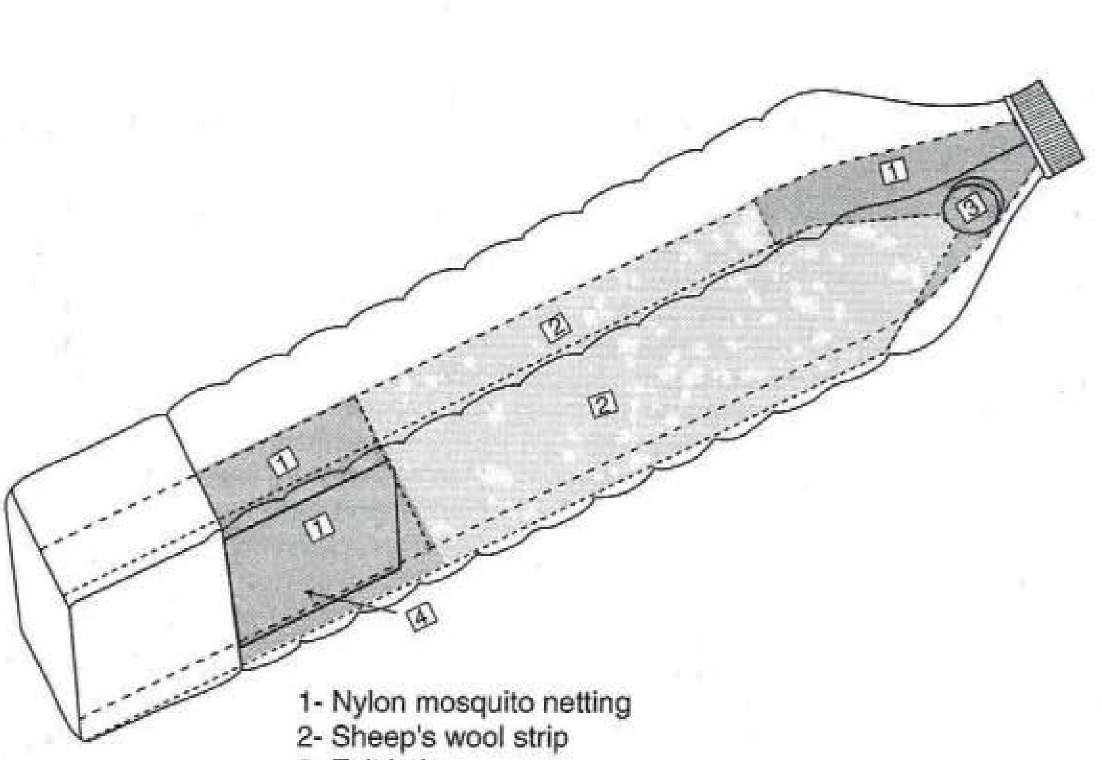

Figure 2.1. Contamination device

The loss of viability of conidiospores did not, however, affect the mortality caused by the fungus: 100% mortality at day 0, and 100 and 94% mortality at 31 days after exposure in Cds exposed to the sun and under shade, respectively.

The implication of this finding is that the improved Cds remain effective if serviced at least once a month. Longer intervals may be possible between servicing with fresh conidiospores and this possibility should be tested. Despite heavy rains recorded during the trial, the Cds remained water-free and the conidiospores formulation did not clump due to the high humidity which prevailed throughout the test. Hence, the new Cd was accepted for field suppression trials.

Passage of flies through the Cd and the number of conidia collected by tsetse were also investigated. An observer was stationed about 5 m from a biconical trap fitted with the fungus-contaminated Cd. The open end of the Cd was fitted with a cage made of white mosquito netting. The observer carefully observed a fly as it entered the Cd, and recorded the time spent by the fly to cross the Cd using a stopwatch, Jemis Quartz. The fly was immediately removed from the cage, transferred into a cryogenic tube and brought to the laboratory. Sterile distilled water (1 ml) containing 0.05% Triton X-100 was added to the tube and the tube vortexed for 2–3 minutes. The concentration of conidia was determined using a Malassez-counting chamber.

The time taken for individual flies to cross the Cd varied between 3 seconds to 5 minutes 39 seconds. About 38% flies spent between 20–60 seconds in the Cd, 19% between 3–20 seconds and 11% more than 240 seconds. The number of conidia picked up by individual flies varied from 4×10^4 to 4.9×10^6. However, there was no correlation between the time taken by flies to cross the Cd and the number of conidia picked up. For example, a fly was able to pick up 6.8×10^5 conidia after about 8 seconds, while another fly could only pick up 1.6×10^5 conidia after spending about 3 minutes in the Cd.

The minimum number of conidia picked was above the fatal limit observed in the laboratory. This suggests that a fly will be able to pick up a fatal dose of the conidia, however little time it spends in the Cd. This result is very encouraging and lends credence to the usefulness of the Cd as a medium for infecting flies under natural field conditions.

2.2 DEVELOPMENT AND VALIDATION OF A SYSTEM TO CONTAMINATE MASS-REARED TSETSE WITH BIOPESTICIDES FOR FIELD RELEASE PURPOSES

The release of mass-reared flies requires that they be infected with conidiospores and repetitively released in a given target area, perhaps on a weekly basis, by the tens of thousands. Success and sustainability of this approach relies on a simple and inexpensive methodology.

Method 1: Contamination of emerging flies was investigated using dry conidiospores of *Metarhizium anisopliae* which were mixed with sand at 1:0, 1:2 ad 1:4 v:v and used as substrate for *G. austeni* pupae. Ten mature pupae were buried in the blend and the treatment was replicated 5 times. The mortality of

100% of emerged flies was observed in all treatments. The incubation time of the disease was similar, i.e. death occurred between 3 to 10 days following emergence, whereas no deaths were recorded from control flies. In order to use less of the contaminant, the ratio of sand to conidiospores greater than 1:4 will be tested.

Method 2: The effects of placing pupae at different depths in the sand/conidiospores mixture was tested. Pupae were placed in containers and covered with a standard 1:1 mixture of sand/conidiospores to depths of 1.6 cm, 2.6 cm and 4.0 cm. Emerging flies were caged separately and mortality was recorded daily. Dead flies were placed in a moist chamber and checked for fungal growth on the surface of the cadavers. The depth of the mixture through which the flies emerged had no effect on death or infection rate as tested, and a reduction in the amount of conidiospore/sand substrate may be possible.

Given that the lethal insect technique (LIT) introduces large quantities of mass-reared flies in nature, and because some newly emerged flies may be less infected than others, the effect of fungi lodged in the head capsule on fly mortality was investigated. Mature pupae were covered with conidiospores mixed with sand at 1:1 v:v and the flies allowed to emerge. These were left undisturbed to fully expand their wings and harden the cuticle, followed by surface sterilisation. The insects, having been isolated singly in small plastic cages, were maintained at ambient temperature (23 to 26°C). The same procedure was applied to the control flies and mortality recorded.

Some of the dead flies were decapitated, the heads opened vertically and observed for the presence of conidiospores. These were collected and their ability to germinate tested. Conidiospores removed from head capsules did not germinate. However, the contaminated, subsequently washed flies died within 4–6 days, while no deaths were recorded in the treated control. Tests using an improved ptilium contamination technique are planned to elucidate this interesting discrepancy.

2.3 PRELIMINARY TSETSE SUPPRESSION TRIAL ON MFANGANO

A total of 5 Cds were deployed along the lakeshore and rivers on Mfangano Island in Lake Victoria, at a density of about 3–4 traps/km². Three pyramidal traps fitted with plastic 'trap and kill' bags were deployed on a relatively small island, Nzenze, close to Mfangano Island, giving about the same trap density and serving as the conventional 'trap and kill' population suppression method. A third nearby island, Ngodhe, remained untreated. Traps were serviced monthly and Cds emptied of loose conidia and recharged. Killing bags were also exchanged. Population monitoring was carried out on a weekly basis in all the three islands. Prior to the setting up of the experiments, samples of flies from the islands were tested for any existing fungal infection in the population, but none was found.

Catches in the monitoring traps are presented in Figure 2.3a. Populations of both female and male *G. fuscipes* in the untreated island fluctuated considerably over the experimental period, with a peak of 200 flies/trap/day at week 14. Fly populations in the 'trap and kill' treatment initially declined, rose from week 11 to reach a peak of 76 flies/trap/day at week 18. Population fluctuation was most rapid on the untreated island, but least rapid on the Cd- treated island. This probably indicates the effectiveness of the control method in maintaining a more stable low population than the conventional 'trap and kill' method. The ability to maintain a stable low

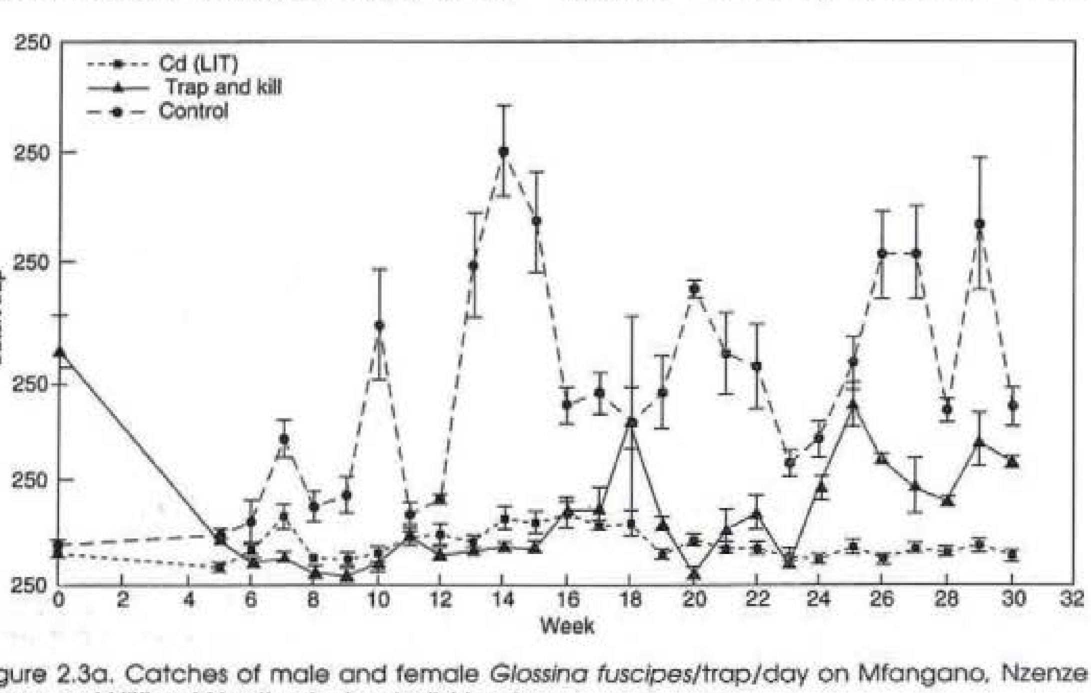

Figure 2.3a. Catches of male and female *Glossina fuscipes*/trap/day on Mfangano, Nzenze ('trap and kill') ad Ngothe (untreated) islands

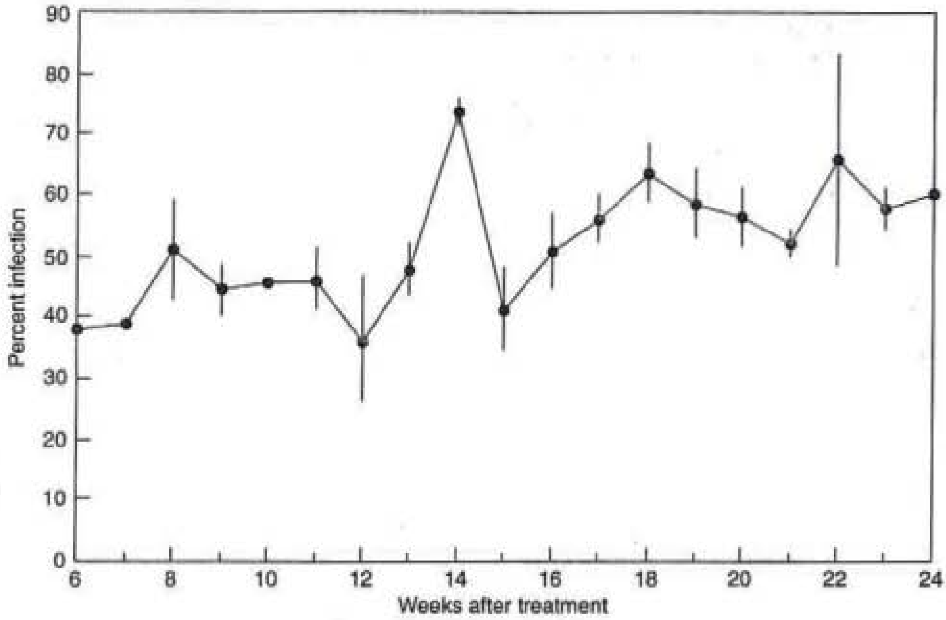

Figure 2.3b. Incidence of *Metarhizium anisopliae* in *Glossina fuscipes* at Mfangano Island during 1999 trial

population is an essential requirement of a sustainable suppression method.

The prevalence of infection by *M. anisopliae* in flies caught on the Cd-treated island is presented in Figure 2.3b. The infection rate was generally low during the first 12 weeks, reaching a peak of 74% at week 14. There is an indication of a steady increase in infection rate over time. No infected flies were found on the two other islands where the Cds were not deployed throughout the trial, ruling out any considerable migration of flies between the islands.

The tsetse population was generally on the increase in all the islands and on the mainland during this time. The low fly catch observed in the Cd areas, therefore, is an indication of the potential of the Cd system for suppression of tsetse.

The possibility of intermittent treating of a population with the Cd, coupled with its seemingly superior ability to maintain a relatively stable low population, may give the LIT an edge over the conventional 'trap and kill' method and makes it a likely focus for future work.

Output

Publications

Maniania N.K. (1998) A device for infecting adult tsetse flies, *Glossina* spp., with an entomopathogenic fungus in the field. *Biological Control* 11, 248–254.

Maniania N.K. and Odulaja A. (1998) Effect of species, age and sex of tsetse (Diptera: Glossinidae) in response to infection by *Metarhizium anisopliae* (Deuteromydetes: Moniliales). *Biocontrol* 43, 311–323.

Maniania N.K. and Nadel D.J. (1999) Tsetse's lethal path. *Biocontrol News and Information* 20, 7N–8N.

Conferences attended

Maniania N.K. and Nadel D.J. (1998) VIIth International Colloquium on Invertebrate Pathology and Microbial Control, Sapporo, 23–28 August 1998, Japan. Paper presented, 'Effect of *Metarhizium anisopliae* infection on mating behaviour of tsetse fly, *Glossina morsitans morsitans*'.

Maniania N.K. and Nadel D.J. (1999) 32nd Annual Meeting of the Society for Invertebrate Pathology. University of California at Irvine, 22–27 August 1999, USA. Paper presented, 'Prospects of the contamination device for the management of tsetse flies, *Glossina* spp.'

Maniania N.K. and Nadel D.J. (1999) 25th meeting of the International Scientific Council for Trypanosomosis Research and Control, Mombasa, 27 September–1 October, 1999, Kenya. Paper presented, 'Prospects of using entomopathogenic fungus in contamination devices for the management of tsetse flies, *Glossina* spp.'

Nadel D.J. (1999) 25th meeting of the International Scientific Council for Trypanosomosis Research and Control, Mombasa, 27 September–1 October, 1999, Kenya. Poster display, 'Simplifying tsetse rearing technology'.

Impact

The difficulties and costs which have, in the past, limited and/or delayed wide-scale tsetse release programmes have, for the most part, been overcome by employing simple, low cost and locally made equipment and simplified fly handling techniques.

Tsetse fly populations have been reduced after Cd treatment at Mfangano Island, and local fishermen report fewer bites when working on the lakeshore.

Models for Determining Tsetse Dispersal and Optimal Trap Placement

1. TSETSE FLY (DIPTERA: GLOSSINIDAE) CATCH DISTRIBUTION AND SPREAD AT NGURUMAN, KENYA

Background, approach and objectives

Movement and redistribution of insect populations are important in their dynamics. An understanding of how insect densities change in time and space is therefore significant in the design of sampling and management schemes, and in the overall study of the ecology of insect pests. In particular, determining the number and deployment of both suppression and barrier traps requires a good knowledge of invasion patterns.

To address the foregoing issues, we analysed spatial and temporal correlations in an extensive geopositioned data set of tsetse trap catches, relevant to one of the best-documented, long-term tsetse suppression exercises ever carried out—the suppression of *Glossina pallidipes* Austen and *Glossina longipennis* Corti with traps at Nguruman in Kenya. We explored the structure of these trapping data, focusing on practical issues of the patterns in catch distribution and spread during a time of population recovery, when control operations broke down at Nguruman between 1993 and 1995.

Participating scientists: *A. Odulaja*, J. Baumgärtner, S. Mihok* (*Biostatistics Unit Head)

Donor: *ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark) and EU (Tsetse project)*

Work in progress

Data used in this study was collected between May 1993 and December 1994, using NG2G traps baited with cow urine (ca 100 mg/h) and acetone (ca 150 mg/h), placed 30 cm behind the trap. Sampling was done monthly at 20 fixed sites for five to seven consecutive days in each of the 20 months. This gave 110 days and a total data set of 2200 trap-days. The distance between any two adjacent traps ranged from 786 to 2954 metres. Trap catches were collected at 24-hour intervals and then counted by sex and species. Catch/trap/day ranged between 0 and 2281 for *G. pallidipes* and between 0 and 280 for *G. longipennis* depending on the month of the year.

Trapping data for both species were transformed to the % (x+0.5) scale to stabilise variance before all analyses. Correlation coefficients between each site and every other site over all sampling days were computed. Each site was assigned to one of three locations (south, river and north). The mean correlations between and within locations were then computed from the overall correlation matrix, ignoring the correlation of each site with itself.

The distances between each pair of all sites were calculated from geo-referenced coordinates. The correlations among trap catches were linearly regressed on inter-site distances. Mean distances at which the correlations were statistically significant, or not, at the 5% level were computed to investigate whether there was a critical distance determining similarity in inter-site trap catches.

Moran's *I* index, which measures spatial autocorrelation, was used for further detailed spatial analysis.

Stepwise regression analysis was used to relate the degree of catch aggregation over months with available weather data (mean monthly maximum and minimum temperatures, and total rainfall). The squares of the weather variables and the product of temperature and rainfall were included in the set of independent variables to allow for curvilinear effects.

Higher values of similarity were evident within than between locations for both tsetse species and all three locations. Similarly, trends were consistent with a rank order of site, greater similarity both within and between locations of South > River > North. Relationships between, or within, locations were stronger for *G. pallidipes* than for *G. longipennis*.

The first principal component axis explained about 65% of the variance for both species. Together, the first two axes explained most of the variation (72%, *G. longipennis* and 78%, *G. pallidipes*), with further axes each explaining 5% or less. Most adjacent sites for *G. pallidipes* were located near each other in principal axes space, suggesting a strong relationship between patterns in trap catches at sites in close geographical proximity. This relationship was not evident for *G. longipennis*, in parallel with the generally lower within-location correlations generated in the previous analysis. In simpler terms, these results suggest that the spatial catch distribution of *G. pallidipes* is more aggregated than that of *G. longipennis*. Alternatively, the catch distribution of *G. longipennis* may be less sensitive to micro-scale conditions of habitat or climate.

The mean distances at which the correlations between sites were significant (positively or negatively), or not, at the 5% level of significance for type I error, was within about 4.8 km for *G. longipennis* and 3.9 km for *G. pallidipes*.

During the dry season, both *G. longipennis* and *G. pallidipes* aggregated in the south or near the river. Apparent density decreased towards the north and away from the escarpment towards the east. During the long rains, the aggregation point for *G. longipennis* shifted towards the river, but nearer the north, with lowest density at the south, whereas that of *G. pallidipes* moved to the extreme south. During the short rains, the catch distribution pattern of both species was nearly uniform over the entire area. These results suggest that the focal point for the spread of tsetse at Nguruman was the southwest end at the base of the escarpment.

The stepwise regression analysis selected the square of maximum temperature (partial $R^2 = 26.37\%$) and maximum temperature (partial $R^2 = 17.58\%$), as the variables that are most important in determining the degree of aggregation of *G. longipennis* catch distribution. Only maximum temperature (partial $R^2 = 19.89\%$) was selected for *G. pallidipes*. These results suggest that the catch distribution of both species of tsetse at Nguruman tend to aggregate when the maximum temperature is low or high, but is random when the between max. temperature is intermediate.

To estimate this threshold maximum temperature at which catch distribution changes from aggregation to random, we fitted a quadratic regression model, $Ia = a + bT + cT^2$, to the relationship between monthly index of aggregation, *Ia*, and maximum temperature (*T*). The model fitted poorly to the *G. pallidipes* data, but predicted a threshold maximum temperature of 32.7°C for this species and 33.3°C for *G. longipennis*. The median maximum temperatures for the dry, long rain and short rain seasons were 32.6, 35.1 and 33.5°C, respectively. The dry season period of June to September is usually accompanied by cold weather. This explains why tsetse catch distribution was more aggregated during the dry season and long rains than the short rainy season.

Our results suggest that the phenomenon of 'reinvasion' at Nguruman occurs from the southwest at the base of the escarpment when both resident and neighbouring populations increase and disperse widely during favourable conditions (the rainy seasons). Overall, it seems as if *G. pallidipes* maintains moderate levels of local sub-structuring over distances of about 5 km; there is only weak evidence for similar behaviour in *G. longipennis*. At distances of about 10 km or more, population trends can be fairly divergent, as in the northern and southern areas at Nguruman.

Studies on 'Geostatistical analysis of tsetse fly (Diptera: Glossinidae) catch distribution and spread at Nguruman, southwest Kenya', by A. Odulaja, J. Baumgärtner, S. Mihok and I.M. Abu-Zinid have been completed.

2. MODELS FOR OPTIMUM TRAPPING OF *GLOSSINA FUSCIPES FUSCIPES* IN RELATION TO DISTANCE FROM VEGETATION

Background, approach and objectives

An understanding of trappability in relation to habitat is necessary for optimal trap placement for both monitoring and suppression of fly populations. Conventional analyses of numbers or percentages of insects caught at different distances from vegetation are usually employed to obtain optimum trap placements. Typically, chi-square or ANOVA tests are used to ascertain significant differences between catches at various distances, and simple regressions used to study trends. Such analyses are only indicative; they lack the ability to predict optimum positioning and are unable to quantify the dependency of positioning on multiple factors. To address these issues, we have constructed practical mathematical models to describe a set of data on optimum trap position in relation to two vegetation types for *G. f. fuscipes* along the shores of Lake Victoria, Kenya: forests and thickets.

Participating scientists: *A. Odulaja*, M. M. Mohamed-Ahmed (*Project Leader)*

Donor: *ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark) and EU (Tsetse project)*

Work in progress

Data for this study were obtained from two locations, Mbita Point (mainland) and Rusinga Island in Lake Victoria, western Kenya. Two large forest patches, one on the mainland and the other on the island, each able to accommodate five trap sites separated by at least 200 m, were selected. Five isolated thickets, constituting five trap sites, were also selected at each of the two locations. Four experimental areas were thus obtained: mainland forest and thickets and island forest and thickets, each area having five trap sites. At each site, five trap positions were selected at specific distances from the edge of the habitat. The five positions were: (a) 1 m inside the habitat, (b) at the edge, (c), (d), and (e) 1, 5 and 10 m from the edge, respectively. An unbaited biconical trap was used for catching flies at each site. For each area, the five traps were rotated for 5 days between the 5 positions and 5 sites, in a 5 x 5 Latin square design (each 5 sites, positions and days). The experiment was repeated once in each experimental area. Traps were emptied daily.

We employed log-linear models to study the patterns of association between vegetation type, sex composition of catches and trap distance from vegetation, in relation to the number of flies caught. We started with the complete model, eliminated the non-significant terms, and concluded that vegetation type, sex composition of catches, and distance of the trap from the edge of the vegetation are conditionally dependent in relation to the trappability of *G. f. fuscipes*.

We employed the log-logistic distribution to model the trappability of the flies in relation to vegetation types. The model fitted well to all the data sets, with R^2 over 98%. The optimum distance from the forest for trapping *G. f. fuscipes* was significantly greater than zero (edge of forest) for both sexes. The results suggest that traps should be set at the exact edge of thickets to catch *G. f. fuscipes* efficiently, but set slightly away from the edge of forests at a distance between 40 cm and 1 m.

A critical parameter of trap efficiency is the radius of attraction, as this largely determines the density of traps required for population suppression. We define this radius as the distance away from the vegetation, at which the probability of catching a fly is zero or nearly so. That is, it is the z value at which the probability distribution function, $f(z)$, approaches zero. In our simulation, we set $f(z) = 0.00001$, and varied the model parameters by stepwise iteration within the asymptotic 95% confidence interval obtained when the model was fitted to each of the four data sets. We then obtained the minimum distance, r (representing the radius of attraction), at which $f(z)$ was less than, or equal to, 0.00001, for different combinations of the model's parameter values. This simulation was carried out for each sex composition of fly catches at each vegetation type.

The mean radii of attraction were not significantly different between males and females within each vegetation type, but were significantly different between the two vegetation types for each sex, being longer for the forest vegetation. After adjusting for the efficiency of the trap, the mean radius of attraction of the biconical trap was estimated to be about 18 m outside the forest vegetation, and 15 m outside the thicket.

Studies on 'Models for optimum trapping of *Glossina fuscipes fuscipes* in relation to distance from vegetation' have been completed by A. Odulaja and M.M. Mohamed-Ahmed.

(See also reports on the Biostatistics Unit and Population Ecology and Ecosystems Science Department.)

Socioeconomic Studies of Community-Based Tsetse Management Programmes

1. ASSESSMENT OF THE EFFECTIVENESS AND SUSTAINABILITY OF COMMUNITY MANAGEMENT OF TRYPANOSOMOSIS USING ODOUR-BAITED TRAPS

Background, approach and objectives

At the completion of phase 1 (1995–1997) of the IFAD-funded ILRI/ICIPE Project, the KISABE community in the Lambwe Valley in western Kenya, relying on its management skills and financial resources and using NGU traps, had lowered trypanosomosis to levels which no longer posed a threat to the lives of people and their livestock. However, three issues had not been resolved:

- It had become clear that relying on voluntary contributions from members would not be a sustainable source of financing trypanosomosis.
- Members of the community who had not participated in trypanosomosis control (free-riders) could not be excluded from enjoying the benefits of control.
- The economic analysis of the project had not been carried out, largely because of lack of personnel.

These issues formed the focus of research in the current phase of this project.

Sustainable community management of trypanosomosis using NGU traps farmers effectively perform three major tasks: management of the organisation, mobilisation and control of required resources, and trap deployment. Effective performance of these tasks brings about several impacts, but research has focused on five of these, namely:

(i) changes in tsetse population and trypanosome infection,
(ii) reduction in trypanosome infection of cattle,
(iii) improvement in cattle productivity,
(iv) human welfare,
(v) application by the community of the acquired knowledge and management skills to solve other problems in an upward spiral of development processes.

Assessment of the performance of community management of trypanosomosis and its impacts has taken three new turns:

- A quantitative approach, previously restricted to resource mobilisation and trap deployment, has been applied to the management of the organisation to incorporate the labour/time budgets of management into the overall estimation of the costs and benefits of the technology.
- Monitoring the community's effort to integrate income generating activities (IGAs) into trypanosomosis control in order to put in place reliable and sustainable sources of finance for trapping activities.
- Monitoring how the community is grappling with a problem inherent to public good technologies. Unlike the case of private good technologies in which the individual invests and reaps the benefits directly, investment in public good technologies, more so, tsetse control by means of trapping technology, is only viable if undertaken within the framework of collective action. A corollary of this is the principle of inexcludability, that is, individuals (free-riders), who do not invest in public good technologies cannot be excluded from enjoying the benefits.

  We hypothesised that the integration of IGAs into tsetse control not only provides incentives to free riders to participate in trypanosomosis control, it also marks the movement by the community to the second level of upward spiral development.

To achieve this objective, we operationalised participation into 19 different activities (dependent variables) and grouped them under four clusters as follows:

(a) **Management of the organisation:** (i) participatory decision-making, (ii) performance of regular and ad hoc roles, (iii) capacity building, (iv) presentation of the organisation's work, and (v) voting.
(b) **Mobilisation and control of resources:** (i) contributing funds, (ii) controlling funds, (iii) raising funds, (iv) provision of premises, and (v)

participation in income-generating activities (IGAs) to finance trapping.

(c) **Performance of trap deployment tasks:** (i) organisation of trap work, (ii) construction of traps, (iii) placement of traps, and (iv) servicing traps.

(d) **Impact assessment:** (i) keeping the sentinel herd, (ii) recording productivity data, (iii) monitoring tsetse population, (iv) monitoring trypanosomosis, and (v) monitoring land-use changes.

We hypothesised that the performance of these activities is influenced by the following nine independent variables: (i) gender, (ii) training, (iii) knowledge of tsetse and trypanosomosis, (iv) adequate skills in trap deployment, (v) rearing livestock, (vi) distance from the reservoir of tsetse, (vii) realisation of the benefits of control, (viii) incentives for promoting participation, and (ix) group dynamics. Complementary qualitative and quantitative methods were used to determine the relationships among the independent and dependent variables.

Participating scientist: *J.W. Ssennyonga (Project Leader)*

Assistants: *M. Ayugi, S. Akinyi, J. M. Muchiri*

Donor: *IFAD*

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

Work in progress

1.1 MANAGEMENT OF THE ORGANISATION

A reliable indicator of management effectiveness is the record and content of meetings, because most of the planning, coordination, control and information management activities are performed and reported in these meetings. Altogether 111 meetings were held, 52.3% by the overarching committee, KISABE and 47.7 % by the 15 Blocks, (lower level constituent units), each comprising 2–5 villages. KISABE had an average of 2.4 meetings per month, compared to 2.2 meetings a year for Blocks. The difference is partly due to the fact that most of the resource mobilisation activities and the organisation of elections was done at the KISABE level, and partly due to weaknesses in Block organisation.

Information was also generated on two important indicators of participatory decision-making: (a) the number and frequency with which important issues were discussed, and (b) the number of times individuals were able to make contributions during meetings. With regard to issues discussed, all the major control activities were discussed, namely management of the organisation (44.3%), finance and physical resources (42.3%), trapping (11.3%) and productivity assessment (2.1%). The extent of participatory decision - making is reflected in the following results: 19.2% spoke once, 30.6% spoke twice, while 26.5 and 12.8 % spoke three and four times, respectively in each meeting.

Two indicators of the capacity for self-renewal deserve mention:

- Elections were held in 1999 at the 15 Blocks and KISABE, in which virtually new teams were elected, albeit after two abortive attempts and bargaining among Blocks.
- It is also worth noting that trapping requires relatively high levels of scientific, technical and organisational knowledge and skills. At the same time, new leaders are elected and new members join the organisation. KISABE has therefore to organise periodic training workshops for its members. In this regard, 10 members trained 30 people (18 men and 12 women) in trap deployment. In addition, 18 members (15 men and 3 women) were also trained in the husbandry of mulberry (for silkworm rearing). The 10 trainers had attended a short course at ICIPE headquarters in 1997.

Finally, management effectiveness was shown in the way KISABE resolved two major conflicts: In December 1997 the KISABE chairman resigned his position and contested one of the positions of Councillor in the District Urban Council on an unpopular party ticket and lost. His attempt to regain the chairmanship created lineage-based wrangles with accusations, including embezzlement of funds, being levelled against his management. A disciplinary committee exonerated him of corruption but recommended fresh elections of KISABE leadership which was effected in May 1998. The second conflict over the choice of the site for the proposed Farmers' Resource Centre escalated, causing the cancellation of the annual elections in 1999 on two occasions, before being held in August and bringing in younger leaders.

1.2 MOBILISATION AND CONTROL OF RESOURCES (MCR)

The major objectives were to determine: (a) the organisation's capability for mobilising the required resources on a reliable and sustainable basis, and (b) the technical efficiency in controlling the resources. In this respect, four kinds of resources were monitored, namely funds, labour and time, construction of a Farmers' Resource Centre (FRC), and the incorporation of income generating activities (IGAs) into trypanosomosis control activities. Results reveal five major features:

(a) The amount shown for 1999 is provisional, because some Blocks have not yet given their returns for the year.

(b) On aggregate, income in 1998 was almost three times (2.8) more than what it was in 1999, the difference being mainly due to the large contribution in 1998 from the District Veterinary office of two bicycles and trap materials worth Kshs. 54,000 (see Table 1.2)

(c) The figures show greater self reliance in 1999, reflected in the fact that donations accounted for only 13% of income, compared to 82% in 1999.

(d) The percentage share and absolute amounts raised from registration and homestead capitation, rose appreciably in 1999, due mainly to the inauguration of IGAs in the last quarter of the year.

(e) IGAs are having a positive effect on the capacity for financial mobilisation. The blocks are raising collateral funds to qualify for the UNDP/ILO credit.

Table 1.2. Amount of money raised by source and percentage share by the KISABE community

	Amount (Kshs)		Percentage	
Source	1998	1999	1998	1999
Registration fees	510	2,790	0.8	11.9
Homestead capitation	70	4,110	0.1	17.5
Fund raising	11,691	13,462	17.6	57.4
Donations by non-members	54,000	3,100	81.5	13.2
Total	66,271 (US$ 933)	23,462 (US$ 330)*	100	100

*1 US$= Kshs 71.1.

1.3 INCOME-GENERATING ACTIVITIES

The community has wholly financed the control of trypanosomosis but it has become increasingly doubtful whether the strategies used (mainly soliciting of funds from individuals), are sustainable. A complementary approach has been adopted through the introduction of three integrated IGAs: apiculture, sericulture and sunflower oilseed processing. The community realised that the tsetse reservoir is suitable for beekeeping, where farmers integrate it into trapping activities. It is estimated that one apiary comprising four beehives will generate an income of US$ 160 at a cost of US$ 200 in the first harvest. Income will rise by a factor of 1.5 in subsequent harvests. Sunflower, through flowering, serves well the objectives of beekeeping and if processed, provides nutritional products for people (edible oil) and livestock (feed). The community produces 0.5 million kg of sunflower annually and it is estimated that a manually-operated oilseed press will generate an annual income of US$ 6954.0 at a cost of US$ 4690.0, yielding a net profit of US$ 2265.0 (48.3%). IGAs will also have multiplier effect in the livestock sector and overall economy.

1.4 TRAP DEPLOYMENT

Four types of data on trap deployment were collected: (a) organisation of trap work, (b) number of traps constructed, placed and serviced, (c) physical condition of traps, and (d) labour budgets. Following the devolution of the responsibility for trap deployment upon the Blocks in 1997, individual Blocks were each assigned a number of traps in a contiguous section of the control zone. Blocks were divided into Group A comprising nine Blocks which are responsible for traps in Nyaboro thicket and Group B consisting of six Blocks which are responsible for traps along Ruma National Game Park (RNGP). Each Block has 6–8 trap managers who organise trap work under the overall supervision of the KISABE senior trap manager.

Trap deployment activities decreased in 1999; the total number deployed declined from 96 in 1998 to 55 in 1999. Similarly, the total labour budget (TLB) fell sharply from 2516 hours contributed by 116 individuals in 1998 to 857 hours contributed by 89 farmers in 1999. The decline was due to increased cultivation in Nyaboro thicket, vandalism and wrangles in the first half of 1999. Just under a third of the traps were in good condition, requiring no repair work whatsoever. Approximately 28.4% of traps had various parts repaired, 32.8% had parts replaced, 7.5% were removed and 10% were inaccessible due to flooding. Clearance of the vegetation was carried out at 21.3 % of trap sites. On the whole, therefore, trap deployment was lower in 1999 than in 1998.

The revival of participation in the activities of the organisation after the elections in August 1999, coupled with the prospect of earning an income from IGAs are likely to improve trap deployment in the coming year.

1.5 FACTORS INFLUENCING PARTICIPATION

The foregoing focused on the group KISABE/Block as the unit of analysis. In order to determine the factors influencing participation, we also adopted the individual as the unit analysis. This entailed the identification of 9 factors influencing participation (independent variables). The search for variables that contributed to community participation was carried out by various analytical procedures, including multiple regression using stepwise selection. Altogether 771 and 426 different individuals participated in the various activities in 1998 and 1999, respectively. The total number of individuals who participated in any one activity varied widely.

The information on each of the factors which influence participation also varies widely. The gender of all the participants was recorded and only a small proportion (20%) received the intensive training in

Table 1.5. Regression analysis of the relationships between selected activities and factors influencing them

Variable	Time on trap work		Time on KISABE+ meetings		Time on Block meetings	
	B. coefficient	P. value	B. coefficient	P. value	B. coefficient	P. value
Block	1.11	0.200	0.637	0.530	0.564	0.099
Zone	6.98	0.391	5.514	0.498	0.224	0.933
Gender	16.00	0.052	20.140	0.016	3.923	0.141
Age	0.36	0.378	0.410	0.302	0.044	0.734
Education	0.77	0.525	0.719	0.524	1.003	0.011
Training (biol./ trap'ng)	31.39	0.058	3.182	0.859	2.824	0.634
Training (manag'nt)	3.97	0.624	14.054	0.081	5.227	0.052
Experience of tryps.	14.33	0.408	18.308	0.124	0.819	0.832
Keeping livestock	11.08	0.443	5.073	0.738	0.752	0.881

+KISABE is the central committee coordinating Block activities.

Table 1.6. Allocation of time in percentage shares to the major trypanosomosis control activities by gender and zone

Category of farmers	Management of the organisation	Mobilisation and control of resources	Trap deployment	Total
Total sample	59.0	7.1	33.9	100.00+
LCZ	46.4	69.6	26.0	40.9
HCZ	53.6	30.4	74.0	59.1
Males	65.2	87.8	57.5	64.0
Females	34.8	12.2	42.5	36.0

+N = 2527 hours.

tsetse and trypanosomosis. The recorded number of livestock keepers in 1999 was 145 (34%). This variability is not only due to arbitrarily choosing activities, but also due to the fact that members who joined the organisation in the last quarter of the year had limited opportunity to participate in most of the activities. Moreover, some activities such as book keeping can only be performed by a small number of people. These factors created problems of data analysis, but some interesting results were obtained: Results obtained in 1998 show that training in management has a strong positive effect on time spent on meetings but not on trap work. Gender has a strong positive effect on both time spent on KISABE meetings and trap work (Table 1.5). More work still needs to be done on data analysis.

1.6 ECONOMIC ANALYSIS

Data has been collected on livestock productivity and labour/time budgets (LTB) of the various trypanosomosis control activities. Data collected in 1999 reveal not only zonal and gender differences, but also the importance of examining issues from both group and individual perspectives. Aggregately men contribute 64% of the total LTB, compared to 34% for women (Table 1.6). Mean number of hours contributed by women (14.3) to trap work is far higher than that for men (8). Women also have a higher mean LTB (12.7) for management of the organisation (MO) than that of men (9.0).

2. ASSESSMENT OF THE IMPACT OF TSETSE CONTROL ON CATTLE HEALTH AND PRODUCTIVITY IN LAMBWE VALLEY, W. KENYA

Background, approach and objectives

Tsetse and trypanosomosis, affecting both humans and livestock in the Lambwe Valley, western Kenya, has resisted all conventional control methods. However, an innovative, alternative community-based approach proved effective in managing tsetse and trypanosomosis. The KISABE community, relying on its own financial and management resources, used a low-cost, NGU tsetse trap developed by ICIPE to suppress tsetse populations by 99.9 %, leading to the reduction of the trypanosomosis challenge from 200 in 1993 to nil in 1997, a level which no longer poses a threat to the lives of people and livestock.

Assessment of the impact of trypanosomosis control has therefore been one of the major components of the ODA/IFAD - funded project. Productivity data has been collected from:

(a) A sentinel herd of 60 head of cattle distributed to 15 farmers, 4 each. The farmers were also selected on a ratio of one farmer per block in the study area.

(b) Cattle (190) belonging to the same 15 farmers. Data were collected on liveweight gain (LWG) (monthly in 1993–1996 and thereafter bimonthly), daily milk-offtake, calving, deaths, morbidity and cost of treatment of sick animals.

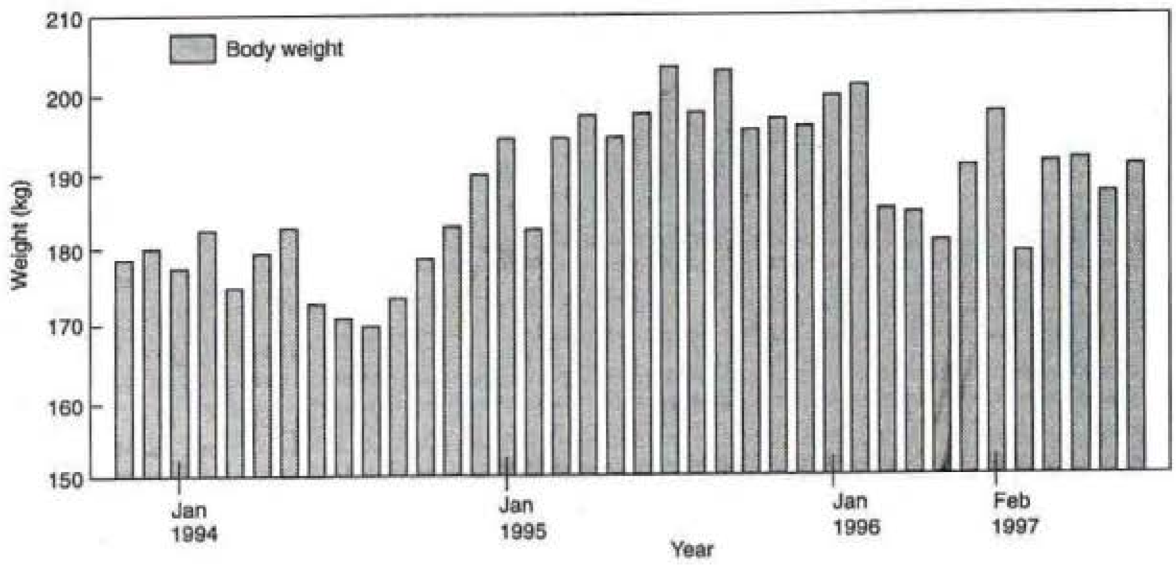

Figure 2a. Mean adult cattle liveweight gain (kg) Lambwe Valley

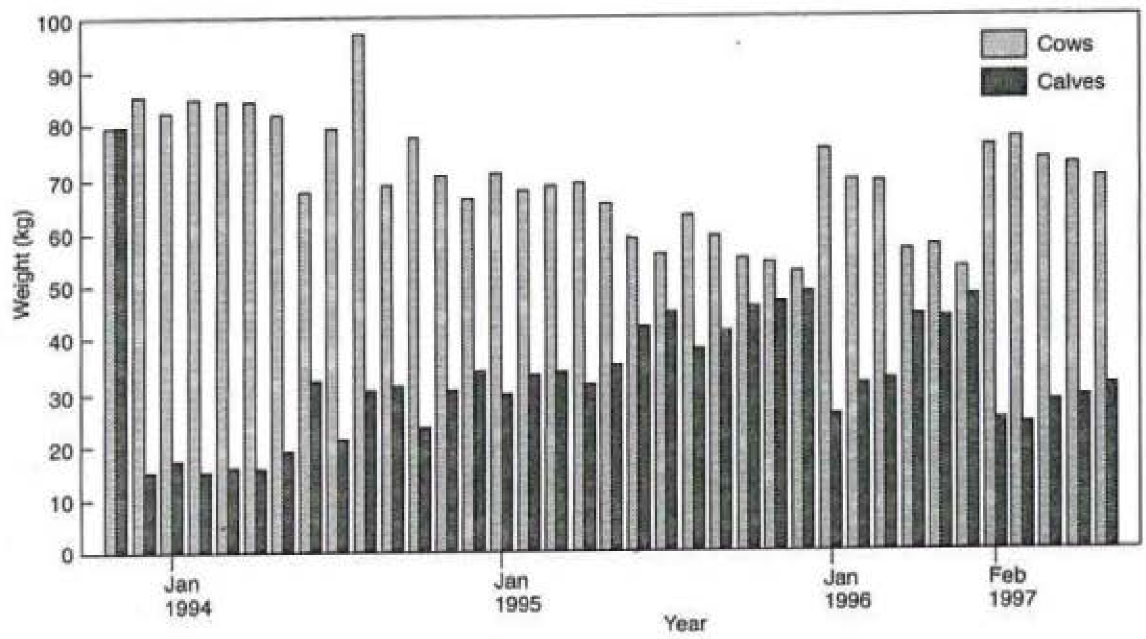

Figure 2b. Cow/calf ratios of sentinel and farmers' cattle in 15 farms, Lambwe Valley

Participating scientists: *J. W. Ssennyonga*, J. Katz (ILRI), J. McDermott (ILRI), D. G. Ochieng (MOALDM)*
*(*Project Leader)*

Assistants: *S. Akinyi, M. Ayugi, J. M. Muchiri*

Donors: *ODA (1992–1996), IFAD (1995–1999)*

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

Work in progress

Overall, small but significant gains were recorded, especially in the LWG of adult cattle (Figure 2a) and fertility measured in cow/calf ratios (Figure 2b). The major reason for the low productivity gains is the endemicity of several debilitating diseases (tick-borne diseases, helminthiasis, anthrax etc.), compounded by poor nutrition.

Future work

Changes in the methods of data collection were undertaken following the preliminary data analysis now nearing completion. There has been a shift from a herd-based focus to an individual animal-based data collection and management. The continuation of the assessment of livestock productivity is therefore required, to enable researchers collect adequate data using the new methodology. More importantly, the long gestation nature of the Zebu cattle under the experiment, makes it necessary to monitor productivity for at least 8 years (1993–2001). Finally, it is worth noting that Lambwe Valley is the only place where ICIPE has undertaken a systematic assessment of the impact of tsetse control on cattle productivity.

Outputs

Publications

Ssennyonga J. W., Katz J., McDermott J. and Ochieng D. G. (1998) Impact of tsetse control on cattle health and productivity in the Lambwe Valley, W. Kenya. Technical report. ICIPE Library.

Ssennyonga J. W., Wawire N., Ayugi M. and Tumba R. (In Press)Developing a methodology for evaluating community participation in the management of tsetse and trypanosomosis (in press). *Proceedings of the 25th Meeting of the International Scientific Council on Trypanosomosis Research and Control*, Mombasa, Kenya 27 September–1 October 1999.

Conferences attended

Ssennyonga J. W. (1998) End of project review of IFAD-funded ICIPE/ILRI Project Phase 1, 1995–1997, ILRI Headquarters, Nairobi, 19–23 January 1998. Paper presented, 'Results and achievements of community management of trypanosomosis using odour-baited traps in the Lambwe Valley, W. Kenya'.

Ssennyonga J. W. (1999) The 25th Meeting of the International Scientific Council on Trypanosomosis Research and Control, Mombasa, Kenya 27 September–1 October 1999. Paper presented, 'Developing a methodology for evaluating community participation in the management of tsetse and trypanosomosis'.

Proposals written

Strengthening Community Capacity for Integrating Trypanosomosis Control into Income Generating Enterprises in the Lambwe Valley. Donor: UNDP. Collaborators: ILO, APROTECH (NGO) and MOALDM, Kenya.

Developing a methodology for evaluating community participation in the management of tsetse and trypanosomosis. Under consideration for funding by EU. Collaborators: MOALDM and EU.

Strengthening Community Capacity for Integrating Trypanosomosis Control into Income Generating Enterprises in East Africa . Under consideration for funding by EU. Collaborators: MOALDM (Kenya), Ministry of Agriculture Livestock Development and Fisheries, Uganda, and EU.

Capacity building

Three Kenyan MOALDM veterinary officers are attached to this project on a part-time basis to train in community management of trypanosomosis using odour-baited traps.

Impact

Three KISABE community leaders participated in developing two projects designed to enable the community to create reliable sources of funding for trypanosomosis control.

ANIMAL HEALTH RESEARCH

ANIMAL HEALTH MANAGMENT

TICKS

Global losses due to ticks and tick-borne diseases (T&TBDs) are estimated at US$ 13.9–18.7 billion annually, with over 800 million cattle being continuously exposed to T&TBDs. In Africa, T&TBDs are considered to be one of the most important animal disease problems. The major TBDs of livestock are theileriosis (transmitted by *Rhipicephalus* spp.), heartwater (transmitted by *Amblyomma* spp.), and babesiosis and anaplasmosis (transmitted by *Boophilus* spp.). Morbidity and mortality due to theileriosis and heartwater in certain breeds of susceptible animals (especially exotic and cross-bred), can approach 100%. TBDs also severely impair the growth of calves of indigenous cattle breeds. Apart from TBDs, tick infestation causes severe economic losses through a reduction in weight, milk yield and fertility. Other losses arise from lack of draught power, damage to hides and skins and predisposition of livestock to bacterial diseases. Economic losses due to theileriosis alone in eastern, central and southern Africa have been estimated at US$ 168 million, including an annual mortality of 1.1 million cattle. T&TBDs are the major factor restricting the introduction of high-yielding exotic breeds of cattle into Africa.

Control of ticks currently relies on the use of inorganic acaricides. However, the widespread use of these chemicals has led to many ecological, medical and financial problems, including the high cost of acaricides (paid in foreign currency), acaricide resistance and contamination of the environment and food with toxic residues. Tanzania and Uganda, for instance, each spend US$ 26 million annually on the importation of acaricides. Ticks develop resistance rapidly, sometimes within 18 months, and there is no acaricide group to which ticks are not at least partially resistant, including the recently introduced synthetic pyrethroids.

Attention is increasingly turning to the use of alternative control strategies which may be used in lieu of acaricides or as part of an integrated vector/disease management system which will reduce the need for synthetic chemicals. To address these problems, the Livestock Ticks Research Programme at ICIPE has been undertaking research aimed at developing sustainable methods for integrated tick management.

A calf ear heavily infested with *Rhipicephalus appendiculatus* ticks, the vector of theileriosis

Animal Health Division

TICKS

Sustainable Methods for Integrated Tick Management

Background, approach and objectives

In the review period, research focused mainly on testing the potentials of botanicals (neem), entomogenous fungi (*Beauveria bassiana* and *Metarhizium anisopliae*) and development of an anti-tick vaccine, as well as studies on tick population genetics. It targeted the three major ticks of Africa, namely *Amblyomma variegatum*, *Rhipicephalus appendiculatus* and *Boophilus decoloratus*.

1. TESTING THE EFFICACY OF AQUEOUS FUNGAL FORMULATIONS IN SUPPRESSING TICK POPULATIONS IN THE FIELD AT KUJA RIVER

Participating scientists: G. P. Kaaya*, S. M. Hassan
(*Project Leader)

Assistants: E. Ouna, J. Odhiambo

Donor: ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark), Finland

Work in progress

The strains of *Beauveria bassiana* and *Metarhizium anisopliae* used were originally isolated from ticks naturally infected in Rusinga Island and confirmed to be pathogenic to ticks in potted grass (*ICIPE 1995–1997 Annual Scientific Report*, pp. 160–161). The fungi were tested on ticks at ICIPE's Kuja River field site. The control paddocks were sprayed with water. Spraying commenced in December 1997 and continued till July 1998.

During the El Nino rains (December 1997 to March 1998), tick populations were generally low, irrespective of treatment. However, from April to July 1998 when the rains subsided, tick populations, especially in the control paddocks, increased. Despite fluctuations, tick populations in the control paddock

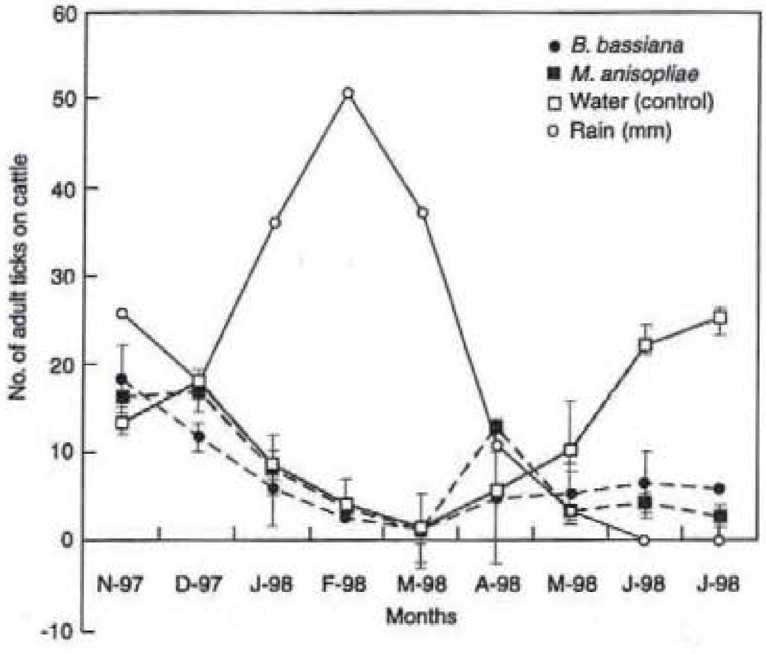

Figure 1. Numbers of adult ticks (*R. appendiculatus*) on 5 cattle in pastures sprayed monthly with *B. bassiana*, *M. anisopliae* (10^8 conidia/ml water) and water (control). Rainfall in mm is also shown

were higher than those in the paddocks sprayed once per month with fungus. In adult *R. appendiculatus*, for instance, there was a significant reduction in tick populations on cattle in those paddocks sprayed with *B. bassiana* and *M. anisopliae*, compared to the control paddocks from May to July 1998 (Figure 1). In paddocks sprayed once every 2 months, no significant reduction was observed.

The populations of adult, larvae and nymphs of *A. variegatum* and *R. appendiculatus* were higher in control than in experimental paddocks. Adult *R. appendiculatus* exhibited the highest level of suppression. Populations of off-host ticks were very low, often zero throughout the experimental period.

Despite using a fairly low concentration of conidia (10^8/ml instead 10^9), the fungi suppressed populations of *R. appendiculatus* on cattle when applied at a frequency of once per month. In future experiments, a higher concentration of 10^9 conidia/ml will be tested at the same frequency of application and at a higher frequency of once per fortnight. Oil formulations will also be tested at high and at ultra-low volume (ULV) applications.

2. EFFECTS OF A NEW FUNGAL OIL FORMULATION ON *RHIPICEPHALUS APPENDICULATUS* IN POTTED GRASS

Participating scientist: *G. P. Kaaya (Project Leader)*

Assistant: *J. K. Njenga (student, Moi University)*

Donor: *ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark)*

Work in progress

Conidia of *Beauveria bassiana* and *Metarhizium anisopliae* (Rusinga isolates) were suspended in a mixture of 20% peanut oil, 79% kerosene oil and 1% Tween-80 at a final concentration of 10^9 conidia/ml. Tick larvae, nymphs and adults were immersed in conidial suspensions (see *1995–1997 ICIPE Annual Scientific Report*, p. 160). Controls were immersed in a similar mixture without fungal conidia. This experiment was done as a preliminary to a field study that will be conducted later in the field.

Both *B. bassiana* and *M. anisopliae* in this formulation were found to induce high mortalities, but *B. bassiana* was more effective. Control mortalities were adults (11%), nymphs (19%) and larvae (14%). The corresponding results for *B. bassiana* were 82, 87 and 81% and those for *M. anisopliae* were 68, 77 and 67%, respectively. This oil formulation is effective in killing all life stages of *R. appendiculatus* and may therefore have potential for tick control in the field.

The oil formulation was sprayed fortnightly on tick-infested paddocks at Kuja River using ultra-low volume (ULV) application sprayers. Tick sampling was done fortnightly in vegetation and on cattle, prior to and during spraying, for a period of 6 months. The results obtained in this study were discouraging and no clear difference in tick populations was observed between the control and experimental paddocks. Samples of ticks collected from the field and incubated at high humidity also showed very low mortality due to mycosis. A high volume application regime should be tested.

3. GERMINATION OF FUNGAL SPORES IN DIFFERENT CARRIERS

Background, approach and objectives

Previous research conducted at ICIPE showed the potential of fungal isolates of *Metarhizium anisopliae* (Rusinga/RA/MA/GPK) and *Beauveria bassiana* (Rusinga/RA/BB/GPK) for tick control. The objective of this study was to find a suitable carrier that can be used to formulate, store and deliver fungal spore formulations.

Participating scientists: *E.O. Osir, E.U. Kenya, O. Odulaja*

Work in progress

Spores obtained from 2-week-old cultures of *M. anisopliae* and *B. bassiana* were suspended in 7 carriers: glycerol, paraffin, 1% Tween-20, 1% Tx-100, corn oil, peanut oil and water (control). Final spore concentration was 3×10^6. Spore germination was monitored before incubation (28° C, 80% RH) in the carriers and after 24 hours and 1 week incubation periods.

The germination of *M. anisopliae* spores after 1 week incubation in the carriers is shown in Figure 3. Statistical analysis showed that the two isolates were not significantly different ($P > 0.05$) in spore germination rates in the different carriers. However, the carriers affected spore viability at significantly different levels ($P < 0.001$).

The choice of carriers for fungal spore germination is crucial, as monitoring spore viability in formulations is of primary importance. Effects on viability after longer periods of incubation in selected carriers should be studied, while still searching for a cheaper medium that can be used on a commercial scale.

4. EVALUATION OF THE TICK CONTROL POTENTIAL OF *BEAUVERIA BASSIANA* AND *METARHIZIUM ANISOPLIAE* IN DEVICES BAITED WITH ATTRACTION-AGGREGATION-ATTACHMENT PHEROMONE (AAAP) FOR *AMBLYOMMA VARIEGATUM*

Background, approach and objectives

Studies were initiated on the potential of the fungi *Beauveria bassiana* and *Metarhizium anisopliae* in combination with the attraction-aggregation-attachment pheromone (AAAP), for the control of *A. variegatum*. The objectives of the study were: (1) to

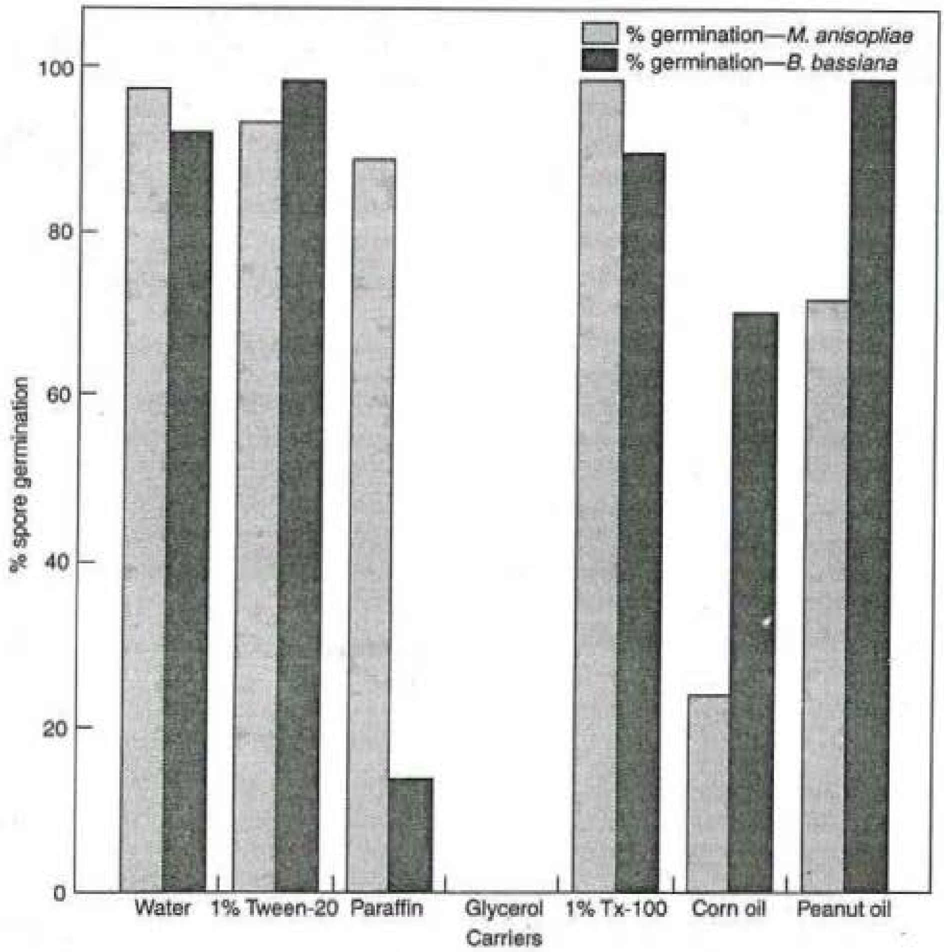

Figure 3. Germination of fungal spores incubated in different carriers for 7 days

determine the range of perception of the optimal dose of the pheromone combined with dry ice (CO_2) in the field; (2) to investigate if there were any synergistic or additive lethal effects of *B. bassiana* and *M. anisopliae* on *A. variegatum* , and (3) to develop and test a device for pheromone delivery and infection of ticks with the fungi.

Participating scientists: *R. O. Maranga, G. P. Kaaya, A. Hassanali** *(*Project Leader)*

Collaborators: *Kenyatta University (Prof. J. M. Mueke)*

Donors: *DAAD and ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark)*

Work in progress

Two- to 3-month old adult ticks (*A. variegatum*) marked with artist's paint were released from distances of 1, 2, 3, 4, 5 and 6 m in different circular plots containing AAAP, AAAP plus CO_2, paraffin oil, and CO_2 alone at Mbita Point Field Station in South Nyanza. Some ticks were treated with various concentrations of the oil and water formulation of the fungi and controls were treated with distilled water.

When AAAP alone was used, an AAAP dose of 6.6 mg attracted the highest number of adult ticks in the field from a distance of 4 m. High soil temperature ranges, 31–52 °C were found to reduce the attraction of ticks to the AAAP.

The oil formulations of each fungus and cocktails of fungi (1×10^8 spores/ml) caused .higher tick mortalities (almost 100%) in the laboratory and water formulations induced less than 25%, even at higher fungal concentrations. Tick mortalities were higher during the wet season (92%) compared to the dry season when the highest mortality recorded was only 30% and these results were significantly different at the 5% level. The fungal cocktail (*B. bassiana* plus *M. anisopliae*) caused significantly higher tick mortalities compared to each fungus separately. Tick mortality increased with increasing fungal concentrations and the highest mortality was obtained with a concentration of 1×10^{11} spores/ml in the field, while in the laboratory 100% tick mortality was obtained with a fungal concentration of 1×10^8 spores/ml.

A special 2-storey tick pheromone-pathogen trap was designed that avoided direct contact between the pheromone and the fungal formulation. Such contact was shown to affect the viability of the fungal spores.

Results from field experiments (Table 4a) showed clearly that most of the ticks that were attracted to pheromone traps baited with the oil formulation of the fungi were successfully infected and eventually died. In another experiment, the ticks were not

Table 4a. Mean percentage numbers (± SE) of *Amblyomma variegatum* killed due to infections caused by the mixture of *Beauveria bassiana* and *Metarhizium anisopliae* in the presence of the attraction-aggregation-attachment pheromone (AAAP) 3 weeks after field exposure to the fungi in traps

Treatment	Mean % number of ticks	
	Attracted	Killed
AAAP + CO_2 + fungi (oil formulation)	79.0 ± 1.4 a*	77.8 ± 1.3 a
AAAP + CO_2 + oil formulation (-fungi)	85.0 ± 3.7 a	1.0 ± 0.30 b
AAAP + CO_2 + distilled water	83.0 ± 2.2 a	0.67 ± 0.22 b
AAAP + CO_2	86.0 ± 3.3 a	0.08 ± 0.08 b

*Means within the same column followed by the same letter are not significantly different at the 5% level based on the SNK test.

collected for incubation in the laboratory. Instead, after 3 weeks the experimental plots were sampled with pheromone traps. In plots that had been exposed to pheromone traps baited with fungi, significantly fewer ticks were recovered compared to control plots (Table 4b). The results show some promise in the deployment of baited traps in off-host control of *A. variegatum*.

Further optimisation of the technology is in hand.

Table 4b. Mean percentage numbers (± SE) of *Amblyomma variegatum* recovered 3 weeks after setting the pathogen-baited pheromone traps in the paddocks

Treatment	Mean % number of ticks recovered
AAAP + CO_2 + fungi (oil formulation)	33.8 ± 9.9 b*
AAAP + CO_2 + oil formulation (-fungi)	76.3 ± 2.0 a
AAAP + CO_2 + distilled water	80.4 ± 4.0 a
AAAP + CO_2	84.8 ± 2.6 a
None	83.8 ± 2.6 a

*Means within the same column followed by the same letter are not significantly different at the 5% level based on the SNK test.

5. EVALUATION OF THE POTENTIAL OF BOTANICAL EXTRACTS FOR TICK CONTROL

Background, approach and objectives

Previous work at ICIPE has shown that neem oil deters attachment of larvae of *R. appendiculatus*, *A. variegatum* and *B. decoloratus* to host animals. In *B. decoloratus*, it was also found to reduce larval engorgement, larval moulting, nymphal moulting, egg mass and viability of eggs (*1995–1997, ICIPE Annual Scientific Report*, pp. 165–167). In 1998, two neem products were tested: (a) neem seed powder taken orally and (b) Neemroc-Combi (0.5%).

Participating scientist: *G. P. Kaaya (Project Leader)*

Assistants: *M. Kimondo (Technician), J. Nalianya (Student, Moi University), J. Karimi (Student, Eldoret Polytechnic)*

Donor: *ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark)*

Work in progress

5.1 EVALUATION OF EFFECTS OF INGESTED NEEM SEED POWDER ON TICK ATTACHMENT, FEEDING AND REPRODUCTION

Neem seed powder was mixed with rabbit pellets to a concentration of 6.25 and 12.50% and fed to goats daily for 4 weeks, in addition to green grass and shrubs *ad libitum*. Control goats were fed on rabbit pellets, green grass and shrubs only. Larvae, nymphs and adults of *R. appendiculatus* were attached to the goats after the goats had fed on that diet for one week. In another experiment, when goats were fed on the same diet, but containing a higher concentration of neem seed powder (25%), larvae of *B. decoloratus* and nymphs and adults of *R. appendiculatus* attached.

About 50% of the larvae attached successfully on control goats and only 3.25% attached on the goats fed on neem seed powder. In nymphs of *R. appendiculatus* fed on the same group of goats, mortality was 82% (control 1.5%) and in adults 50% (control 28%). Moulting in nymphs was also reduced, as was oviposition in adults. In adult *R. appendiculatus*, a significant reduction in egg hatchability was observed in eggs produced by goats fed on neem, compared to the control group. In nymphs of *R. appendiculatus*, there was also a reduction in attachment and increase in feeding periods. In larvae of *R. appendiculatus*, similar observations were made.

Preliminary results show that neem compounds taken orally with animal feed affect ticks attaching and those already feeding on the animals. This phenomenon therefore merits further research to determine the real potential of using this method for tick control.

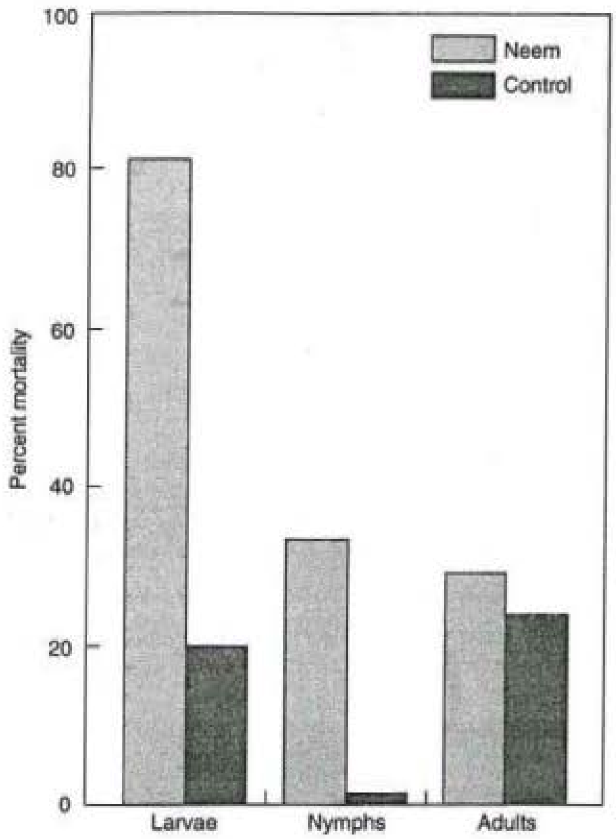

Figure 5.2a. Percent mortality in *R. appendiculatus* sprayed with 20% Neemroc-Combi (0.5%)

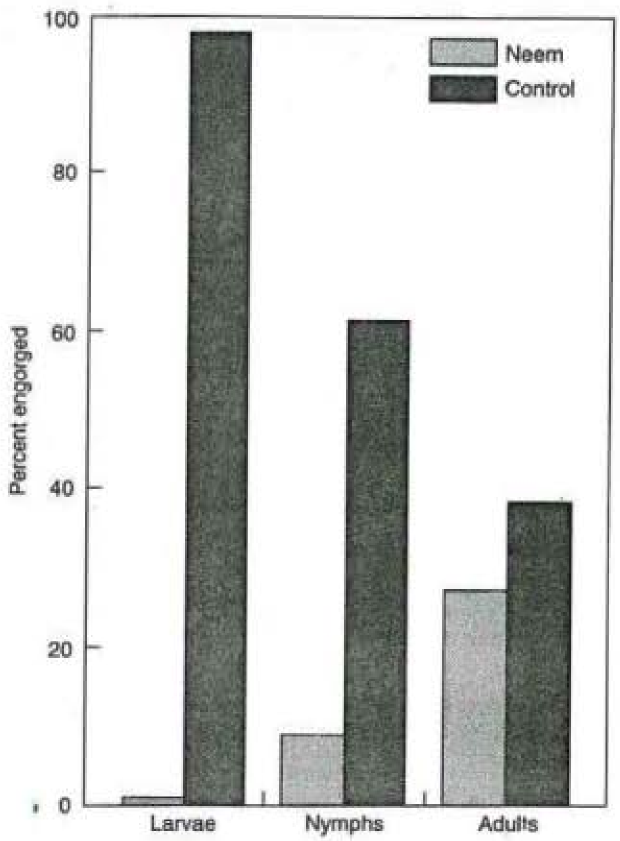

Figure 5.2b. Percent engorging *R. appendiculatus* after spraying with 40% Neemroc-Combi (0.5%)

5.2 EVALUATION OF THE EFFECTS OF NEEMROC-COMBI (0.5%) ON *RHIPICEPHALUS APPENDICULATUS*

All stages of *R. appendiculatus* and New Zealand white rabbits were obtained from ICIPE Animal Rearing and Quarantine Unit (ARQU). Neemroc-Combi (0.5% azadirachtin), a liquid agricultural insecticide made from neem seeds by Saroc Ltd. in Nairobi, was diluted to 40 and 20% and then applied on all stages of *R. appendiculatus* feeding on rabbits. Mortality, feeding performance (engorgement) and moulting were recorded.

Neemroc-Combi, both 20 and 40% concentrations, induced mortalities and reductions in numbers of ticks feeding in all life stages of *R. appendiculatus* (Figures 5.2a and 5.2b). It also induced a reduction in moulting in larvae and nymphs. Mortality was highest in larvae, followed by nymphs and adults (Figure 5.2a). Likewise, Neemroc-Combi inhibited feeding more severely in larvae, followed by nymphs and then adults.

Neemroc-Combi (0.5%), a neem-based agricultural insecticide, is used to control pests such as cabbage moth, berry borers, aphids, spider mites, whiteflies, mealybugs, thrips, etc. at a concentration of 0.02%. The concentrations of 20 and 40% used in our experiments were therefore higher than those used for agricultural pests and yet they were not able to induce 100% mortality or inhibition of feeding in ticks. Thus, a formulation with higher concentration of azadirachtin may be needed for tick control.

5.3 COMPATIBILITY STUDIES BETWEEN NEEM AND FUNGI

Participating scientists: *E.O. Osir, E.U. Kenya, O. Odulaja*

As work continues to progress on the use of fungi and neem for tick control, it is important to assess their compatibility. Hence, the attempt to evaluate the effect neem would have on certain biological parameters of two fungal isolates, *Metarhizium anisopliae* and *Beauveria bassiana*.

Fungal spores (3×10^{8}) were suspended in different concentrations (0% - control, 20, 40, 60, 80 and 100%) of pure neem oil (Neemsar, 0.65 - 1% Aza). Peanut oil was used as diluent. Spore germination was observed before incubation and after 24 hours' incubation period.

Metarhizium anisopliae spores incubated in 60–100% neem oil for 24 hours lost their viability and did not germinate (Figure 5.3) and only 3% germination was recorded after incubation in 100% neem oil for 24 hours of *B. bassiana* spores. The effect of neem oil on spore viability showed a similar trend in both isolates, with the loss of spore viability being directly proportional to increasing concentrations of neem oil in the incubation medium. However, *M. anisopliae* appeared to have a lower germination rate in all concentrations as compared to *B. bassiana*.

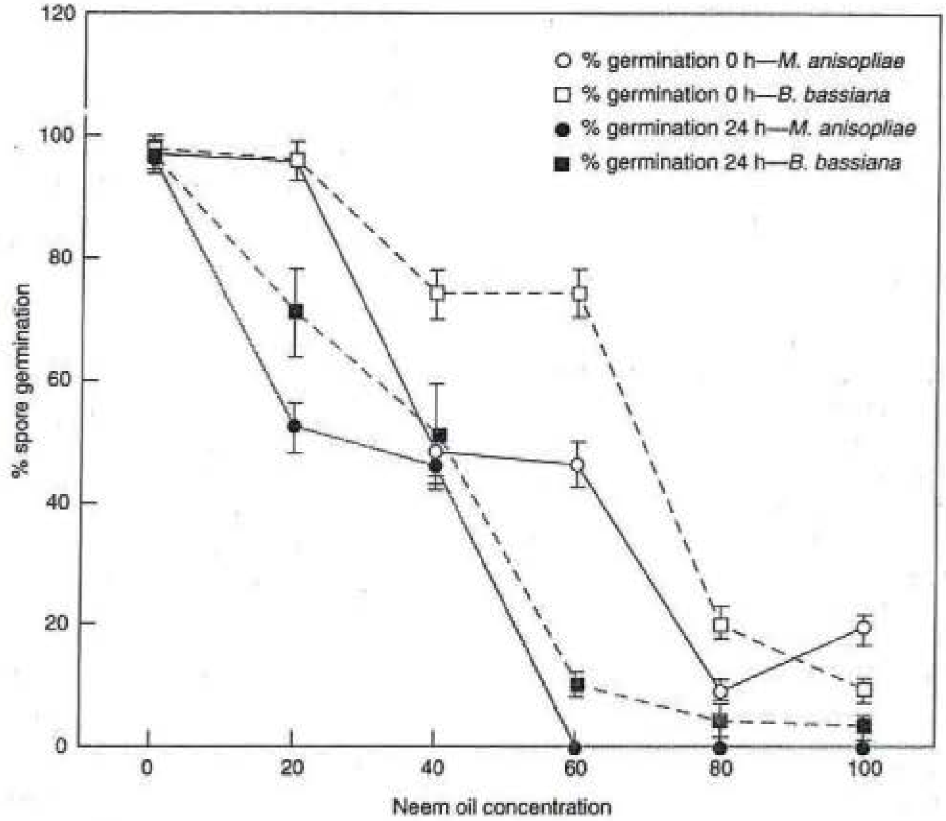

Figure 5.3. Effect of neem oil on germination of *Metarhizium anisopliae* and *Beauveria bassiana* spores

The results clearly indicate that neem oil at certain concentrations reduces the viability of fungal spores. Cocktail formulations of neem and fungi will need to be constituted carefully to ensure continued viability of the spores. Using these results, fungal-neem formulations should be made and bioassays conducted on the three African tick species under both laboratory and field conditions.

5.4. EFFECTS OF *EUPHORBIA* SPECIES EXTRACTS ON *RHIPICEPHALUS APPENDICULATUS*

Participating scientists: *E. O. Osir, A. Odulaja*

Assistant: *S. Obuya*

Donor: *ADB and ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark)*

A number of plants have been shown to exhibit acaricidal effects. Extracts of these plants present effective and sustainable methods of tick control.

In this study, 3 batches of 50 unfed adult *Rhipicephalus appendiculatus* ticks enclosed in 10 x 10 cm^2 nylon gauze tetrapacks were immersed in solutions of *Euphorbia candelabrum* latex for 5, 10 and 30 minutes and the induced mortality of the ticks assessed. Excess latex was drained off by dabbing the tetrapacks on paper towels. This experiment was repeated with batches of 100 flat nymphs and 200 flat larvae. The tetrapacks containing the ticks were then placed in an incubator at 28°C and 80% relative humidity, and the induced mortality monitored every 24 hours.

The bioassays revealed that *E. candelabrum* was able to induce mortality in all the developmental stages of *R. appendiculatus*, with 100% mortality being reached at 35% (w/v) latex concentration in adults and 25% (w/v) in nymphs, when exposed for only 5 minutes. The larval stage was very susceptible to the latex, reaching 100% mortality at concentrations as low as 5% (w/v) following a 5-minute exposure period. Adults and nymphs exhibited some resistance to the latex at low concentrations, with no mortalities being recorded at concentrations lower than 25% (w/v) when exposed for 5 minutes. Longer exposure times remarkably improved the efficacy of the latex in mortality induction in *R. appendiculatus*. Mortality (80%) for both adults and nymphs was achieved at 10% (w/v) latex concentration when exposed for 10 minutes. Concentrations exceeding 50% (w/v) and exposure times longer than 10 minutes did not show any remarkable change in mean mortality.

These observations indicate that *E. candelabrum* possesses a biological activity against *R. appendiculatus* and has a potential as a natural acaricide which is biodegradable and readily available. Future plans are aimed at assessing the safety levels of the latex and its impact on both the target and non-target organisms.

Plans are in place to determine the active principle in the latex and to develop effective formulations, dosages and application regimes for this product.

Both socioeconomic and cost/benefit analysis need to be carried out to assess the appropriateness of its adoption.

6. INFECTIVITY OF NEMATODES (STEINERNEMATIDAE) TO TICKS

Background, approach and objectives

The use of biological control agents presents an effective and sustainable alternative to synthetic chemical acaricides. Among these agents, two facultatively parasitic nematodes from the families Steinernematidae and Heterorhabditidae have shown potential for the control of the non-parasitic phase of ticks. These nematodes are characterised by their symbiotic relationship with bacteria of the genus *Xenorhabdus* and by ready adaptation to arthropod hosts, especially the soil-inhabiting species. In addition, they are reported to be specific to insects.

Many insect species, including pests and vectors of disease, are susceptible to nematodes. They present no hazard to mammals and non-target organisms. Most studies on the pathogenicity and efficacy of nematodes have been limited to agricultural pests. Only recently have nematodes been reported to be effective against the one-host tick, *Boophilus annulatus*. Preliminary experiments at ICIPE have shown that the engorged brown ear tick, *Rhipicephalus appendiculatus* females are susceptible to nematodes. Despite demonstration of infectivity, the effect of the nematodes on the reproductive performance of the surviving ticks has not been assessed.

The objective of this study was to assess the infectivity of a local isolate of entomopathogenic nematodes (Steinernematidae) to female *R. appendiculatus*.

Participating scientists: *J. Okello-Onen, E. O. Osir, A. Odulaja*

Donor: *USAID*

Collaborators: *• Livestock Health Research Institute (LIRI), Uganda • University of Namibia, Department of Biology, Namibia • Department of Nematology, The Agricultural Research Organisation (ARO) • The Volcani Centre, Israel*

Work in progress

A local strain of *Steinernema* was obtained from soil samples collected in the western region of Kenya. After isolation, they were maintained in *Galleria mellonella*. To determine infectivity, infective juveniles (IJs) of the nematodes were suspended at various concentrations (200, 400, 600, 800, 1000, 2000, 3000, 4000 and 5000 IJ/ml) in deionised water. A 0.5 ml aliquot of each nematode suspension was applied to four 5-cm diameter Petri dishes padded with Whatman No.1 filter paper. Water was applied to the control Petri dishes. Into each Petri dish, 5 engorged ticks that had dropped off the host within the prior 24 hours were transferred and incubated at 27 – 28° C and 85% relative humidity in the dark. Each treatment was replicated with four dishes and repeated twice. Mortality was recorded daily for 21 days after infection. The ticks that did not die were also monitored with respect to pre-oviposition period, duration of oviposition, egg numbers (fecundity), eclosion period and hatchability.

Increasing the nematode concentration from 200 to 1000 IJ/ ml resulted in 50–100% mortality starting from day 7 after exposure. On the other hand, nematode concentrations of above 1000 IJ gave complete mortality 2–3 days post-treatment. The pre-

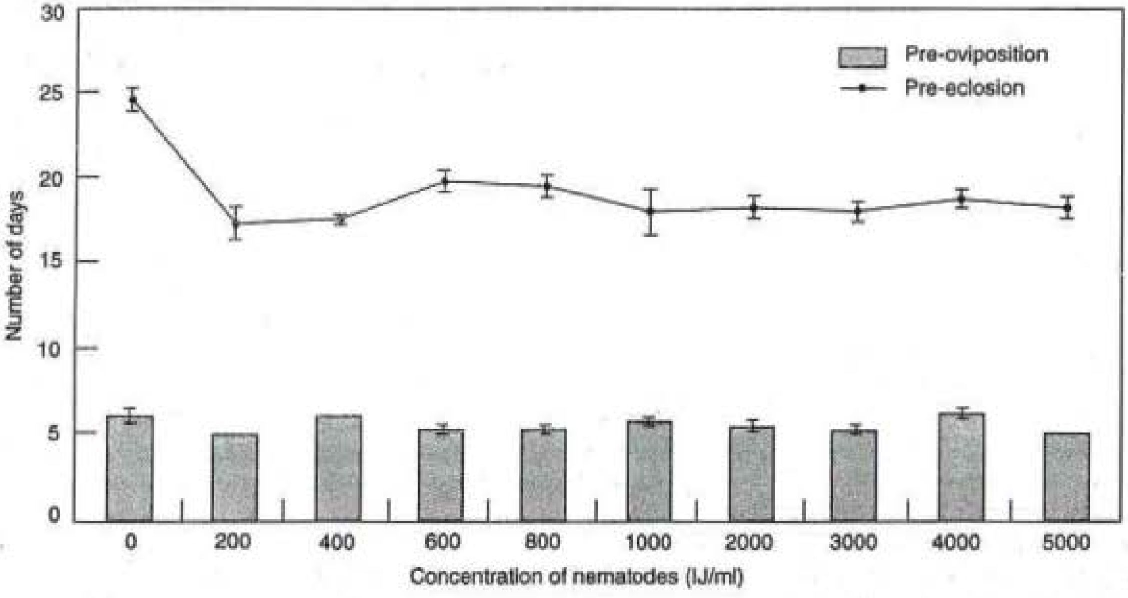

Figure 6a. Pre-oviposition and pre-eclosion periods of *R. appendiculatus* ticks at different concentrations of nematodes

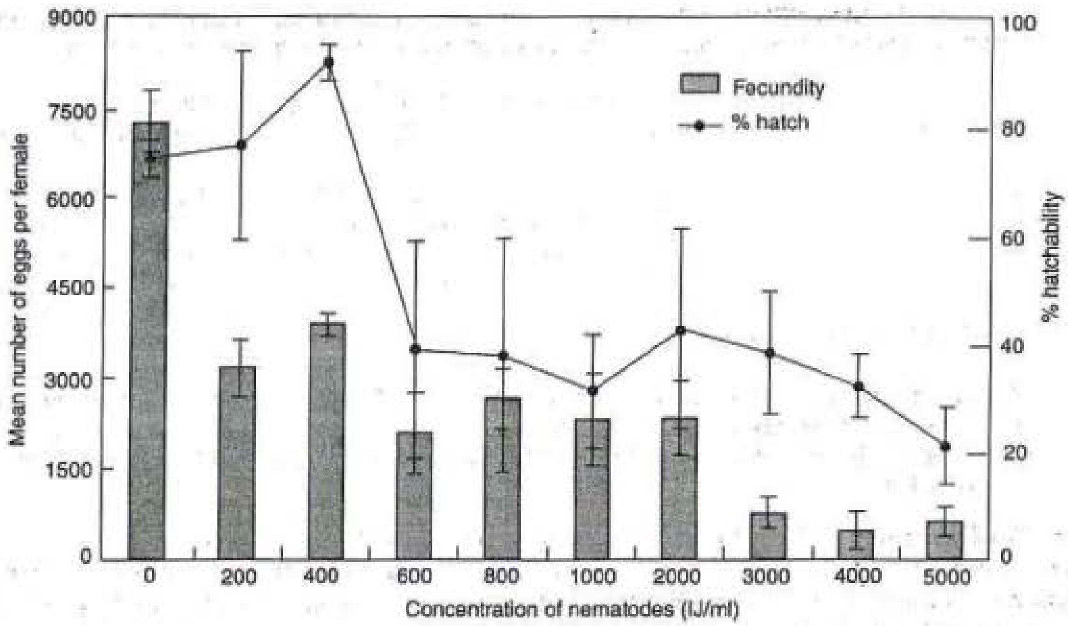

Figure 6b. Fecundity and viability of eggs of *R. appendiculatus* ticks at different concentrations of nematodes

oviposition periods were not significantly affected (P>0.05) at different concentrations of nematodes (Figure 6a). However, the pre-eclosion period was significantly higher (P<0.05) in the control than in the treatment group. The nematodes had a significant effect on the fecundity and viability of ticks eggs (Figure 6b). The mean number of eggs laid per female tick was significantly reduced (P<0.05) with increasing nematode concentration. Similarly, the percent hatchability of eggs was also significantly reduced (P<0.05) with an increase in nematode concentration.

The preliminary results obtained in this study showed that *Steinernema* sp. of nematodes caused 100% mortality in engorged *R. appendiculatus* females at concentrations of 1000 IJ/ml and above. Thus, it may be possible to target nematodes at engorged female ticks that drop off the hosts onto the ground. That the surviving *R. appendiculatus* females, exposed to lower concentrations of nematodes (200–800 IJ/ml), had their reproductive performance greatly suppressed, demonstrates an additional potential of the nematodes in suppressing the field populations of ticks.

Based on the above results, it is evident that entomopathogenic nematodes could provide an effective tactic for controlling engorged off-host female ticks when applied strategically at the sites where ticks are concentrated. Given the traditional herd management practices in Africa, the nematodes could be applied in the kraals (enclosures) where animals are confined at night. These are the sites where most engorged female ticks drop off the hosts in the morning before the animals are released for grazing. However, the long-term impact of the nematodes in suppressing tick populations in the field needs more careful assessment. Additional studies should also include methods for formulation and dispensation.

7. DEVELOPMENT OF IMMUNOLOGICALLY-MEDIATED APPROACHES TO THE MANAGEMENT OF TICKS

Participating scientist: *S. Essuman (Project Leader)*

Assistant: *J. Kinyua*

Donor: *Toyota Foundation*

Collaborator: • *KARI*

Work in progress

7.1 DEVELOPMENT OF AN ANTI-TICK VACCINE FOR *AMBLYOMMA VARIEGATUM*

The *A. variegatum* ticks used were from two sources: (i) Adult ticks were obtained from a laboratory colony that is being maintained on tick-naive rabbits and kept at 28°C and 85% relative humidity (RH) when not being fed. (ii) Field-collected *A. variegatum* adult ticks were collected from cattle in the field. New Zealand white rabbits (5 months old) were used for the preliminary immunisation experiments.

The midguts of 1000 partially-fed female *A. variegatum* were dissected into separate containers. About 10 g (frozen weight) of midguts were washed several times in PBSE buffer (0.1 M PBS, pH 7.2, containing 1mM EDTA) and then homogenised in the PBSE containing a battery of protease inhibitors. The protein contents of the preparations were estimated by BCA (Bicinchoninic acid) protein assay reagent (Pierce) using bovine serum albumin (BSA, Fraction V) as the protein standard. The three fractions were analysed by SDS-PAGE under denaturing conditions and stained for total protein compositions of the fractions with silver stain.

Table 7.1.1. Immune effects of detergent (DET) and aqueous (AQ) phases on the engorgement weights, eggs batch weights and hatchability in female *Amblyomma variegatum*

Treatments	No. of ticks	Mean engorged weight (± SE)*	Mean egg weight (± SE)	Mean % hatchability (± SE)
Control	28	147.74 ± 0.009 a	90.23 ± 0.02 c	62.647 ± 0.069 c
AQ	28	117.48 ± 0.014 b	44.11 ± 0.015 d	33.036 ± 0.076 f
DET	28	111.31 ± 0.015 b	41.41 ± 0.016 d	14.286 ± 0.069 g
CV		6.37	8.44	28.05

CV = Coefficient of variance

*Means with the same letter are not significantly different at ($P < 0.05$) by Student-Newman-Keuls (SNK) test. Data were analysed using the general linear model procedure (a special type of ANOVA). Analysis of variance was adopted using the Statistical Analysis System (SAS) program.

The method employed for the isolation of membrane-bound proteins was able to distinctly separate integral membrane proteins (detergent phase) from the peripheral ones (aqueous phase). It was observed that protein compositions of all the fractions from the laboratory ticks were, to some extent, different from those obtained from the field ticks. The implication of these differences with regard to experimental design (e.g. challenge after immunisation) is being discussed.

Experiences from our previous work with a different tick, *R. appendiculatus* and that of others working on other tick species have shown that protective antigens are usually integral glycoproteins. We are therefore preparing lectin affinity columns for use in further purification of the detergent phase fraction. In order to find out which of the three fractions (soluble, detergent- and aqueous-phase) induce protective immunity in the natural host, rabbits are being immunised with the fractions. The protective fraction will then be used to immunise cattle.

7.1.1 *Immunisation of rabbits with the three membrane fractions*

Three groups of rabbits, each containing five rabbits, were used for immunisation. The groups 1 and 2 were tested with the detergent and aqueous membrane fractions. The third group was a control. Each rabbit in the experimental groups received 100 mg immunogen for every immunisation. They were all boosted twice with the same immunogen dose. Saponin was used as the adjuvant. Briefly, the immunisation showed that both the detergent and aqueous membrane fractions contain protective activity and the degrees of protection were not significantly different ($P < 0.05$). The biological effects of the fractions on female ticks after feeding on the treated animals are shown in Table 7.1.1.

7.1.2 *Isolation and identification of the protective immunogens (glycoproteins)*

We previously speculated that the protective proteins in the gut membrane are glycoproteins. We therefore used Con A to prepare affinity columns for isolation of the glycoproteins. Glycoproteins with molecular weights of about 66.5, 40, 31 and 14.4 kDs were found to be more prominent. Only the high molecular weight proteins were prominently bound by the IgG from the protected animals. In this case also, the proteins which seem to be involved in the induction of protection are acidic in nature.

From the results, it is evident that the proteins which induced the immune protection in the rabbits were high molecular weight proteins. It is also evident that glycoproteins are playing a role in the protection. This suggests that further attempts at searching for a vaccine against *A. variegatum* should include strategies which will purify high molecular weight acidic glycoproteins. Another important aspect would be to establish the location of immunogenic proteins within the tick midgut structure.

8. STUDIES ON TICK POPULATION GENETICS

Background, approach and objectives

The use of chemical acaricides is the main method currently employed 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 naturally tick- resistant breeds. Available data suggest that no single control strategy is likely to provide effective control of ticks and tick-borne diseases alone. 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:

- Contribution 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 *Theileria 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.

- 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.
- 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*.

Participating scientist: *E. O. Osir (Project Leader)*

Assistant: *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

8.1 GENETIC DIVERSITY OF *RHIPICEPHALUS APPENDICULATUS* POPULATIONS IN KENYA IN RELATION TO THEIR SUSCEPTIBILITY TO *THEILERIA PARVA* INFECTIONS

Approximately 100 engorged females were collected from eight geographical locations in Kenya. Eggs from these females were kept up to the nymphal stage. Nymphs were fed on steers that had previously been infected with *T. parva* Marikebuni for infection studies. 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). After amplification, the samples were separated on 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—Embu, Lanet, Maralal, Kitale, Kakamega, Muguga, Baragoi and Rusinga. Generally, the Embu and Lanet stocks were more susceptible and the Kakamega, Kitale, Maralal and Baragoi stocks were refractory to *T. parva* infection. Rusinga and Muguga populations showed intermediate susceptibility.

Seven populations (Lanet, Embu, Kitale, Maralal, Muguga, Kakamega and Rusinga) were selected for PCR analysis. Considerable variations were observed within and between the different tick populations. Based on the presence/absence of bands, a genetic distance matrix was constructed (Table 8.1). This information was subsequently used to construct a UPGMA dendrogram representing the genetic relationships of the seven populations (Figure 8.1). It was observed that Lanet and Embu formed one cluster and Kitale, Maralal, Muguga, Kakamega and Rusinga 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.

Kitale and Maralal, shown to have low susceptibility to *T. parva*, have very low genetic distance values. Embu and Maralal seem to be the most diverse with a distance of 183 units between them. A similarly large distance (0.153) was observed between Kitale and Embu. This RAPD data suggests a wider genetic divergence between *T. parva* susceptible and refractory ticks. Considering these RAPD results and the vector competence data, it appears that the differences in the ability of various stocks of ticks to transmit ECF may be accounted for by genetic differences.

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.

Table 8.1. Nei's genetic distance matrix for seven *Rhipicephalus appendiculatus* populations in Kenya

	Ma	Ka	Ru	Mu	Em	La
Ki	0.020	0.024	0.005	0.032	0.153	0.093
Ma		0.047	0.006	0.053	0.183	0.132
Ka			0.019	0.013	0.126	0.077
Ru				0.022	0.122	0.070
Em					0.121	0.070
La						0.050

Number of loci compared 37; Ki=Kitale, Ma=Maralal, Ka=Kakamega, Mu=Muguga, Ru=Rusinga, Em=Embu and La=Lanet.

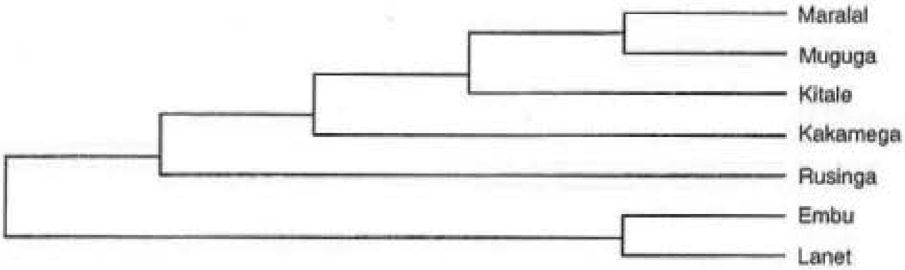

Figure 8.1. Dendrogram showing the genetic distances among the various *R. appendiculatus* populations. The dendrogram was constructed using UPGMA with NJBAFD Program of analysis

Output

Publications

Dossa S. C., Essuman S. and Kaaya G. P. (1998) Characterization of *Amblyomma variegatum* tick saliva and salivary gland antigens inducing anti-tick immunity in Boran cattle. *International Journal of Acarology* 24, 149–157.

Kaaya G. P. and Mwangi E. N. (1998) Control of livestock ticks in Africa: Possibilities of biological control using the entomogenous fungi, *Beauveria bassiana* and *Metarhizium anisopliae*, pp. 5–16. In *Tick-Borne Pathogens at Host–Vector Interface: A Global Perspective*, Vol. 1 (Edited by L. Coons and M. Rothschild). United Litho.

Sebitosi E. N., Kaaya G. P., Young A. S. and Agbede R. I. S. (1998) Lectins in brown ear tick, *Rhipicephalus appendiculatus*: Detection and partial characterization. *International Journal of Acarology* 24, 159–164.

Solomon G. and Kaaya G. P. (1998) 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* 75, 241–253.

Solomon G., Kaaya G. P., Gebreab F., Gemetchu T. and Tilahun G. (1998) Population studies on ticks feeding on indigenous cattle and incidence of tick-borne parasites in Didtuyura ranch in southern Ethiopia. *Insect Science and Its Application* 18, 56–66.

Workshops

A workshop entitled 'Development of Integrated Strategy for the Management of Livestock Ticks' was held at ICIPE from 27–28 July 1998 and was attended by 30 scientists from ICIPE, KARI, ILRI, UON and Kobe University in Japan.

A training workshop on tick management entitled 'Novel Approaches to the Management of Ticks' was held at ICIPE from 1–29 September, 1998. It attracted 20 trainees from 13 African countries from West, East and southern Africa. Lecturers came from ICIPE, KARI, ILRI, and KETRI.

A workshop entitled 'Tick and Tick-Borne Diseases Workshop—Priorities for Research' was held at Oasis Hotel, Harare from 11–14 April 1999 and was attended by 40 scientists from ICIPE and various research institutes in Africa and Australia.

Training

G. P. Kaaya attended a 3 weeks training at Kimron Veterinary Institute and The Volcani Institute, Israel, on the procedure for isolation of entomogenous nematodes and infection of insects and ticks, from 20 October to 9 November, 1998.

Twelve students from local universities and polytechnics on short attachments undertook short projects on tick research in the LTRP during 1998.

Report to donor

The project entitled 'Validation of the Australian Model of the tick *Rhipicephalus appendiculatus* in Kenya and investigation of its use to facilitate collaboration with NARS' ended on 30 June, 1998. A final report was prepared and submitted to the donor, ACIAR.

New project

A 3-year USAID-funded project to evaluate pathogenicity and biocontrol potentials of entomogenous nematodes to ticks commenced in April 1998. The collaborating institutes are ICIPE, Kimron Veterinary Institute (Israel) and The Volcani Institute (Israel).

Conferences and workshops attended

Kaaya G. P. (1998) Development of Integrated Strategy for the Management of Livestock Ticks, 27–28 July, ICIPE, Nairobi, Kenya.

Kaaya G. P. (1998) Novel Approaches to the Management of Ticks, 1–29 September, ICIPE, Nairobi, Kenya.

(See also reports on Neem, the Entomopathology Unit, the Behavioural and Chemical Ecology Department and the Molecular Biology and Biochemistry Unit.)

AGRICULTURAL RESEARCH

PLANT HEALTH MANAGEMENT

HORTICULTURAL CROP PESTS

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

This generally positive scenario is put in jeopardy by at least two concerns: Firstly, increased intensity both in local market production but particularly in export-oriented systems, has led to increased use of chemicals, rising production costs and decreasing productivity. This is associated with high risks to human health, especially among farm labourers, many of them women and children, as well as producing intolerable environmental pollution. Secondly, consumers in the importing European countries are becoming increasingly concerned about the prevailing production methods. More stringent regulations for pesticide residue levels and concern about hygienic standards in production will force producer countries to invest much more in research and farmer education, to ensure compliance with these standards.

Research and the 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. 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 to date, especially with respect to the plant protection discipline, despite 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 the context of a vigorously growing horticultural export industry in eastern and southern Africa. Despite its phenomenal growth during the last 10 years, the horticultural sector is suffering from a general lack of locally adapted production technologies. A number of research projects in production for both local and export markets try to address these problems.

ICIPE's Horticultural Research Project and the German-funded IPM Horticulture Project amalgamated in May 1998; a planning workshop for the joint Programme was held in October. The theme for ICIPE's new Horticulture Sub-division was selected as 'Development of environmentally and economically sound plant protection solutions for horticultural production'.

Four pests or pest complexes were given highest priority:

- Diamondback moth, *Plutella xylostella* L., with the aim to improve natural control;
- Whiteflies *Bemisia tabaci* (Genn.) and *Trialeurodes vaporariorum* (Westwood) as virus vectors;
- Thrips, *Thrips tabaci* Lind., *Frankliniella occidentalis* Pergande and *Megalurothrips sjostedti* (Trybom);
- African bollworm, *Helicoverpa armigera* (Hb.).

A proposal for a biological control project for the diamondback moth was submitted in January 1999 and was granted funding in November. A proposal for a large whitefly project is also under preparation. Another proposal to improve the use of egg parasitoids against *H. armigera* and diamondback moth is ready for submission to donors.

The Horticultural Crop Pests Sub-Division has also taken the initiative to improve ICIPE's relationship with the cut flower sector. A scout training course for the flower industry is being developed in cooperation with the Kenya Flower Council (KFC) and will be offered first to all members and then to other Kenyan producers.

Plant Health Division

HORTICULTURAL CROP PESTS

Development of Options and Awareness Building Models for IPM in Major Vegetable Crops in Eastern Africa

Background, approach and objectives

Production of vegetable crops by smallholder farmers in sub-Saharan Africa is fast transforming from a subsistence activity to intensive cultivation in areas with access to supplementary irrigation. Year-round vegetable production to supply urban and export markets is emerging as an important income-generating activity. In Kenya, there are about 1 million smallholder farm families producing vegetable crops for export as outgrowers. The premium prices offered for blemish-free vegetable produce is motivating these farmers to look for better ways of intensively protecting their crops from pests and diseases.

The most common method of pest control by vegetable farmers is still the use of chemical pesticides. However, the increasingly stringent regulations of the importing countries governing maximum residue limits (MRLs) on fresh produce is stimulating the adoption of safer alternatives. As long ago as 1992, an FAO-sponsored African regional seminar in Senegal recommended initiatives to strengthen research, training and awareness building on IPM (integrated pest management) for promoting the sustainability of vegetable production in the region.

The present initiative is a regional ICIPE-NARES (national agricultural research and extension system) partnership to develop and disseminate IPM for vegetable crops grown for the urban/export market by smallholder farmers. The three-year project activities were initiated in mid-1998. The supportive research component is focused on expanding the IPM options for priority pests in the region, especially the use of biological and botanical products and preventive strategies. Adaptive research is largely geared to fine tuning and validating promising IPM options.

Capacity building activities cater to nationals from the region. Farmers' group learning activities are aimed at developing locally adapted models of the Farmers' Field School (FFS) approach of IPM awareness-building at farmer-to-farmer level.

Participating scientists: *S. Sithanantham*, K. Ampong-Nyarko, K.V. Seshu Reddy, A. Varela, N. K. Maniania, E. Osir, M. Oketch* (*Project Leader)

Assistants: *W. Ogutu, G. Jira, A. Wanyonyi, J. Ondijo, D. Irungu, B. Gikaria*

Research scholars: *A.T. Haile (Ethiopia), A. Akol (Uganda), T.C.M. Matoka, J. Baya, R. Gathu, S. Muchemi (Kenya)*

Donors: *IFAD and USAID*

Collaborators: • *Kenya Agricultural Research Institute (KARI), Kenya* • *National Agricultural Research Organisation (NARO), Uganda* • *Ethiopian Agricultural Research Organisation (EARO), Ethiopia* • *Horticultural Research and Training Institute, Arusha, Tanzania* • *Asian Vegetable Research and Development Centre, Arusha, Tanzania* • *USAID-IDEA Project, Uganda* • *GTZ-IPM Horticulture Project, ICIPE, Kenya* • *Jomo Kenyatta University of Agricultural and Technology (JKUAT), Juja, Kenya* • *B.t. Research and Development Centre (BtRDC), Hubei, China*

Work in progress

1. SUPPORTIVE RESEARCH FOR DEVELOPING IPM OPTIONS

Supportive research for IPM development is focused on identifying improved sources of biological control agents and on developing preventive options for pest management in vegetable crops. It also includes assessment of the pest status and pest spectrum. The options being evaluated in collaboration with NARES include habitat management, host plant tolerance, use of botanicals and the environmental interactions of IPM components. Capacity building of NARES is taking place through joint MSc/PhD research projects focused on some of the above themes.

1.1 PEST STATUS AND YIELD LOSS

1.1.1 *Pest spectrum on okra and capsicum*

Observations were made on insect pests infesting okra and capsicum crops in field plots grown for two seasons at Kibwezi, Kenya in 1998–1999. This study was meant to complement the very limited information presently available in Kenya. The results

Table 1.1.1. List of insect pests infesting okra and capsicum, Kibwezi, Kenya 1998–1999

Common name	Scientific name	Family	Relative severity status*	
			Okra	Capsicum
Aphid	*Aphis gossypii* (Glover)	Aphididae	xxx	x
Whitefly	*Bemisia tabaci* (Gennadius)	Aleyrodidae	xxx	xxx
Leafhopper	*Empoasca* sp.	Cicadellidae	x	-
Cotton stainer	*Dysdercus* sp.	Pyrrhocoridae	xx	-
Leaf caterpillars	*Ancylolomia* sp.	Pyralidae	xx	xx
	Plusia sp.	Noctuidae	xx	xx
Leaf miner	*Liriomyza* sp.	Agromyzidae	xxx	x
Leaf beetles	*Leptaulaca fissiocollis* (Thoms)	Chrysomelidae	xx	-
	Copa delata (Er.)	Chrysomelidae	xx	-
	Lagria villosa (Fabricius)	Lagriidae	xx	-
	Lixus sp.	Curculionidae	xx	xx
	Apion sp.	Apionidae	xx	x
Sucking bug	*Oxycarenus hyalinipennis* (Costa)	Lygaeidae	xx	x
Flower beetle	*Coryna apicicornis* (Fabricius)	Meloidae	xx	x
Flower thrips	*Frankliniella occidentalis* (Pergande)	Thripidae	xx	x
	Haplothrips gowdeyi (Franklin)		xx	x
Fruit borers	*Helicoverpa armigera* (Hübner)	Noctuidae	xx	xxx
	Earias spp.		xx	-

*xxx Very common x Not common
xx Common - Not recorded

(Table 1.1.1) showed that while aphids, whiteflies, defoliating beetles and fruit borers occur commonly on the two crops, okra appeared to have a wider spectrum of pests than capsicum. Several of the insect pests observed are apparently new records for Kenya.

1.1.2 *Avoidable yield loss due to pests in okra and capsicum*

The effects of insect pests on yields of okra and capsicum were observed for two crop seasons at Kibwezi, Kenya. The avoidable yield loss in two seasons was in the range of 5.5 to 10 % for okra and for capsicum the range was 10.6 to 16.5%. Further on-station studies of yield loss in okra are being planned at the coastal lowland site in Muhaka.

1.1.3 *Spectrum of insect pests on cucumber*

Among several species of insects found to infest this crop, the more common were aphids, whiteflies, thrips, the African melon ladybird beetle and melon fruit fly (Table 1.1.3). The insect pests occurring during the reproductive stage of the crop (flower thrips and beetles, fruit flies), appeared to be more important compared to those occurring in the vegetative stage (leafminers, aphids, whiteflies, defoliators). Assessment of the number of thrips infesting the flowers showed that they were significantly lower in plots receiving protection during the reproductive crop stage. This suggests a possible role for the flower-infesting thrips in affecting the yield of marketable fruits in cucumber; other pests, including fruit flies, also affected the quality and yield. These results have provided a basis for planning further research directed towards IPM development for cucurbit crops of importance in the region.

1.1.4 *Effect of pests on cucumber yields*

Two field experiments were conducted on cucumber for assessing the overall effects of insect pests on the yield and quality of the produce. The treatments listed below were compared in a randomised complete block design with six replications:

T_1 – No protection (non-sprayed control)
T_2 – Protection from pests in crop vegetative stage
T_3 – Protection from pests in crop reproductive stage
T_4 – Protection from pests in crop vegetative and reproductive stages

The results showed that the yield of marketable (damage-free) fruits was enhanced significantly in both the seasons when the crop was protected from pests during the reproductive stage; no significant increase occurred when protection was given during the vegetative stage (Figure 1.1.4). It is therefore important to focus further research on pests occurring in the reproductive stage of cucumber.

2. ROLE OF COMPANION CROPS IN REDUCING PEST INFESTATION

2.1 POTENTIAL OF *CLEOME GYNANDRA*

Cleome (Gynandropsis) gynandra L. is an indigenous plant used traditionally in several African countries for control of ticks on cattle. Eaten by some communities as a leafy vegetable, it is known locally as 'chisaga' and 'dek' in Kenya. The crude extract of this plant has also been reported to reduce the pest infestation on some tropical crops when applied as a spray. Studies were initiated recently at ICIPE to

Table 1.1.3. Spectrum of arthropod pests infesting cucumber (at Kasarani and Kibwezi), Kenya, 1998–1999

Common name	Scientific name	Family	Relative pest severity
Sucking pest			
Tobacco/onion thrips	*Thrips tabaci* (Lindeman)	Thripidae	xxx
Flower thrips	*Frankliniella schultzei* (Trybom)	Thripidae	xxx
Thrips	*Mycterothrips* sp.	Thripidae	x
Leaf footed bug	*Leptoglossus membranaceus* (Fabricius)	Coreidae	xx
Cotton stainer	*Dysdercus cardinalis* (Gerst)	Pyrrhocoridae	xx
Green-house whitefly	*Trialeurodes vaporariorium* (Westwood)	Aleyrodidae	xxx
Tobacco whitefly	*Bemisia tabaci* (Gennadius)	Aleyrodidae	xxx
Cotton aphid	*Aphis gossypii* (Glover)	Aphididae	xxx
Green peach aphid	*Myzus persicae* (Sulzer)	Aphididae	xxx
Chewing insects			
African melon lady bird beetle	*Epilachna chrysomelina* (Fabricius)	Coccinellidae	xxx
Defoliating beetle	*Epilachna misella* (Weise)	Coccinellidae	xxx
Spotted cucumber beetle	*Diabrotica undecimpunctata* (Barber)	Chrysomelidae	xx
Striped cucumber beetle	*Diabrotica trivitattum* (Fabricius)	Chrysomelidae	xx
Red pumpkin beetle	*Aulacophora foveicollis* (Lucas).	Chrysomelidae	x
Defoliating beetle	*Casnoidea* sp.	Carabidae	x
Black shiny beetle	*Lagria villosa* (Fabricius)	Lagriidae	x
Cutworm	*Agrotis* sp.	Noctuidae	xx
Caterpillar	*Plusia* sp.	Noctuidae	x
Caterpillar	*Leptaulaca fiscicollis* (Thoms)	Noctuidae	x
Miners/borers			
Fruit borer	*Helicoverpa armigera* (Hübner)	Noctuidae	xx
Melon fruit fly	*Dacus ciliatus* (Loew)	Tephritidae	xxx
Leaf miner	*Liriomyza* sp.	Agromyzidae	xx

xxx Very common x Not common
xx Common - Not recorded

evaluate the potential of *C. gynandra* as a companion crop for reducing infestation by the diamondback moth, *Plutella xylostella* infesting cabbages, and promising results were obtained. The present study tests the plant's protective properties in French bean.

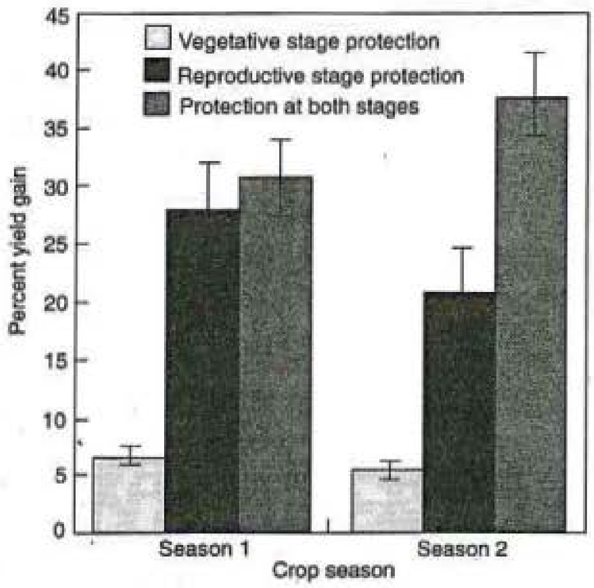

Figure 1.1.4. Effect of protection regimes on yield of damage-free (marketable) produce in cucumber, Nairobi, Kenya

2.1.1 *Field testing of* Cleome gynandra *for flower thrips infestation in French bean*

An exploratory field trial was conducted with French bean (cv. Monel) at ICIPE-Mbita to test whether *C. gynandra*, when grown as an intercrop, can help reduce the incidence of flower thrips. Two ratios of main and intercrop were used: 1:1 and 4:1. Other treatments consisted of sole French beans sprayed with crude leaf extract of *C. gynandra* (10%), sole French bean sprayed with the insecticide lambdacyhalothrin (Karate at 2 ml/litre), and an unsprayed check plot. The treatments were replicated four times.

Random sampling of flowers at three time intervals showed a lower thrips infestation in the intercropped plots, comparable to the pest infestation level in plots receiving chemical insecticide sprays. The differences were significant during two of the three sampling times. The thrips infestation in the intercropped plots was even lower than the levels in plots sprayed with *C. gynandra* extract. These results suggest that *C. gynandra* may have pest control benefits as a companion crop. Further studies in utilising this response in a 'push-pull' strategy are being planned.

3. UTILISING HOST PLANT RESISTANCE/ TOLERANCE TO PESTS IN VEGETABLE CROP VARIETIES

Background, approach and objectives

Genetic diversity within vegetable crops can be used for reducing the loss caused by pests and increasing marketable yields. ICIPE staff are working to identify crop genotypes in promising export vegetables like eggplant, okra and capsicums which produce acceptable yields under minimal or no pesticidal protection as a component of IPM development. This research is largely demand-driven in response to requests from NARES from Kenya, Uganda and Tanzania , and is done in close collaboration with AVRDC and other sources of improved genetic materials.

3.1 ASSESSMENT OF PEST TOLERANCE

3.1.1 *Evaluation of eggplant genotypes*

Over 30 accessions assembled from the Indian Vegetable Research Project (IVRP), Varanasi and other sources were planted at Mbita Point Field Station under pesticide-free conditions. At the vegetative stage there was no appreciable natural pest infestation. During the reproductive stage, borers (mainly *Helicoverpa armigera)*, caused fruit damage. Three accessions that were found promising for combining higher yield potential with relatively low/moderate fruit damage were PPR, Arka Shrish and Pusa Hybrid.

Besides conserving the promising genotypes for further evaluation, seeds for the full set of genotypes were also shared with the African Regional Programme of AVRDC for enabling their further evaluation and utilisation.

3.1.2 *Adaptation testing of okra genotypes*

A total of eight okra genotypes, including four from IVRP, were evaluated for pest infestation levels and yield potential under pesticide-free conditions at the Muhaka coastal research station of ICIPE during 1999. The results showed that the variety Kangwane was on a par with the locally popular variety Pusa Sawani with respect to yield potential, while pest damage to fruits was relatively lower than in the variety Anamike. Further field evaluation in the same site continues.

4. DEVELOPING A RANGE OF BIOLOGICAL CONTROL OPTIONS

Studies were initiated to assess the relative efficiency of locally available *Bacillus thuringiensis (B.t.)* products for control of two key lepidopteran pests, *Plutella xylostella* and *Helicoverpa armigera*. A new *B.t.* product, Greenguard, received from China (*B.t.* Research and Development Centre, Hubei), was also included in the evaluations.

4.1 TESTING OF *B.T.* PRODUCTS FOR CONTROL OF *PLUTELLA XYLOSTELLA*

4.1.1 *Laboratory testing on* Plutella xylostella

The efficacy of various *B.t.* products against the diamondback moth, *P. xylostella* on cabbage was investigated in a laboratory bioassay. This involved rearing the insect culture collected from the Jomo Kenyatta University of Agriculture and Technology, Nairobi (JKUAT) farm. Cabbage leaf discs were sprayed with the recommended rates of the *B.t.* products, allowed to dry in the air, and then placed in Petri dishes. Ten 2-day-old larvae were placed in each Petri dish on the treated leaves and larval mortality recorded daily from the first to the sixth day after treatment. Two synthetic insecticides (bifenthrin and fenitrothion) and a botanical product (neem oil) were included for comparison. The control was sprayed with distilled water alone and the treatments were replicated four times.

The pattern of daily cumulative mortality (Figure 4.1.1) showed that among the four *B.t.* products, Dipel and Greenguard produced marginally greater mortality than the other two products from days 2 to

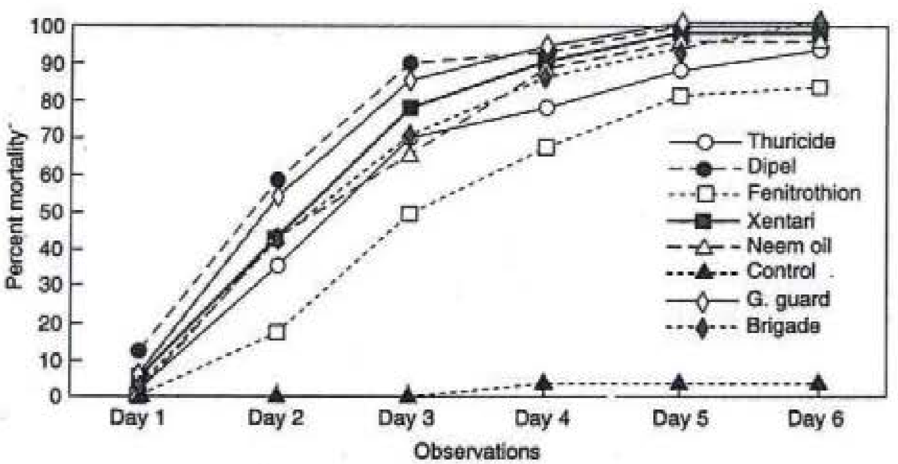

Figure 4.1.1 Cumulative daily mortality of *Plutella xylostella* on cabbage due to *Bacillus thuringiensis* products tested. Laboratory assay, ICIPE, 1999

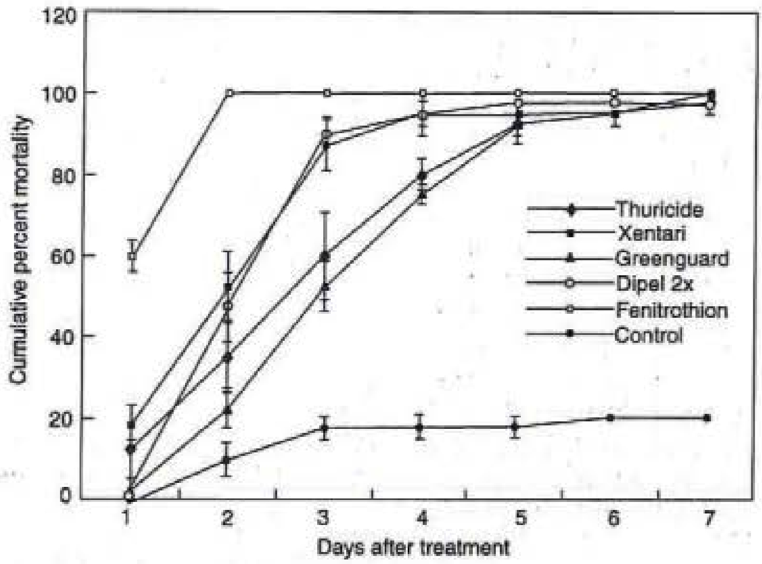

Figure 4.2. Percent mortality of second instar *H. amigera* treated with *B.t.* products. Laboratory assay, ICIPE, 1999

4. However by day 5, the mortality levels were not significantly different. All the four *B.t.* products recorded significantly greater mortality than the untreated (control) set from day 2 onwards. Of the *B.t.* products, Dipel was significantly superior to the neem product in cumulative mortality at day 3. Dipel and Greenguard were also on a par with the synthetic insecticide by day 2, while the other two *B.t.* products were at par from day 3 onwards. The results indicate the satisfactory pest control potential of the *B.t.* products on *P. xylostella*. Further testing under field conditions was therefore undertaken.

4.1.2 *Field testing of* B.t. *products on* P. xylostella *in cabbage*

A field trial for assessing the performance of *B.t.* products was undertaken in cabbage planted in JKUAT in 1999. A regime of the 5 weekly sprays was applied and the pest infestation recorded periodically.

The insect infestation was significantly reduced by the *B.t.* and other treatments from the third count onwards, compared to the non-sprayed (check) plots. A significant reduction in leaf damage was also observed in plots treated with the *B.t.* products and also with the chemical and botanical treatments, even from the second count. Larval infestation in plots treated with the four *B.t.* products was usually on a par with both the chemical insecticides. The *B.t.* products were also significantly more effective than with the botanical check (neem). The test product Greenguard was mostly at par with the other three commercial *B.t.* products. These results indicate the satisfactory potential of the *B.t.* products for field use in control of *P. xylostella* on cabbage. The yield data could not be recorded due to disease attack in the crop, but will be considered in further trials for assessing the potential of *B.t.* to affect the value of the produce.

4.2 LABORATORY ASSAY OF *B.T.* PRODUCTS ON *HELICOVERPA ARMIGERA* HBN. LARVAE

The four *B.t.* products (Thuricide, Xentari, Greenguard and Dipel) were compared with the chemical insecticide (fenitrothion) for their relative efficacy in causing mortality to *H. armigera* larvae in a laboratory bioassay. The results showed that larval mortality reached over 50% for all *B.t.* products from day 3 (Figure 4.2). Significant differences in mortality were observed between the *B.t.* treatments and the untreated (control) set, even on the first day after treatment. The chemical insecticide produced the greatest percentage kill of *H. armigera* larvae, beginning at day 1. It was evident that while all the *B.t.* products gave good control of *H. armigera* larvae within 4 days after treatment, Xentari and Dipel 2X appeared slightly more effective than Thuricide and Greenguard in causing early mortality. From day 5 onwards, the percentage mortality for all the *B.t.* products were at par with that of the chemical (fenitrothion). These results will be followed up with field testing of the *B.t.* products in controlling *H. armigera* on vegetable crops.

4.3 EVALUATION OF NATIVE BACULOVIRUSES (NPV) FOR BIOCONTROL OF *H. ARMIGERA*

4.3.1 *Survey of natural field occurrence of NPV in Kenya*

Visits were made to various parts of the country in 1998–1999 to collect samples of field populations of *H. armigera* larvae for incubating in the laboratory. A number of native, nuclear polyhedrosis virus (NPV) isolates were obtained from the larvae collected from various agroecological zones and different host plants (Table 4.3.1). The results indicate that this insect pathogen occurs naturally in many parts of the country

Table 4.3.1. Pilot survey for natural occurrence of baculovirus (NPV) in *Helicoverpa armigera* larvae in Kenya, 1998–1999

Site	Crop	Number of *H. armigera* larvae		Incidence of virus (%)
		Sampled	Infected by virus	
Juja (JKUAT)	Chick pea	168	44	26.2
	Tomato	-	-	-
Kiboko	Pigeon pea	21	3	14.3
Kibwezi	Pigeon pea	116	26	22.4
	Capsicum	6+	1	16.7+
	Egg plant	50	10	20.0
	Sweet corn	84	17	20.2
	Tomato	31	6	19.4
Kilifi	Pigeon pea	5+	2	40.0+
Malindi	Lablab	48	15	31.3
Mbita	Pigeon pea\	29	2	6.9
Mtito Andei	Tomato	30	3	10
Nairobi (KISE)	Pigeon pea	40	6	15.0
	Chick pea	184	23	12.5
Nguruman	Okra	56	13	23.2
Shimba Hills	Tomato	17	4	23.5

+Limited sample size.

and may also be playing a role as a natural enemy of this pest.

4.3.2 *Field trial of Kenyan NPV isolate in control of* H. armigera *Hbn.*

One of the Kenyan local NPV isolates was tested in the field for control of *H. armigera* on vegetable pigeon pea crop. The treatments compared were polyhedral suspensions of NPV (with and without 1% molasses) and lambdacyhalothrin (Karate®). The trial was laid out in a randomised complete block design replicated four times, with the unsprayed control as a check treatment. Larval numbers of *H. armigera* in the plots were not counted, since destructive plant sampling could not be undertaken; the data were therefore limited to *H. armigera*-damaged pods and the damage yield of seeds.

There were significant differences in the mean number of healthy pods among the treatments (Figure 4.3.2). The least pod damage by *H. armigera* was apparently achieved with the chemical (Karate®) followed by NPV + 1% molasses. NPV alone also resulted in appreciable reduction in pod damage compared to the control. The damage-free seed yield

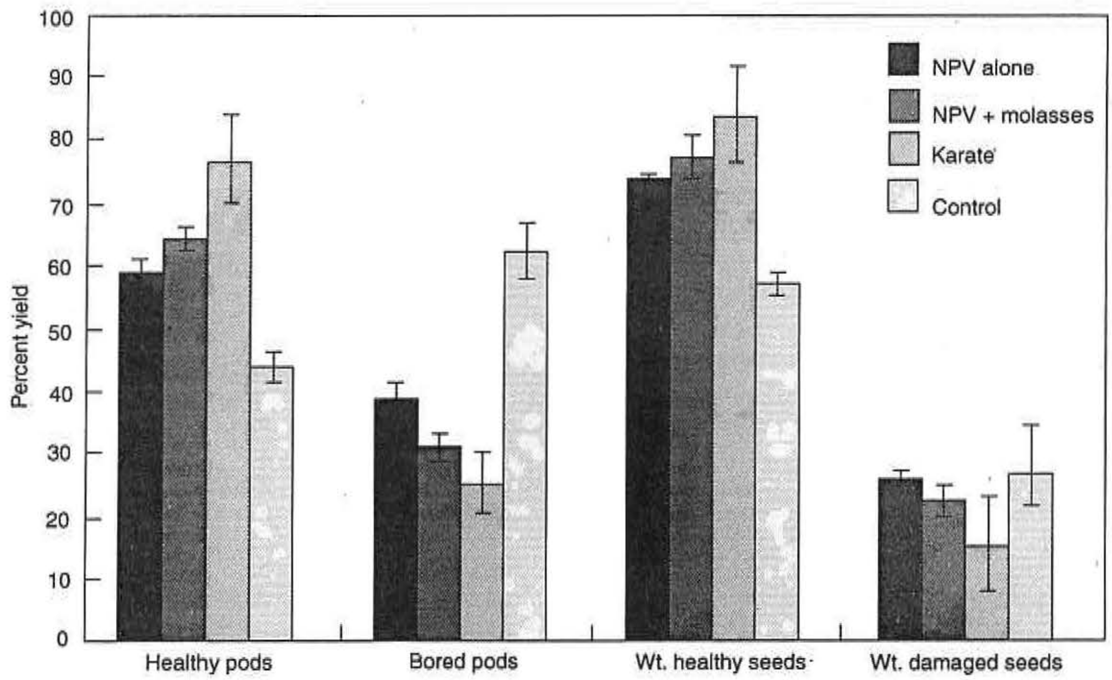

Figure 4.3.2. Percent pod and seed yield per 20 plants in vegetable pigeon pea treated with NPV. Preliminary field efficacy te

was greatest with the insecticide but was also significantly greater in NPV-treated plots than in the non - protected plots. These results confirmed the potential for using Kenyan NPV isolates for control of *H. armigera*.

4.4 EVALUATION OF NATIVE EGG PARASITOIDS FOR BIOCONTROL POTENTIAL

This study was aimed at selecting promising native species of egg parasitoids (mainly *Trichogramma*) as potential biocontrol agents for two key vegetable pests: *Plutella xylostella* and *Helicoverpa armigera*. Mass rearing and inundative releases of such parasitoids could be a promising biocontrol component of IPM for vegetable crops.

4.4.1 *Survey for native egg parasitoids*

A survey for native egg parasitoid species undertaken in Kenya during 1998–1999 has so far resulted in 96 collections: 48 of *P. xylostella*, 43 of *Chilo* spp. and 5 of *H. armigera* (Table 4.4.1). Their identification to species level is being ascertained in collaboration with the University of Hohenheim, Germany.

4.4.2 *Lifetable study of native* Trichogramma *species*

The main objective of this lifetable study was to select promising species of *Trichogramma* on the basis of population parameters like the intrinsic rate of natural increase, the net reproductive rate and the finite population growth rates. Lifetables were constructed using a cohort of 60 adult females of *Trichogramma* sp. nr. *mwanzai* Schulten and Feijen and *Trichogramma bournieri* Pintureau and Babault at the Federal Biological Research Centre for Agriculture and Forestry, Institute for Biological Pest Control (FBRCAF) (Darmstadt, Germany) in 1999. The native *Trichogramma* spp. were collected from maize crops at Muhaka, Mombasa and Mbita, Lake Victoria.The most important population parameters were recorded.

4.4.3 *Effect of temperature on local and exotic* Trichogramma *species*

The adaptation of locally occurring and exotic *Trichogramma* egg parasitoid species to different temperature regimes was evaluated at the FBRCAF in 1999. The study made use of 60 female mated 0–24-hour-old individuals of *T.* sp. nr. *mwanzai* and *T. bournieri*, as well as the exotic species *T. chilonis* Ishii and *T. evanescens* Westwood. The adults were compared for their parasitism and progeny production potential under four regimes of temperature (13,18,25 and 34°C) and 70± 10% RH, 16:8D photoperiod. For each individual female parasitoid,fresh *Sitotroga cerealella* eggs (ca 150–175) were offered in a vial for a period of 4 hours. The eggs were then withdrawn and observed to record the rate of parasitism.

Among the four egg parasitoid species compared (Figure 4.4.3), *T. bournieri* resulted in the greatest parasitism at 18°C, while *T. evanescens* fared better at 13° and 25°C, with *T.* sp. nr. *mwanzai* recording the greatest parasitism at 34°C. The source of *T.* sp. nr. *mwanzai* was coastal Kenya, and it would be useful to ascertain if its relative adaptation to the higher temperature regime is reflected by the ecology of its area of origin. The trend in progeny production by the four species was comparable to the parasitism levels observed. Further studies on comparing the relative attributes of performance of the native and exotic parasitoids are in progress.

Table 4.4.1. Results of survey for native egg parasitoids, Kenya 1998–1999

		Parasitism		Parasitoid emergence	
Site	Host plant	No. of parasitised eggs+	% parasitism	No. of egg parasitoid adults	% emergence
Kasarani (Nbi)	Tomato	5	3	3	60
Kibwezi	Maize	29	19	13	44
	Maize	11	7	7	63
Mtito Andei	Sukuma wiki	2	1	2	100
	Maize++	11	7	8	72
	Maize	66	44	22	33
	Maize	70	46	45	64
	Maize	35	23	27	77
	Maize	75	50	52	69
Muhaka	Sukuma wiki	4	2	2	50
	Maize	83	55	64	77
Shimba Hills	Maize	42	28	28	66
	Maize	3	2	1	33
	Maize	56	37	31	55

+ Mean number of *Corcyra cephalonica* eggs per egg card is 150.
++Recovered from transect survey 1.

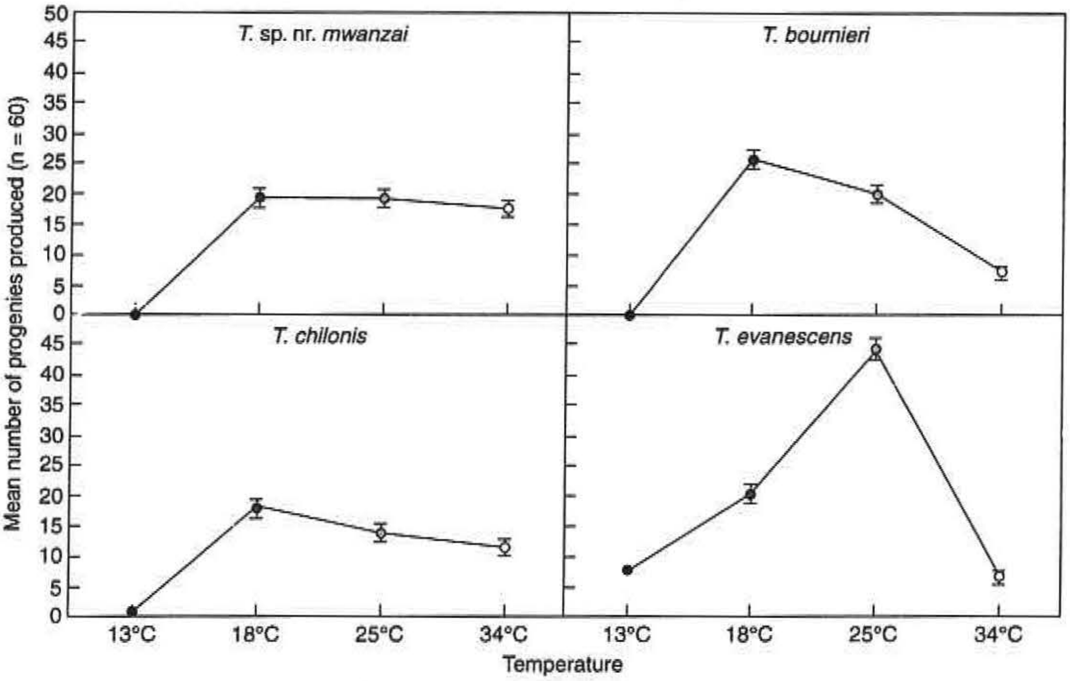

Figure 4.4.3. Mean number of host eggs successfully parasitised per adult female of four *Trichogramma* spp. egg parasitoids

5. BOTANICALS

5.1 NEEM PRODUCTS FOR CONTROL OF APHIDS AND DIAMONDBACK MOTH ON CABBAGE

Cabbages are commonly grown for local and urban markets in the region and are usually attacked by two destructive pests, namely aphids and the diamondback moth (DBM), *Plutella xylostella* L. These two pests, cause damage to the cabbage heads, reducing the growers' profit margins through price reduction or rejection in the market. The present study was initiated to assess the potential of two new products developed from neem, *Azadirachta indica* in controlling these pests. The neem products (neem powder, 0.5% azadirachtin; neem oil, 0.03% azadirachtin) were developed recently with quality control back-up from ICIPE.

A field trial was conducted at KISE, Kasarani, Nairobi to compare these two products with a chemical insecticide lambdacyhalothrin (Karate) and a *B.t.* biocontrol product (Dipel). The latter is known to be effective against DBM. The products were applied as high-volume sprays and the level of pest infestation was recorded a week after each spray by visual rating. The number of pest-damaged heads of cabbage and the yield of marketable (damage-free) heads per plot were recorded.

Comparing the two neem products, neem oil (one dose) provided marginally better control of aphids and caterpillars than neem powder (two doses). Both neem products caused a significant reduction in DBM infestation levels. Treatment with neem oil resulted in a reduced number of pest-damaged cabbage heads per plot, comparable to the two check treatments (lambdacyhalothrin and *B.t.*). Both neem products resulted in significantly greater yield of marketable (damage-free) cabbage heads than the non-protected crop. Use of neem oil resulted in a significantly greater marketable yield than neem powder. The former was exceeded only by the chemical insecticide treatment in improving the marketable yield. Further trials are planned to evaluate the neem products at lower dose rates and to compare their economic benefit in pest control.

5.2 TESTING NEEM PRODUCTS FOR THRIPS CONTROL IN FRENCH BEAN

Thrips (*Megalurothrips sjostedti* and *Frankliniella occidentalis*) are important pests in French bean, as they result in loss of both yield and quality, due to the blemishes they cause on pods.

The neem products were tested as seed treatment, soil application and spray, to determine their effect on thrips infestation. It was observed that while neem as seed treatment or soil application did not result in appreciable control, spray application of neem appeared promising, with neem oil being marginally more efficacious. The extent of thrips control was comparable on the adults of *Frankliniella* and *Megalurothrips*, as well as on the larval stages of the two species. Spray application resulted in more exportable blemish-free pods at harvest than either the seed- or soil-treatments with neem products.

6. SAFETY OF NEEM TO NATURAL ENEMIES

While the use of neem products in vegetable crops is regarded as a promising pest control option, the relative safety to key natural enemies needs to be ascertained and compared with commonly used synthetic insecticides. Observations were made on the indirect effects of neem use on cabbage for controlling the diamondback moth and on French bean for flower thrips.

6.1 EFFECT OF NEEM PRODUCTS ON A FRENCH BEAN ECOSYSTEM

Two field trials were performed on the use of neem products for thrips control in French bean at JKUAT. The relative abundance of *Orius* sp., a common predator of thrips, was monitored in plots receiving different neem treatments. The results (Table 6.1) showed that while synthetic insecticides tended to substantially reduce the population of this predator, the neem products had only a limited, if any, adverse effect on their numbers. Since the relative abundance of *Orius* sp. is also likely to be influenced by the numbers of prey (thrips) available, further evaluation to distinguish these effects are being considered.

Observations of other predators, *Anthocoris* sp. and ladybird beetles, and the parasitoid *Ceranisus menes* confirmed that the neem products appeared to be safer to these non-target organisms, even at the high dose rates tested, than the synthetic insecticides.

6.2 EFFECT OF NEEM ON LARVAL PARASITOIDS OF DBM IN CABBAGE

The present study focused on the effect of two neem products on field parasitism by three hymenopteran larval parasitoids of *P. xylostella* in a cabbage ecosystem. The field trial was conducted at JKUAT farm in Juja, Kenya in 1999. Two neem products, NKCP (with 0.5% azadirachtin at 25 g/litre) and neem oil (0.03% azadirachtin at 15 ml/litre), were compared as sprays with non-sprayed (control) plots in a RCBD design with 6 replications. The neem products were applied with manual knapsack sprayer in several weekly applications. Samples of DBM larvae were collected from the different plots at weekly intervals after each spray. The results (Figure 6.2) showed that parasitism by *Diadegma* sp. was not appreciably affected by either of the neem products. In the case of *Oomyzus* sp., there appeared to be some adverse effect from neem oil, but not with NKCP. The overall parasitism by *Cotesia* sp. was very low, and yet NKCP appeared marginally safer than neem oil to this parasitoid.

These studies, although undertaken with high dosages of neem, have indicated the apparent safety of at least one product (NKCP). The variation among parasitoid species with respect to tolerance to the neem products has been demonstrated. Further studies are being pursued using lower dosages of neem . *(See also the following report on Neem.)*

7. NETWORKING WITH NARS FOR IPM DEVELOPMENT AND CAPACITY BUILDING

For developing IPM options for control of pests on vegetable crops, an ICIPE partnership has been

Table 6.1. Non-target effect of neem on the predator (*Orius* sp.) of thrips in French bean, 1999

Treatment	29 DAE Mean ± SE	33 DAE Mean ± SE	36 DAE Mean ± SE	40 DAE Mean ± SE	43 DAE Mean ± SE	47 DAE Mean ± SE	50 DAE Mean ± SE
Seed treatment							
NKCP/wannin	5.00 ± 1.41 a	5.00 ± 1.41 a	12.50 ± 1.44 ab	14.50 ± 1.19 a	13.00 ± 3.00 a	6.50 ± 0.65 ab	6.00 ± 0.91 ab
Gaucho	3.00 ± 1.73 ab	3.00 ± 1.73 ab	8.00 ± 0 b	14.00 ± 2.89 a	9.67 ± 1.86 a	3.67 ± 0.67 bcd	4.33 ± 0.67 b
Soil application							
NKCP	5.25 ± 1.03 a	5.25 ± 1.03 a	10.25 ± 0.48 b	15.50 ± 2.22 a	12.75 ± 1.60 a	5.75 ± 0.48 abc	4.50 ± 0.50 b
Furadan	3.75 ± 1.32 ab	3.75 ± 1.32 ab	8.75 ± 0.95 b	12.25 ± 1.49 a	11.25 ± 1.49 a	5.00 ± 0.58 bc	3.75 ± 0.63 b
Spray application							
NSO	3.50 ± 1.04 ab	3.50 ± 1.04 ab	8.50 ± 0.65 b	6.00 ± 1.08 bc	8.25 ± 1.65 ab	2.50 ± 0.29 cd	16.00 ± 0.58 ab
NKCP/WE	2.75 ± 0.25 ab	3.00 ± 0.41 ab	8.00 ± 1.73 b	7.25 ± 1.03 b	7.00 ± 0.41 ab	3.25 ± 1.25 bcd	4.75 ± 0.63 ab
Karate	0.75 ± 0.48 b	0.75 ± 0.48 b	3.00 ± 0.41 c	2.50 ± 0.87 c	2.75 ± 1.11 b	1.50 ± 0.50 d	0.75 ± 0.25 c
Control							
No spray	5.75 ± 0.95 a	5.75 ± 0.95 a	16.25 ± 0.95 a	16.00 ± 1.68 a	11.75 ± 2.02 a	8.75 ± 0.63 a	7.50 ± 0.96 a
Mean	3.74	3.77	9.45	10.9	9.55	4.65	4.71
CV%	46.6	45.54	76.65	17.5	30.72	30.65	26.58

Means followed by the same letter in the same column are not significantly different at P=0.05% (REGWQ).

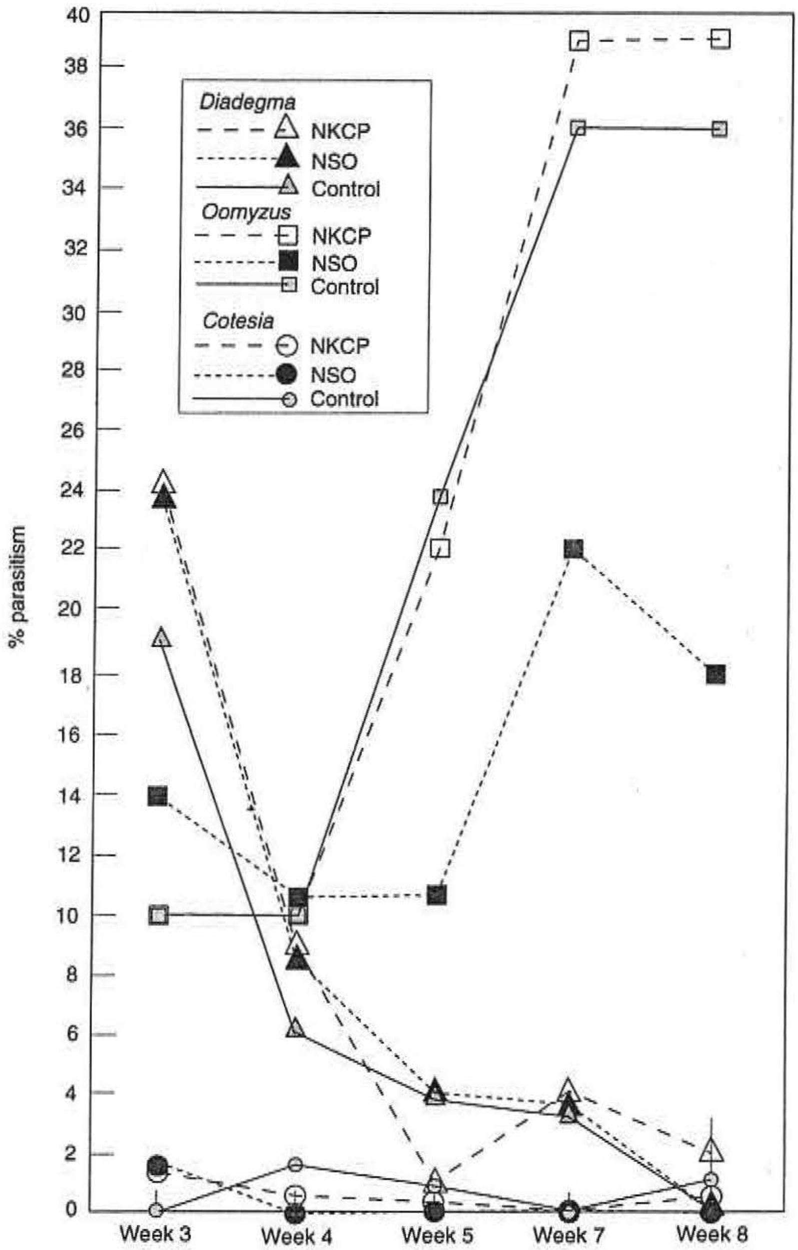

Figure 6.2. Field parasitism by three larval parasitoid species on *Plutella xylostella* in response to neem application on cabbage; JKUAT, 1999

initiated with scientists from NARES of four countries—Kenya, Ethiopia, Tanzania and Uganda. The major thrust of this initiative is to evolve suitable local models for IPM awareness-building among smallholder farmers. The models utilise many of the features of the Farmers' Field School (FFS) approach in order to cater for local needs. The focus is on enabling farmers to identify their own pest problems and to shift from reliance on synthetic pesticides to safer IPM options like biocontrol and botanicals.

7.1 IPM AWARENESS-BUILDING MODEL DEVELOPMENT

The complementary role of farmers as local trainers and creation of awareness are seen as important aspects in the dissemination of IPM options at local community level. The development of suitable models featuring trained farmers as second line extensionists in implementing group learning through the Farmers' Field School approach is an important focal theme of this project. This section describes start-up activities in year 1 of this project and the results of a baseline survey undertaken in the four partner countries to determine the knowledge, attitude and practices (KAP) of the participating farmers.

7.1.1 *Identification of participating farmers' groups*

The NARES teams in the partner countries were assisted in identifying groups of vegetable farmers (2–4 groups per country) for participating in the project activities.

The criteria used for the identification of the groups were:

- involvement of farmers in the production of vegetables for income generation;
- functional linkages among the participating farmers in the group;
- willingness to involve themselves in group learning activities on IPM;
- commitment to the 'self-help' strategies being promoted by the project;
- proximity to the participating NARES research institution.

The extension and research officials of the local co-ordinating institutions held start-up consultations and briefings with the farmers' groups on the project's goals and the participatory IPM awareness-building activities proposed. Altogether, a total of 246 smallholder vegetable farmers, including 72 women, in the 13 groups were identified for participation, with each country having between 2–4 groups.

7.1.2 *Establishment of local IPM advisory panels*

The establishment of IPM advisory panels was also completed in the four partner countries. The membership of the panel includes research specialists—entomologist, pathologist, agronomist/ breeder, social scientist and postharvest technologist—in addition to representatives from extension and farmers' groups. These panels function as the local 'think tank' by advising the local co-ordinator in the prioritisation and selection of IPM options, as well as providing back-up for the training and group learning activities. The panel members are the main resource persons for training of local trainers in each of the partner countries. The panels meet periodically to plan and review the progress of the project activities and to advise on the up-coming tasks and policy/ priorities relating to IPM activities. The farmers' representatives in the panels provide the feedback and input in planning the participatory activities.

7.1.3 *Baseline survey of farmers' knowledge, attitudes and practices*

Gender roles in farming and local decision-making

Within the participating farm families, the relative gender roles in farming operations were analysed. In farming activities, the involvement of men and women was found to be shared in some operations like land preparation, digging holes, planting nurseries, transplanting and application of fertilisers and manure. Women alone were involved in gap filling and thinning, watering of crops and harvesting, while men alone attended to pest control operations and scaring off of wild animals. Children assisted in land preparation, watering of crops and harvesting. Transporting the produce for marketing was the domain of women. Hired labour was only used for land preparation, since it is labour-intensive and needs additional hands to complete in a limited time.

The roles of female and male family members with respect to access to farm resources and decision-making were also examined.

Access and control of farm resources by gender

Survey results from Kenya showed that both men and women farmers had access to all the major farm resources. However, while decisions are made by both, men tend to have wider control of the resources than women. Men seemed to have exclusive control over utilisation of land, participation in training, purchase of pesticides for pest control and dealing with cash incomes. However, decisions are usually made jointly by men and women on how to utilise cash earned from the produce and on who will attend training.

Awareness among farmers on names of pests and their symptoms

The survey results point out that there is a gap in farmers' awareness of pest/disease problems, more so for the export-oriented vegetable crops. In general, it was observed that except for tomato, the majority of farmers in the target countries were not aware of the name of even one pest occurring on each of the other seven income-generating vegetable crops grown in the region for urban/export markets (Figure 7.1.3a).

The extent of awareness of the common pest problems in different vegetable crops in terms of recognising them by name was found to be low to moderate and varied among the vegetable crops (Table 7.1.3a). Awareness of the names of insect pests was greater among the more commonly grown vegetables like tomatoes, cabbage and onion than among those grown for export, such as French bean, okra, brinjals (eggplant) and cucurbits, the exception being capsicums. Among the individual crops, more farmers knew tomato pests by name in all the countries, while okra pests were the least known.

Farmers' awareness of pest damage symptoms

The proportion of farmers expressing awareness of symptoms of pest damage also differed for the vegetable crops and with each farmers' group in the different countries. Table 7.1.3b and Figure 7.1.3b illustrate the extent of recognising pest damage through symptoms on the crops. The trend was of limited awareness about pests of common urban market vegetables and of virtually no awareness about pest symptoms on export market vegetables. Even for tomato, only about half of the farmers expressed awareness, while for the other crops, about 30% or less were aware.

Sources of advice on pesticide use

The survey indicated that the predominant source of advice on pesticide use available locally to farmers was from the agro-input shops or local pesticide stockists (Table 7.1.3c). To some extent, farmers also accessed information from neighbouring farmers. Not many farmers seemed to receive advice from the extensionists. Some depended on labels or technical

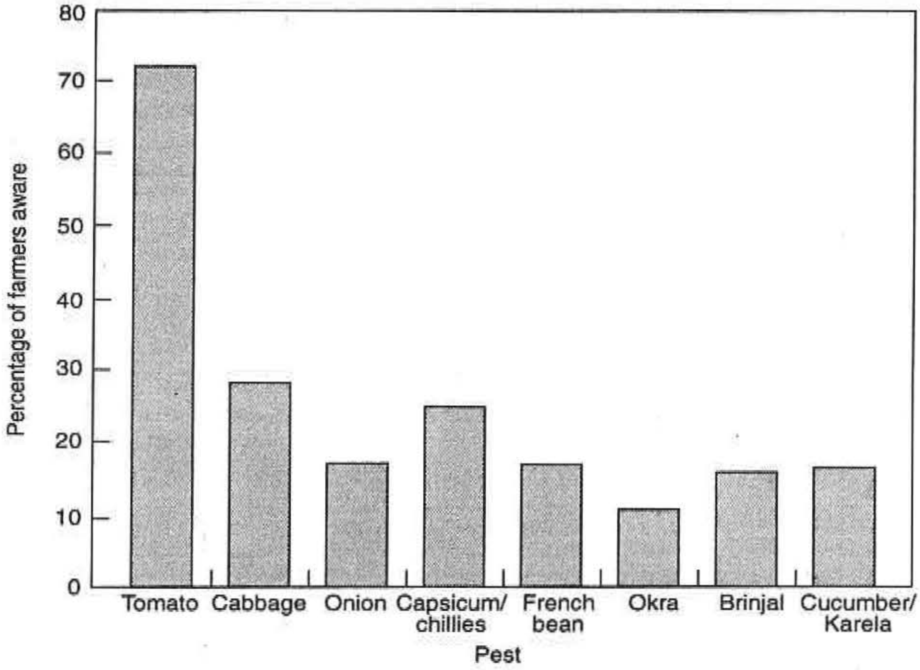

Figure 7.1.3a. Percentage farmers aware of names of pests occurring in major vegetable crops. Survey in four countries in eastern Africa, 1998–1999

Table 7.1.3a. Farmers' awareness of names of pests on different vegetable crops. Survey in four countries in eastern Africa 1998–1999

Crop	Percentage of aware farmers			
	Kenya n=60	Uganda n=60	Tanzania n=50	Ethiopia n=30
Tomato	77	40	87	83
Cabbage	22	22	23	48
Onion	5	7	8	48
Capsicum/ chillies	7	31	31	0
French bean	31	2	0	0
Okra	0	7	13	0
Brinjal/ eggplant	12	18	15	0
Cucumber	13	2	33	0

handouts. Evidently a good proportion of farmers did not have adequate access to dependable and precise advice on choice of pesticide for use in relation to the specific pest problem on the target crops. This observation helps to reaffirm the importance of strengthening farmers' access to technical information relating to appropriate and selective use of pesticides at local level.

One major concern among participating farmers is their perception that pesticide use on the different income generating vegetables is indeed becoming more expensive. Comparing the survey year (1998/99) with the scenario 3 years previously (1995), when the intensity of pesticide use was apparently less, 200 farmers surveyed were under the impression that it was not so expensive to use pesticides then. This observation also corresponds with the overall impression of farmers that pesticide use is apparently less effective 'now' than 3 years ago, as indicated in the responses by groups in the four countries.

The farmers' perception of the high expense of pesticide use could be due to the increased frequency/

Table 7.1.3b. Farmers' awareness of symptoms of pest damage on different major vegetable crops. Survey in four countries in eastern Africa, 1998–1999 (in percent)

Crops	Percentage of aware farmers			
	Kenya n=60	Uganda n=60	Tanzania n=50	Ethiopia n=30
Tomato	60	40	75	80
Cabbage	13	20	13	73
Onion	2	7	8	44
Capsicum/chillies	9	33	18	31
French bean	17	2	0	0
Okra	0	7	10	8
Brinjal/eggplant	10	16	11	0
Cucumber/karela	7	0	26	0

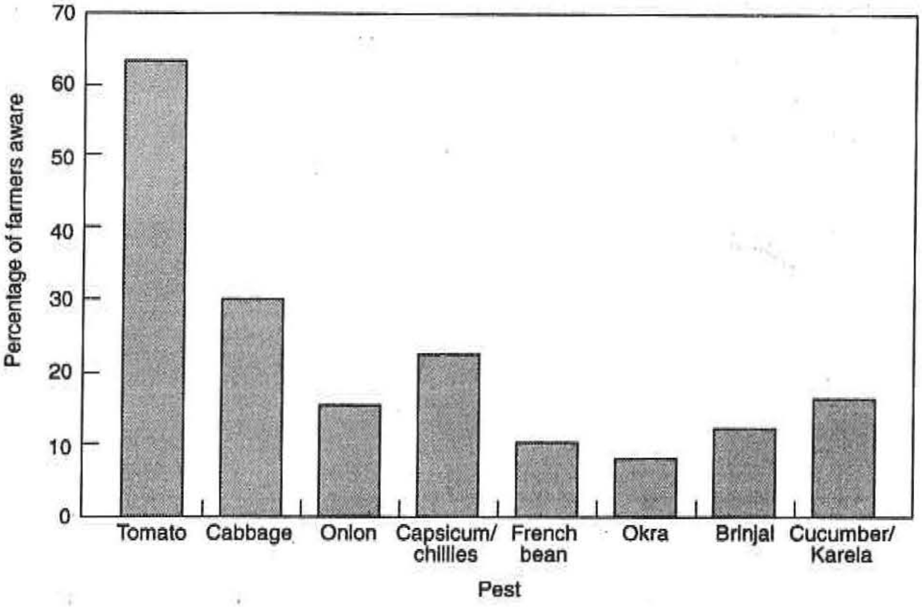

Figure 7.1.3b. Awareness of farmers of pest symptoms occurring in major vegetable crops. Survey in four countries in eastern Africa, 1998–1999

Table 7.1.3c. Sources of information/advice on pesticide use available locally to vegetable farmers. Survey in East Africa, 1998–1999

	Number of farmers reporting			
Sources of information	Kenya n=60	Uganda n=60	Tanzania n=40	Overall N=160
Stockists/dealers	20	20	15	55
Neighbouring farmers	12	18	13	43
Pesticides labels	20	–	8	28
Extensionists	4	12	2	18
Meetings/ seminars	4	5	–	9
Technical handouts	–	2	1	3
Other sources	–	3	1	4

Table 7.1.3d. Insecticide usage on vegetable crops. Survey in four countries in eastern Africa, 1998–1999

Pesticide		Percentage of farmers using pesticides				
Common name	Trade name	Kenya (n=60)	Ethiopia (n=30)	Tanzania (n=50)	Uganda (n=60)	Overall (N=200)
Permethrin	Ambush	33	–	–	55	22
Mercaptothion	Malathion	11	72	–	–	20
Lambdacyhalothrin	Karate	25	10	40	–	18
Endolsulfan	Thiodan	3	13	35	–	12
Dimethoate	Rogor	25	6	3	8	6
Diazinon	Diazinon	13	17	–	–	6
Chlorpyrifos	Dursban	–	3	7	10	5
Carbofuran	Furadan	5	–	–	2	2
Cypermethrin	Sherpa	–	–	–	8	2
Bifenthrin	Brigade	3	–	3	–	1
Carbosulfan	Marshal	2	–	–	–	0.5

dosage needed to derive satisfactory control, which is probably due to the build-up of pesticide resistance among pests, since some pesticides are being repeatedly (and often indiscriminately) used. Another possible reason for the escalation in pesticide use costs might be the apparent increase in the overall severity of pest infestation due to killing of the natural enemies like parasitoids and predators on account of the overuse and misuse of pesticides on the farm. It is possible that some of the farmers have already fallen into the pesticide 'treadmill'. They should now be made aware of the need to shift to the rational use of pesticides and to evaluate and adopt alternative control methods.

COMMON PESTICIDES USED BY FARMERS AND AFFORDABILITY OF PESTICIDE USE

The survey revealed that several chemical insecticides were being used for pest control with varying frequency on vegetable crops (Table 7.1.3d). These include a range of synthetic pyrethroids as well as organophosphates, carbamates and even organochlorines. It was evident during group discussions, however, that farmers' awareness of the choice of the appropriate pesticides to control the individual pests and diseases on the vegetable crops and of the correct dosage was mostly inadequate. The farmers' group discussions during this survey also confirmed that they were desperately looking for local guidance, especially on the correct choice of pesticides and the correct dose for achieving effective control of the most important individual pests.

7.2 TRAINING OF FRONT-LINE TRAINERS IN IPM AND PARTICIPATORY METHODS

Farmers were able to identify their own information needs in several topics based on the constraints they experienced. These included aspects of crop production and protection (Table 7.2a). While crop management technologies appeared to be their priority, three major areas relating to crop protection —appropriate pesticides, correct method and dose of application, as well as capacity for correct identification of pests—were apparently next in priority. Such a listing of their different information needs was very helpful in planning the group learning and training sessions of local trainers, to cater specifically to each group's information needs.

Each farmers' group elected 2–3 farmers among them to be trained as 'second-line extensionists' in preparation for the season-long group learning activities. This farmers' cadre of trainers participated in 2- to 3-day pre-season training workshops and was envisaged to cater to the local need for technical information/guidance. The main knowledge areas for year 1 learning sessions were (i) the correct diagnosis of the common pest and disease problems on the major vegetable crops, and (ii) how to select and use pesticides more appropriately and safely.

The 'Training of Trainers' sessions for year 1 activities was completed in all the partner countries. The farmers' own cadre of elected trainers (2–3 per group) together with extensionists working with these farmers groups (a total of 9–12 per country) were trained on various topics identified by the beneficiaries. These trainers were requested to bring with them locally collected samples and specimens of insect pests and diseased plant parts for symptom identification. Topics chosen for the training were handled by the relevant IPM advisory panel members and experts from other projects and institutions. The training was structured into practical and theory sessions. In the practical sessions, the trainees were assisted in correctly identifying the different common insect pests, natural enemies and plant diseases on the major crops. They were also introduced to the need and scope for adopting improved pest (insect, disease and weeds) management strategies. The trainers were initially subjected to a pre-training assessment to test their knowledge on the various aspects of pest control on vegetable crops. A similar exercise was undertaken after the training sessions to assess their knowledge status. A summary of the training impact assessment in three partner countries is shown in Table 7.2b.

It was observed that the knowledge and awareness of the trainees was substantially improved due to the training received on several aspects of IPM.

Table 7.2a. Topics of technical information identified as priority needs by farmers growing income generating vegetable crops. Survey in four countries in eastern Africa, 1998–1999

Technical information topics	Number of farmers identifying the need				
	Kenya (n=60)	Ethiopia (n=30)	Tanzania (n=50)	Uganda (n=60)	Overall (N=200)
Information on improved crop management practices	35	2	24	29	90
Appropriate choice of pesticides	32	6	7	10	55
Correct identification guidance of pests and their symptoms	28	4	7	13	53
Pesticide application method and dosage	17	12	1	13	43
Advice on safe handling of pesticides	–	–	–	16	16
Improved supply of quality seeds	4	12	–	–	16
Dependable source of pesticide	–	12	1	2	15
Fertiliser application practices	5	1	1	1	8
Alternatives to chemical pesticides	3	1	1	1	6
Record keeping on pests and their control	1	–	–	2	3
Crop rotation practices	1	–	1	–	2

Table 7.2b. Impact assessment of training of trainers (farmers cadre and extensionists) in Kenya and Uganda, 1998–1999)

	% trainers with awareness+			
	Uganda		Kenya	
Aspects related to IPM	Pre-training	Post-training	Pre-training	Post-training
Knowledge of pests (insects, diseases and weeds)	58	92	100	100
Knowledge of damage symptoms	42	67	92	92
Knowledge of pest life cycle	33	50	83	92
Knowledge of pre-harvest waiting periods	50	67	54	62
Knowledge on safe use of pesticides	58	67	92	100
Knowledge of safer pest control methods	42	58	62	92
Knowledge of beneficial insects	50	50	62	100

Table 7.3. Women's participation in various project activities

Role/activity	% women involved
Farmers in group learning activities	
Kenya (n=15)	3
Tanzania (n=14)	73
Uganda (n=12)	13
Participation in training as local trainers	
Farmers' cadre (n=20)	21
Local extensionists (n=12)	9
Involved as resource persons	
In IPM advisory panel (n=48)	24
In training of trainers (n=30)	21
Involved as local coordinators for NARES partners (n=4)	50

7.3 WOMEN'S PARTICIPATION IN PROJECT ACTIVITIES

Efforts were made to encourage the participation and involvement of women, not only among the farmers' groups but also in training and other activities, as illustrated in Table 7.3.

Capacity building

PhD training (ARPPIS Programme)

Abera T. Haile (Kenyatta University): Research on 'Evaluation of native egg parasitoids for biological control of *Helicoverpa armigera* and *Plutella xylostella*'.

Anne M. Akol (Kenyatta University): Research on 'Studies on tritrophic interactions on use of neem with larval parasitoids *Plutella xylostella*'.

MSc training (DRIP Programme)

Ruth K. Gathu (Kenyatta University): Research on 'Evaluation of bioefficacy and non-target effect of neem in French bean ecosystem'.

Charles M. Matoka (Kenyatta University): Research on 'Assessment of pest spectrum and yield loss due to pests in cucurbit crops'.

Samuel K. Muchemi (Kenyatta University): Research on 'Assessment of pest spectrum and yield loss due to pests in okra and capsicum'.

Joseph M. Baya (Kenyatta University): Research on 'Exploration and evaluation of locally occurring nuclear polyhedrosis virus (NPV) for control of *Helicoverpa armigera* on vegetable crops'.

Output

Publications

Hailu G., Rao M. and Sithanantham S. (1999) Effect of hedgegrows on insect pests of beans and maize, and beneficial arthropods in semi-arid Kenya. *Agroforestry Journal* (in press).

Sileshi G. Weldessemayat, S. Sithanantham, C.K.P.O. Ogol, M.R. Rao, J.A. Maghembe (1999) Biology of *Mesoplatys ochroptera* Stal (Chrysomelidae: Coleoptera) on *Sesbania sesban* (L) Merril in Southern Africa. *Agroforestry Journal* (accepted).

Papers in conference proceedings

Akol A.M., Sithanantham S., Baumgärtner J., Varela A., Njagi P. and Mueke J.M. (1999) Evaluation of impact of neem formulations on some population parameters of the diamondback moth in cabbage ecosystem, p. 5. In *Integrated Pest and Vector Management and Sustainable Development in Africa: Abstracts.* Proceedings of the Joint Congress of the African Association of Insect Scientists (13th Congress) and the Entomological Society of Burkina Faso, Ouagadougou, Burkina Faso 19–23 July 1999. (Edited by D. Giga and M. Ali Bob). ICIPE Science Press, Nairobi.

Haile A.T., Sithanantham S., Hassan S. A., Monje C., Zebitz C. P. W., Baumgärtner J., Löhr B. and Ogol C.K.P.O. (1999) Studies of *Trichogramma* parasitoids towards potential utilisation for biological control of lepidopteran pests on vegetable crops in Kenya, p.6. In *Integrated Pest and Vector Management and Sustainable Development in Africa: Abstracts.* Proceedings of the Joint Congress of the African Association of Insect Scientists (13th Congress) and the Entomological Society of Burkina Faso, Ouagadougou, Burkina Faso 19–23 July 1999. (Edited by D. Giga and M. Ali Bob). ICIPE Science Press, Nairobi.

Ogutu W., Sithanantham S., Atonya B. and Waiganjo M. M. (1999) Developing need-based training for farmer trainers in improved pest management on vegetable crops: Recent ICIPE partnership initiatives in Kenya, p.4. In *Integrated Pest and Vector Management and Sustainable Development in Africa: Abstracts.* Proceedings of the Joint Congress of the African Association of Insect Scientists (13th Congress) and the Entomological Society of Burkina Faso, Ouagadougou, Burkina Faso 19–23 July 1999. (Edited by D. Giga and M. Ali Bob). ICIPE Science Press, Nairobi.

Sithanantham S., Nyarko K. A., Seshu Reddy K. V., Maniania N. K. and Varela A. (1999) Research progress at ICIPE on pest management in vegetable crops: Overview, p.2. In *Integrated Pest and Vector Management and Sustainable Development in Africa: Abstracts.* Proceedings of the Joint Congress of the African Association of Insect Scientists (13th Congress) and the Entomological Society of Burkina Faso, Ouagadougou, Burkina Faso 19–23 July 1999. (Edited by D. Giga and M. Ali Bob). ICIPE Science Press, Nairobi.

Sithanantham S., Waiganjo M. M., Ssekyewa C., Akemo C., Swai I. and Gashabweza A. (1999) Towards improved information dissemination on integrated pest management among smallholder vegetable farmers: An ICIPE-NARES network initiative in eastern Africa, p.3. In *Integrated Pest and Vector Management and Sustainable Development in Africa: Abstracts.* Proceedings of the Joint Congress of the African Association of Insect Scientists (13th Congress) and the Entomological Society of Burkina Faso, Ouagadougou, Burkina Faso 19–23 July 1999. (Edited by D. Giga and M. Ali Bob). ICIPE Science Press, Nairobi.

Waiganjo M. M., Sithanantham S. and Waithaka M. W. (1999) Survey of perceptions, attitudes and knowledge status of smallholder vegetable farmers relating to pests and their management in Thika, Kenya, p.32. In *Integrated Pest and Vector Management and Sustainable Development in Africa: Abstracts.* Proceedings of the Joint Congress of the African Association of Insect Scientists (13th Congress) and the Entomological Society of Burkina Faso, Ouagadougou, Burkina Faso 19–23 July 1999. (Edited by D. Giga and M. Ali Bob). ICIPE Science Press, Nairobi.

Consultancy

S. Sithanantham provided a 4-week consultancy for FAO to advise on Horticultural IPM Research for Eritrea (December 1999).

Symposia convened

Convened two symposia, one on 'Biocontrol Potential of Egg Parasitoids and Baculoviruses in Africa' and another on 'Integrated Management of *Helicoverpa armigera*' during AAIS scientific conference in Ouagadougou, Burkina Faso, July 1999.

Project proposals

Project proposal written on 'Utilisation of egg parasitoids for biocontrol of *Helicoverpa* and *Plutella* in Africa'.

Provided input in revising the project proposal entitled 'Strategic planning of vegetable production: A synoptic analysis for assessing land use potential in the East and Central African Highlands'.

Concept notes on 'Collaborative research for pest management on capsicum' being developed jointly with AVRDC and NARS partners.

Training lectures/seminars

Lectures were given (and practicals arranged) by project staff for the following international training courses at ICIPE:

- Vegetable IPM Training Course for Africa, May–June 1999.
- International Training Course on *Bacillus thuringiensis*, November 1999.
- Neem Awareness Training Workshop for Africa, November, 1999.
- Seminar lectures were also given to NARS officials in Kenya (May 1999), Ethiopia (October 1999) and for IFAD loan project managers from eastern and southern Africa in Zimbabwe (November 1999).

(See also the reports on Neem, Biosystematics Unit, Behavioural and Chemical Ecology Department and Social Sciences Unit.)

The African Fruit Fly Initiative: Development, Testing and Dissemination of Technologies for the Control of Pests and Fruitflies

Background, approach and objectives

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 requests from fruit growers in East Africa, and based on IFAD-funded pre-project assessments, ICIPE initiated research on African fruit flies of economic importance. ICIPE's African Fruit Fly Initiative is an integrated programme for applied research, technology adaptation, transfer and training.

The programme was discussed and endorsed during a meeting organised jointly by ICIPE, IFAD and FAO on 16–18 February 1998, attended by representatives of farmers, local authorities, regional organisations (ASARECA, SACCAR, OAU/STRC), collaborators and donors. The Initiative is focused on mango and addresses the objectives set out by the relevant International Commodity Body. It was endorsed for support during the Second Session of the FAO-Intergovernmental Group on Tropical Fruits, held in May 1999 in Gold Coast, Australia. In addition to IFAD being the lead donor, the Executive Board of the Common Fund for Commodities (CFC) approved support for the applied aspects of the African Fruit Fly Initiative.

The objective of the Initiative is to develop and evaluate through a phased programme of activities, a cost-effective and environmentally friendly package of fruit fly control and management options. The work will be implemented with the close participation of smallholder fruit producers. It will focus on the adaptation of fly management options by combining elements that are at an advanced stage of development, and which are suitable for other tropical regions and not specific to only one species of fruit fly. These elements include: (i) baiting, (ii) physical protection of the fruit, such as bagging or netting, and (iii) post-harvest treatments and preventive measures such as sanitation and simple community-based quarantine systems, e.g. restriction of uncontrolled fruit movements.

In view of its importance to the region, during the initial phase the Programme is assembling a simple package for the management of fruit flies currently infesting mangoes in East Africa through adaptation and, where necessary, development of additional bait-based techniques. Such techniques build on those currently in use in other tropical regions. Adaptation and necessary validation trials are being carried out on smallholder fields in typical East African locations that are also representative of other regions of Africa. The pest management solutions developed for mango are likely to be relevant to most other African fruits.

Work in progress

1. ECONOMIC ROLE AND DISTRIBUTION OF FRUIT FLIES

Participating scientists: *S. A. Lux, N. Zenz, S. Kimani*

Assistant: *H. Mburu*

Donor: *IFAD*

Collaborators: *• Agricultural Research Institute Mikocheni, Dar-es-Salaam, Tanzania • Plant Protection Division, Ministry of Agriculture, Zanzibar, Tanzania • Centre National de Recherche Agronomique, Abidjan, Côte d'Ivoire • Kawanda Agricultural Research Institute, Kampala, Uganda • ARC-Institute for Tropical and Subtropical Fruits, Nelspruit, South Africa • Natal Museum, Pietermaritzburg, South Africa*

Exploratory surveys were continued in several areas in Kenya (Nairobi, Thika, Embu, Koru, Nguruman, South and North Coast), and on Pemba and Zanzibar in Tanzania. Additional surveys were initiated in 1999 in Uganda, Côte d'Ivoire, Namibia and South Africa. Our results confirmed that in East Africa, the mango fruit fly, *Ceratitis cosyra* (Walker), (Diptera:Tephritidae) is the major pest in most mango growing areas. Other fruit flies such as the Natal fruit fly, *Ceratitis* (*Pterandrus*) *rosa* Kirsch and the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) are of local and secondary importance. The latter do, however, play an important role in other fruits.

Data confirmed 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. In some areas like Nguruman, the infestation level occasionally reaches 70%. The smallholders, who produce most of the fruit, lose 30–70% of mangoes due to infestation by fruit flies. A similar situation was reported in other countries in the region.

The distribution and composition of the fruit fly complex in East Africa is not uniform and continuous. For instance in Kenya, *C. capitata* and *C. rosa* dominate in Thika, *C. cosyra* and *C. rosa* in Embu and North Coast, *C. capitata* and *C. (Pterandrus) anonae* Graham in Nyanza and only *C. cosyra* in Nguruman. Therefore, the results from one area cannot be extrapolated to other areas and more detailed description of the fruit fly distribution in the region is necessary.

2. EXPLORATION FOR AND RESEARCH ON NATURAL ENEMIES OF FRUIT FLIES

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

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

Donor: *USDA*

Collaborators: *• University Experimental Station, Kauai, Hawaii, USA • University of Florida, USA • Texas A&M University, USA • USDA-APHIS-PPQ Methods Station, Guatemala*

USDA provided limited funding through the universities of Hawaii, Florida and Texas A&M and ICIPE continued surveys of fruit flies and their natural enemies in four locations in Kenya. To date, over 40,000 field-collected fruit fly puparia have been sent to quarantine in Hawaii. From these puparia, 10 parasitoid species in at least four genera, *Fopius, Diachasmimorpha, Psyttalia* and *Tetrastichus* have been reared. One species, *Psyttalia humilis*, has been successfully cultured and is being evaluated in the USDA-APHIS-PPQ Methods Station, Guatemala in laboratory and field trials.

3. PRELIMINARY STUDY ON LONGEVITY AND LIFETIME BEHAVIOUR OF *CERATITIS COSYRA, C. ROSA* AND *C. CAPITATA*

Participating scientists: *S. A. Lux, N. Zenz, P. Nemeye*

Assistant: *T. Chole*

Donor: *IFAD*

This study aimed at investigating the activities and behaviour of three different fly species at dawn, all day, dusk, and early night throughout the flies' lifetime. Pupae were placed in perspex cages for adult emergence. The flies were observed every 30 minutes on different objects for their behavioural aspects.

Ceratitis capitata was found to have the longest lifespan with 77 days, followed by *C. cosyra* and *C. rosa* with 68 and 65 days, respectively. Only *C. rosa* showed clear patterns of feeding behaviour, being attracted to food items in the first half of the day. During the flies' lifespan, their feeding activity peaked at 27, 29 and 19 days after emergence (DAE) for *C. capitata, C. rosa*, and *C. cosyra*, respectively.

Male 'calling' as a part of the courtship behaviour was visible from the early morning hours until 1600 hours for *C. capitata, C. cosyra* and *C. rosa*. Males called after 1700 hours and were active into the night, whereas *C. rosa* had a peak between 1900 and 2000 hours. A maximum number of males of *C. capitata* 'called' at 22 DAE, *C. rosa* between 13 and 17 DAE and most males of *C. cosyra* at 49 DAE.

Mating of *C. capitata* took place during the first half of the day until 1400 hours. *Ceratitis cosyra* and *C. rosa* were observed mating after 1730 hours and 1800 hours, respectively, and a few couples of *C. rosa* could still be found in the early morning hours. Mating activities of *C. capitata, C. rosa* and *C. cosyra* reached their highest intensity at 7, 33 and 9 DAE, respectively. Considering activities over time, *C. rosa* and *C. capitata* showed patterns for male 'calling' and mating that clearly deviated from those of *C. cosyra*. Focusing on the daily rhythm, *C. capitata* had its reproductive activities shifted by approximately 12 hours from both other species.

4. ESTABLISHMENT OF COLONIES OF *CERATITIS COSYRA, C. ROSA* AND *C. CAPITATA*

Participating scientists: *S. A. Lux, N. Zenz*

Assistants: *F. Nyamu, P. Nderitu, J. Kiilu*

Donor: *IFAD*

Permanent colonies of the three tephritid fruit fly species, *C. cosyra, C. rosa* and *C. capitata* are being reared at ICIPE in a rotating cage system which keeps all age categories in weekly succession. *Ceratitis capitata* is reared worldwide and its rearing method is widely known. However, only a few laboratory colonies of *C. rosa* exist in Africa and there is limited knowledge on optimum conditions. *Ceratitis cosyra* has never been reared in considerable numbers and its methodology is basically unknown. In recent months, the colony of the latter species has reached important numbers and has produced continuous records.

The adult flies are reared on artificial diet (commercial yeast autolysate) and oviposition devices are offered as fruits or semi-artificial medium:

- *C. capitata*: modified balls (after Hooper), banana
- *C. rosa*: modified balls, banana
- *C. cosyra*: mangoes, banana

The offspring are reared for colony maintenance and supply to various experiments. In particular, C.

Table 4. Performance of three tephritid species, *Ceratitis capitata*, *C. rosa* and *C. cosyra* in laboratory colonies as measured by three qualitative factors: pupal output per week, pupal emergence and pupal weight

Fly species	*C. capitata*	*C. rosa*	*C. cosyra*
Pupal output per week (no.)	6500	4500	2600
Pupal emergence rate (%)	80.2	75.1	82.0
Pupal weight (g per 100 pupae)	0.63	0.82	1.3

cosyra has shown promising improvements in performance, reflecting the increased knowledge in rearing conditions (Table 4). Present efforts geared towards all three species aim at stabilising and increasing output of insects at various stages, optimising vital performance criteria and standardising larval diet and oviposition devices across species. The production cycle of the colonies is fully computerised and all data produced are monitored through the Programme's network facility.

Output

Conferences and workshops attended

Lux S. A. (1999) Update on Launching the African Fruit Fly Initiative. FAO Meeting of the Committee on Commodity Problems, Sub-Group on Tropical Fruits, Gold Coast, Australia, 3–8 May, 1999.

Lux S. A. (1999) Worldwide Comparisons of Medfly Courtship Behaviour. Final FAO/IAEA Research Co-ordination Meeting on 'Medfly Mating Behaviour Under Field Cage Conditions', 29 June–3 July 1999, Antigua, Guatemala.

Lux S. A. (1999) Workshop of the Working Group on Fruit Flies of the Western Hemisphere, Guatemala City, 4–9 July 1999.

Workshops organised

Lux S. A. (1998) Launching the African Fruit Fly Initiative. Collaborator and Stakeholder meeting. ICIPE, March, 1998.

Lux S. A. (1998) Progress Review and Planning for the African Fruit Fly Initiative. Collaborator and Stakeholder meeting. ICIPE, November 1998.

(See also reports on the Biosystematics Unit, the Animal Rearing and Quarantine Unit, the Biodiversity and Conservation Programme.)

Whiteflies as Pests and Vectors of Viruses in Vegetables and Mixed Cropping Systems in Eastern and Southern Africa

Background, approach and objectives

The horticultural industry in eastern Africa is expanding rapidly, especially with regard to the production of export vegetables, fruits and cut flowers. Over the last decade, the industry has grown significantly in smallholder participation, thus providing income to millions of farmers and rural labourers. In Kenya, horticulture is the fastest growing industry and provides the much-needed boost to the economy. In the past decade, whiteflies (Homoptera: Aleyrodidae) have become one of the most serious crop production problems in the tropics. As pests and vectors of plant viruses, they have caused devastating crop losses and unprecedented insecticide abuse.

As part of the CGIAR inter-Centre initiative for ecoregional collaboration for integrated pest management (IPM), a 'System-Wide Programme on IPM of Whiteflies' was launched under the leadership of Centro International de Agricultura Tropical (CIAT), Cali, Colombia in 1997. The Whitefly IPM Project was launched to:

- organise a network for researchers in the tropics who are working on whiteflies and whitefly-transmitted viruses,
- promote the standardisation of research methodologies among researchers, and
- facilitate the collection of critical data in order to develop and implement effective IPM packages for whitefly and virus management.

Under this System-Wide Initiative, four sub-projects have been developed. The one on whitefly problems in vegetable-based cropping systems in eastern and southern Africa is led by ICIPE. The partners include ICIPE, the Asian Vegetable Research and Development Centre (AVRDC), John Innes Centre (UK) and national teams from four countries: Kenya, Malawi, Sudan and Tanzania. CIAT and the International Institute of Tropical Agriculture (IITA) are leading the other three sub-projects under this Initiative. The first phase of the ICIPE-led whitefly IPM project was for two years (1997–1999). Details on the start-up activities and progress in 1997 were reported in the *1995–1997 ICIPE Annual Scientific Report*, pp. 21–27.

Participating scientists: *M. Ali Bob, L. Riis, S. Sithanantham*, B. Löhr (*Project Leader)*

Assistants: *J. Asimba, R. Raini*

Donor: *Danish International Development Agency (DANIDA)*

Collaborators: *• Asian Vegetable Research and Development Centre, African Regional Programme, Tanzania • John Innes Centre, UK • Kenya Agricultural Research Institute (KARI) • Bvumbwe Agricultural Research Station, Malawi • University of Gezira and the Agricultural Research Corporation, Sudan • Horticultural Research and Training Institute and Selian Agricultural Research Institute, Tanzania*

Work in progress

1. SYSTEM-WIDE WHITEFLY IPM PROJECT

1.1 SURVEY OF WHITEFLY SPECIES AND TRANSMITTED DISEASES

ICIPE collaborated with the Whitefly IPM Project team in the development of the standardised survey methodology, coordination of the implementation of diagnostic surveys in partner countries, and development of a database for the entry and analysis of diagnostic survey data for the sub-project. Field surveys were undertaken in the four partner countries. The completed questionnaires were received at ICIPE and are being used to create a database on the whitefly problems in the target countries. Results reveal that *Bemisia tabaci* (Gennadius) is the most common whitefly species in the region. It is the dominant species in all the Tomato Yellow Leaf Curl (TYLC) hotspot areas where the disease has been reported to cause significant yield reduction. The *Bemisia*-transmitted TYLC symptoms were found throughout the region in varying levels of severity.

All the specimens of whiteflies that were collected from Sudan were *B. tabaci* and from Tanzania and Kenya, *B. tabaci* made 78% and 65% of the collected specimens, respectively. Exceptions are in the highlands of Kenya, where *Trialeurodes vaporariorum*

(Westwood) is the dominant species, and in Malawi where *Bemisa afer* (Priesner & Hosney) is more prevalent than *B. tabaci*. *Bemisia afer*, *Siphoninus phillyreae* (Haliday), *Aleurothrixus floccosus* (Maskell), *Trialeurodes ricini* (Misra), *B. hirta* Bink-Moenen, *Orchamoplatus citri* (Takahashi) and *Tetraleurodes andropogon* (Dozier) were occasionally encountered in Kenya and Tanzania; the last four were registered for the first time in Tanzania. In Malawi, *Aleyrodes proletella* (Linnaeus) was occasionally encountered. *Trialeurodes vaporariorum* was found to be the dominant species at Nguruman (Kajiado, Kenya) despite the area being at about 800 m high with high temperatures throughout the year. Survey of other areas at similar altitude and temperature conditions in the country showed *B. tabaci* to be the dominant species and the presence of TYLC symptoms. The highest TYLC symptoms in Uganda have been observed in Mbale, Mpigi and Kampala areas.

The Phase 1 survey revealed silverleaf symptoms on squash, *Cucurbita pepo* L. in Sudan. Elsewhere, these symptoms are associated with *B. tabaci* biotype-B as the transmitting vector. This is the first observation of silverleaf symptoms in the region and may indicate that this feared biotype B has now reached the East African region. The biotype was responsible for yield losses estimated at US$ 500 million in the USA in 1991, thus the concern about its possible presence in the region. Characterisation of *B. tabaci* specimens collected at the site where the silverleaf symptoms were found is underway and the biotype B identification is yet to be confirmed.

1.1.1 *Planning for Phase 2*

A planning and methodology workshop for Phase 2 of the whitefly IPM project was held at the ICIPE headquarters in September 1999, with participants from ICIPE, CIAT, AVRDC, Danish Institute for Agricultural Sciences, Tel Aviv University and the NARS partners from Kenya, Uganda, Sudan and Tanzania. During the workshop, the NARS representatives clarified some of the issues highlighted in the questionnaires in relation to the whitefly/ whitefly-transmitted virus problems in their respective countries and discussed their experience from Phase 1 and what needs to be done in Phase 2. Perceived on-farm losses due to tomato geminiviruses and the average cost to control whitefly and TYLC per hectare of tomato in one season were documented. The work done so far has made it possible to identify hotspot target areas in the four partner countries. The range of whitefly and natural enemy species that are common in vegetable-based systems in the region has been documented.

1.1.2 *African Whitefly and Geminivirus Network*

ICIPE took a leading role in promoting the formation of an African Whitefly and Geminivirus Network during the 12th Meeting of the African Association of Insect Scientists held in June 1997 in Stellenbosch, South Africa. Collection of more information for incorporation into the Network is still going on. ICIPE has also extended assistance to the IITA-led sub-project on whitefly problems in cassava and sweetpotato in Africa.

Substantial grey literature on whitefly and whitefly-transmitted viruses from local stations and project reports from the Sudan has been collected and stored at ICIPE as reference material. Five presentations on the project and on experience and preliminary progress were made during year 1.

1.2 UNDERSTANDING THE OCCURRENCE OF WHITEFLY SPECIES

The number of whitefly species that are now known to occur in the target countries are 5 in Malawi, 13 in Tanzania, 23 in Kenya and 27 in the Sudan. Surveys in the target areas of the four countries (Table 1.2) have shown that *B. tabaci* is by far the most common species in all partner countries. The following whitefly species are new records for the region: *A. proletella* Linnaeus in Malawi, *B. afer* Priesner and Hosney in Tanzania, *S. phillyreae* (Haliday) in Kenya, *T. ricini* (Misra) in Kenya, Malawi and Tanzania and *T. vaporariorum* (Westwood) in Malawi. Some of the whitefly and natural enemy samples collected from the countries are yet to be identified. Contrary to what was recorded in 1997, *Bemisia* was found to breed successfully on tomatoes in a number of ecologies surveyed in Kenya (for instance, in Kitui, Kibwezi and Mwea areas). Work is underway to further establish the suitability of various tomato varieties in the highlands for the breeding of *Bemisia*.

1.3 IDENTIFICATION ASSISTANCE PROVIDED BY ICIPE

Assistance in identification of whitefly species and natural enemy collections from surveys across 9 countries in Africa has been extended by ICIPE to the IITA-led sub-project on whiteflies on cassava and sweetpotato (Table 1.3). Results of identification of the whitefly specimens have been forwarded to IITA.

1.4 WHITELFY REPRODUCTIVE HOSTS

The most important alternative host plants for whiteflies in the region have been identified. In addition to more than 25 crop and weed species identified as whitefly hosts in 1997, some new host plant records for Kenya were: *Rhynchosia hirta* (Andr.) Meikle & Verdc. (Fabaceae), *Sida acuta* Burm f. (Malvacea), *Ocimum kilimandsharicum* Guerke (Labiatae), *Jacquemontia tamnifolia* (L). Griseb (Convolvulacea), *Achyranthes sicula* L. (Amaranthaceae). Some of the weed hosts which may also act as reservoirs of TYLCV are *Achyranthes aspera* L. (Amaranthaceae), *Euphorbia heterophylla* L. (Euphorbiaceae) and *Nicandra physalodes* Scop.

Table 1.2. Target areas for surveys in partner countries

Country	Region/Province	Areas
Kenya	Central	Kirinyaga, Mwea, Embu, Muranga, Kiambu,Thika
	Eastern	Kibwezi, Machakos, Meru, Kitui
	Western	Funyula, Kabras, Malava, Vihiga
	Nyanza	Homa Bay, Kisii, Migori, Nyando, Siaya, Ugunja
	Rift Valley Province	Nguruman, Magadi, Naivasha
	Coast Province	Kwale, Kilifi, Taita/Taveta, Shimba Hills
	Nairobi	Kitisuru, Kihara
Malawi	Blantyre (Southern ecozone)	Bvumbwe, Nedza, Thyolo
	Lilongwe (Central ecozone)	Ntcheu, Chikwina
	Mzuzu (Northern ecozone)	Mzimba, Mkhata Bay, Salima
Sudan	Gezira Region	Kamlin, Hasaheisa, Sinnar, Managil, Musalamia, Ummelgura, Taiba, Fadasi
	Northern Region	Dongola
	Western Region	Omrawaba
	Botana Province	Ruffaa
	Dindir Province	Karkoj, Suki
Tanzania	Arusha	Arusha, Arumeru, Babati
	Kilimanjaro	Hai, Moshi, Rombo, Mwanga
	Dodoma	Dodoma, Mpwapwa
	Iringa	Iringa, Njombe
	Mbeya	Mbeya, Vwawo, Tukuyu
	Tanga	Lushoto
	Morogoro	Morogoro
	Zanzibar	Zanzibar

Table 1.3. Summary of identification assistance extended by ICIPE to IITA for whitefly samples collected from surveys in 9 African countries

Country	Samples received	Samples identified
Benin	70	70
Cameroon	62	62
Ghana	60	55
Kenya	75	62
Madagascar	138	88
Malawi	55	48
Nigeria	70	70
Tanzania	100	91
Uganda	155	155
Total	785	701

(Solanaceae). However, tomato is the principal host for the disease, while cassava and *E. heterophylla* are among the main reproductive hosts for *Bemisia* in the region. The role of *E. heterophylla* in the off-season survival of the disease and the vector needs to be investigated.

Bemisia tabaci was primarily found breeding on both the cultivated and wild species of plants belonging to the families Solanaceae, Leguminosae, Euphorbiaceae and Malvaceae. Other host plants belong to the families of Cucurbitacea, Convolvulaceae, Amaranthaceae, Labiatae and Fabaceae. *Bemisia tabaci* was also occasionally found breeding on hosts plants belonging to Acanthaceae, Asteraceae, Commelinaceae and Verberaceae. Continuous cropping of vegetable crops favoured by *B. tabaci* guarantees continuous availability of reproductive hosts throughout the year.

1.5 IDENTIFICATION OF TOMATO YELLOW LEAF CURL VIRUS (TYLCV)-AFFECTED ZONES IN TARGET COUNTRIES

Tomato Yellow Leaf Curl symptoms were found in 93% of the surveyed fields in Sudan and Tanzania, in 72% of the surveyed fields in Malawi and in 55% of the surveyed fields in Kenya. In 69% of the fields in Sudan, 34% of the fields in Tanzania and 11% of the fields in Kenya and Malawi, more than a quarter showed the presence of TYLC symptoms.

DNA hybridisation tests using a TYLCV-specific probe was used for identification of tomato whitefly-transmitted viruses. The incidence of TYLCV in partner countries is high, particularly during the hot seasons. Out of 271 tomato samples collected from Tanzania, 73 tested positive for TYLCV. Likewise, 23 out of 81 tomato samples collected from various areas in Kenya were found positive to TYLCV. The TYLCV-Israeli strain occurs in all the target countries.

On-farm surveys showed that TYLCV incidence was highest in Sudan followed by Tanzania, Malawi and Kenya, respectively. Other interesting patterns are emerging which need further exploration. For example, TYLCV symptoms have not been identified from Nyanza and Western Provinces in Kenya despite the presence of *Bemisia* which is spreading African cassava mosaic diseases in the region. Relatively high incidences were found at higher elevations elsewhere (above 1500 m), where the disease is expected to be less frequent (Machakos, Athi River and Thika).

Many of the virotic tomato samples collected have tested negative for TYLCV, suggesting that there may also be a complex of indigenous tomato-infecting geminiviruses in the region. Surveys by AVRDC in Tanzania indicated that several tomato samples showing typical symptoms of TYLCV did not hybridise with the Egyptian and/or Israeli DNA probes. However, polymerase chain reaction (PCR) work has shown that the Tanzanian geminivirus is different from all previously characterised geminiviruses of the Old World and is tentatively named TLCV-Tan. Another unique geminivirus was isolated from Uganda and has been named TLCV-Ug. In northern Tanzania (ca 1550 m) there was a very high incidence of whiteflies and leaf curl disease, while in the southern highlands (ca 1870 m) there was a lower incidence of leaf curl and the vector. In the Sudan, tomato, watermelon, muskmelon, okra and pepper were among the crops most affected by the whitefly-transmitted viruses.

In tomato, the most important viruses are TYLCV and Tomato Vein Thickening (TVTV). Okra Leaf Curl is another whitefly-transmitted virus affecting okra in the Sudan. Watermelon and muskmelon are affected by Watermelon Chlorotic Stunt Virus (WCSV) with consequential loss in revenue to melon farmers estimated at about 64%. A yellowing inducing poty-like virus and Cucumber Yellow Vein Virus (CYVV) have been observed in cucurbits. In peppers, whiteflies are responsible for transmission of TYLCV and perhaps another yet unidentified virus. In legumes, *Vigna* and French beans are affected by a geminivirus and a colesterovirus which are under investigation. WCSV is considered to be the most important single factor responsible for high yield losses in eastern and central Sudan and has badly affected Sudan's melon export in recent years. The Government of the Sudan has formulated an official policy of crop protection aimed at combating the whitefly problem.

Sudan is historically known as one of the worst hit countries by the whitefly problem, particularly in the cotton production system. This scenario has changed recently and the whitefly problem seems to have become less acute. This is partly attributable to the reduction in area under cotton cultivation in the last decade as well as adoption of economic threshold recommendations resulting in more effective control of major cotton pests and probably changes in the global climate. This finding requires further investigation to reveal the reasons behind this fortunate change in the Sudanese cotton pest complex. However, the country has recently experienced increasing whitefly-transmitted virus problems in vegetable-based systems, especially tomatoes and cucurbits, with the result that the number of farmers who have abandoned tomato cultivation because of Tomato Yellow Leaf Curl Virus is on a sharp increase. Reservoirs for TYLCV in the wild vegetation were found in plant species belonging to the families Solanaceae and Euphorbiaceae in particular, and also in Amaranthaceae.

1.6 IDENTIFICATION OF WHITEFLY NATURAL ENEMIES

In addition to confirming the local occurrence of several known natural enemies of whiteflies, additional genera and species of predators and parasitoids have also been identified. *Encarsia transvena* (Timberlake) was by far the most common parasitoid encountered in the region. However, *Eretmocerus* spp. also occurs frequently and *Encarsia formosa* Gahan was identified. The predators collected were mainly coccinellids, predatory bugs and phytoseiid mites. The mirid bug, *Macrolophus caliginosus* (Wagner), a whitefly predator, was collected from Nguruman, Mwea and Kibwezi in Kenya.

1.7 ASSESSMENT OF FARMERS' PERCEPTION OF WHITEFLY PROBLEM

The majority of farmers interviewed were able to recognise whiteflies and the problems they cause. The proportion of farmers who were able to recognise whitefly and TYLCV problems varied between the countries. Not surprisingly, the highest number of farmers who reported whitefly and/or TYLCV problems were from Sudan and Tanzania. The majority of farmers believe that the whitefly problem has become more acute during the last few years and is related to changes in the weather pattern. Most of the farmers reported that 1997 was the year when they had the most severe whitefly/disease problems.

1.8 ECONOMIC IMPORTANCE

Farmers' estimates of yield loss in tomatoes due to whitefly and whitefly-transmitted viruses were as high as 75% in Kenya and 100% in the Sudan, Malawi and Tanzania (Table 1.8). Some farmers in all four countries have reported abandoning their tomato crops due to the TYLCV problem, with the highest number being from Sudan. These data were obtained from on-farm surveys of 80 farms in each of the countries.

1.9 SURVEY OF PESTICIDE USE AGAINST WHITEFLY AND WHITEFLY-TRANSMITTED VIRUSES IN AFFECTED AREAS

Almost all farmers interviewed reported using synthetic pesticides to control the whitefly/disease problems with a significant proportion of farmers spraying more than ten times per season. On the average, farmers in Kenya claim that it costs them US$ 225 per hectare of tomato to control the whitefly/disease problem. The cost was US$ 212 in Malawi, US$ 187 in Tanzania and US$ 265 in the Sudan. However, this information should be treated with reservation since many farmers, especially in Kenya and Malawi, did not apparently direct the control effort exclusively against whiteflies, but rather against a pest complex.

Table 1.8. Farmers' estimates of yield loss related to whiteflies in tomatoes

Country	%-loss	No. farmers	% farmers	Average % loss
Sudan	0	13	16	0
	25	8	10	2.50
	50	8	10	5.00
	75	30	38	28.13
	100	21	26	26.25
Total		80	100	62
Kenya	0	15	19	0
	25	38	48	12.03
	50	22	28	13.92
	75	4	5	3.80
	100	0	0	0
Total		79	100	30
Tanzania	0	4	5	0
	25	33	42	10.44
	50	25	32	15.82
	75	10	13	9.49
	100	7	9	8.86
Total		79	100	45
Malawi	0	7	9	0
	25	23	29	7.37
	50	27	35	17.31
	75	11	14	10.58
	100	10	13	12.82
Total		78	100	48

1.10 ESTABLISHMENT OF WHITEFLY CULTURES AT ICIPE

Laboratory cultures of *B. tabaci* and *T. vaporariorum* have been established at ICIPE and were used as controls in resistance assessment work. Plans are underway to carry out studies on virus transmission and host suitability by ICIPE and AVRDC.

1.11 ASSESSMENT OF INSECTICIDE RESISTANCE IN WHITEFLY POPULATIONS WITHIN THE REGION

Much has been done over the years in studying whitefly resistance to insecticides in the Gezira (Sudan) cotton growing area. Grey literature from the extensive research work was collected in Phase 1 and indicates very high resistance to commonly used insecticides in some localities.

Assessment of the level of resistance to bifenthrin, cypermethrin and methomyl insecticides in *B. tabaci* (Gennadius) and *T. vaporariorum* (Westwood) whitefly populations from selected sites in Kenya was carried out as an MSc project. The results document for the first time in Kenya the status of resistance of whiteflies in the mixed vegetable cropping systems commonly practised in the country. The study sites were Nairobi, Mwea, Nguruman, Kitui and Kibwezi. High levels of resistance to cypermethrin were recorded with resistance factors of up to 87.97. Cypermethrin was the most commonly used of the insecticides tested, while bifenthrin was the least used.

No comprehensive research on whitefly resistance to insecticides in the other partner countries appears to have been done.

2. IMMIGRATION AND EMIGRATION OF WHITEFLIES, *BEMISIA TABACI* (GENNADIUS) (HOMOPTERA: ALEYRODIDAE) ON SELECTED CROPS IN EAST AFRICA

Background

Epidemic outbreaks of whiteflies and whitefly-transmitted viruses, emerging globally in new crops and geographic zones, has posed a serious problem for world agriculture since the mid-1980s. Whitefly-transmitted viruses, already known on vegetables in the southern USA, Mexico, Central America and the Caribbean, are now emerging in eastern Africa.

An improved understanding of the development of whitefly-transmitted virus epidemics will enable focusing of control efforts. An epidemiological model of whitefly-transmitted viruses is under development by scientists at CIAT and Harvard University. This model will contribute to the epidemiological analysis of the whitefly and whitefly-transmitted virus system and will help define parameters of crucial impact on virus spread and damage. Parameters on whitefly immigration and emigration have not yet been quantified. Whitefly migration is a key constituent in the epidemic dispersal of whitefly- transmitted plant viruses, and immigration and critical period are thought to be the driving forces in the system model.

The objective of this project, which began in mid-1998, is to corroborate a standard protocol of sampling strategies for the quantification of whitefly immigration and emigration parameters in annual field crops. The project involves methodology development, testing and application.

The study approach is based on a stochastic birth-death-migration (BDM) model and includes captures in non-attractive interception traps surrounding a field facing the prevailing wind direction. A regression analysis between migration estimates from the BDM model and captures in interception traps is planned.

Participating scientist: *L. Riis*

Assistant: *P. A. Obonyo*

Donor: *The Council of Development Research, DANIDA.*

Collaborators: *• CGIAR System-Wide Whitefly IPM Project • Centro Internacional de Agricultura Tropical (CIAT) • University of Copenhagen*

Work in progress

2.1 ESTIMATION OF IMMIGRATION RATE

In the first phase of this study we focused on the first whitefly generation time in the crop (French beans), i.e. approximately the first 3 weeks of the crop cycle. This was to reduce the contribution to the adult population through reproduction in the crop to zero. We assumed that emigration from the crop is insignificant during the early crop stage (young leaves). However, this assumption has still to be verified.

Daily immigration and death rates in the crop are estimated through sampling. Sampling units comprise one plant randomly selected within a spatial strata and provide an absolute numbers of whiteflies. Additionally, individual plants in the crop, including their whitefly infestation, are caged in exclusion mesh cages for 24 h followed by an absolute estimation of numbers of whiteflies on the plant. The death rate within the 24 h period was calculated by finding the difference between the 'free' whitefly population counted immediately after caging and the 'caged' population 24 h later. Immigration rate is defined as the difference between today's 'free' population, and yesterday's 'free' population, minus the death rate. Immigration rates will be extrapolated to provide an estimation of population increase per hectare per day, compared to whitefly captures in the interception traps.

2.1.1 *Change of whitefly host and study site*

During 1998 the project suffered from a scarcity of natural whitefly populations in the fields, presumably due to excessive El Niño rains, particularly during the normally dry season of January through March. Furthermore, it was necessary to change the host plant used in the studies from tomatoes to French beans, since it was found that whiteflies scarcely reproduce on tomatoes in East Africa. (A reproductive host was required for the studies to establish immigrating whiteflies in the field.) French bean proved to be the best reproductive host among several plants tested and was selected as the experimental host plant.

Whitefly hotspot outbreak areas seem inconsistent from year to year. The fieldwork started out in 1998 in Mwea Tebere Irrigation Scheme based on observations of heavy whitefly attacks the previous years. However, the project was moved to Kitisuru on the outskirts of Nairobi District by the end of the year due to very low whitefly populations at the first experimental site.

2.2 NEW TRAPS FOR WHITEFLIES

New whitefly traps have been developed, tested, modified and re-tested in the field. These include stationary window traps (interception traps) consisting of a piece of perspex (0.5 x 1 m) placed in a metal frame at ground level. On the perspex surface, low-cost cooking oil has been shown to be durable for at least 12 hours, during both harsh sunshine and temporary rainy spells. At lower temperatures, e.g. during dusk hours, the perspex steams up and the tiny whiteflies become difficult to see.

Wind projecting rotating window traps (another kind of interception trap) are still to be re-tested in the field. The rotating trap consists of a 0.5 x 1 m piece of perspex attached to two metal arms which carry the perspex 10 cm from the rotating centre with friction reducing ball-bearings. The perspex is placed 10 cm above ground level. The Muffin fan trap (interception trap), which is a stationary suction trap consisting of a 12V fan replacing the bottom of a square flower pot (10 cm diameter) lined with a fine net material, has been copied and tested in the field. The window traps capture between 0 and 32 whiteflies in 1 hour, whereas the Muffin fan trap captures only between 0 and 2 whiteflies in 3 hours.

A new trapping device has been developed for sampling numbers of whiteflies per plant in the field. The trapping device consists of a non-translucent PVC flower pot of any size. The bottom is replaced with a plastic cone painted black. The modified flower pot is placed upside down to cover one plant. A translucent plastic vial is attached to a hole in the centre of the cone with the opening of the vial facing the plant inside the modified flower pot. The whiteflies take off from the leaves of the plant inside the dark pot and fly to the light inside the vial. The innerside of the vial is lined with thin translucent yellow plastic sheets, to enhance the attractiveness of the vial. Cooking oil applied to the yellow plastic sheets ensures that the whiteflies are captured and stay in the vials. The vials are detached from the modified flower pot and the yellow plastic sheet is removed from the vial for easy counting of whiteflies.

Whitefly captures during the preliminary experimental work in 1998 showed that the whiteflies passed through the field without stopping on the crop. This is assumed because a similar high number of whiteflies were captured both before and after the field by trapping (on the side of the windows that faced the prevailing wind direction), coupled with very low numbers of whiteflies sampled from the field. This observation shows that our assumption on insignificant emigration from a young host plant may prove false. Preliminary data also show that whiteflies fly most actively in the afternoon, peaking at 1500 hours. This is in contrast to other statements on daily movement activity found in the literature which state that whiteflies fly most actively during the morning. Recently, whitefly researchers at the University of Arizona have found whiteflies taking off in clouds before dusk (D. Byrne, personal communication).

Output

Publications

Riis L. (1999) Melusens svøbe. Succesfuldt pan-tropisk samarbejde om at opnå større høst udbytte and mindre miljøbelastning. *Jord & Viden* 144 (11), 12–14 (a bi-weekly journal for Danish agronomists, horticulturists and forestry engineers).

Sithanantham S., Ali Bob M., Anderson P., Baumgärtner J., Markham P., Nono-Womdim G., Dafalla and Osir E. (1998). Recent initiatives for whitefly-virus problem diagnosis in vegetable-based cropping systems and research networking in Africa, p. 26. In *Proceedings of the 2nd International Workshop on Bemisia and Geminiviral Diseases*, San Juan, Puerto Rico. June, 1998 (abstract).

Sithanantham S. and Ali Bob M. (1998) Waging War Against Whitefly. Radio programme. WREN media. World Radio for the Environment, UK June 1998.

Conferences attended

Whitefly IPM Project Review Meeting: A one-day meeting was held in June 1998 at ICIPE to review progress of the two African sub-projects of the Whitefly IPM Project led by ICIPE and IITA. The Project Coordinator, Dr Pamela Anderson of CIAT chaired the meeting which was attended by the Whitefly Project scientists of ICIPE, IITA, AVRDC, CIP and national partners from Kenya, Sudan, Uganda and Tanzania.

S. Sithanantham and M. Ali Bob attended the 2nd International Workshop on Bemisia and Geminiviral Diseases, San Juan, Puerto Rico. June 1998.

Ali Bob made a presentation on ICIPE's Whitefly IPM Project at the ICIPE's Horticulture Programme Workshop. Nyeri, 12 October 1998.

Research proposals

Parasitoid-based management of *Bemisia* through exploitation of tritrophic interactions. (A joint proposal between ICIPE and Tel Aviv University, Israel). Proposal submitted in August 1998 to CDR-USAID.

Sustainable integrated management of whiteflies as pests and vectors of plant viruses in the tropics. Proposal submitted to DANIDA and awarded funds.

Development of IPM components for the control of whiteflies and whitefly transmitted viruses in vegetables and mixed cropping systems in ASARECA countries. Proposal to be submitted to a donor through ASARECA.

Capacity building

The following were contributions of the whitefly project to capacity building in the region:

PhD project: Distribution of whitefly species (and biotypes) and their natural enemies in vegetable-based cropping systems in Sudan (Ahmed Gaffar, University of Gezira, Wad-Medani, Sudan).

MSc project: Assessment of the level of resistance to bifenthrin, cypermethrin and methomyl insecticides in *Bemisia tabaci* (Gennadius) and *Trialeurodes vaporariorum* (Westwood) whitefly populations from selected sites in Kenya (Thomas Njuguna, Kenyatta University, Nairobi).

Ali Bob attended a short training course on identification of whiteflies and their natural enemies at the International Institute of Entomology (London).

A short-term evaluation of the effect of host plants on the oviposition and survival of the sweetpotato whitefly, *Bemisia tabaci* (Gennadius) was carried out (Rebecca Raini, University of Nairobi).

A horticulture IPM training workshop was conducted at ICIPE in 1999 and participants from various African countries enlightened on the importance of the whitefly pest/vector, its control and identification of various species.

Impact and recommendations

- An improved understanding of the whitefly problem, whitefly-transmitted viruses, whitefly species, natural enemies and whitefly reproductive hosts has been created in partner countries and identification of areas severely affected by Tomato Yellow Leaf Curl Virus has been done.
- More biological and molecular characterisation of WF and WFTV is needed in the region.
- There is need to test a package of resistant cultivars and control measures for whiteflies in order to lower the disease pressure.
- There is need to study insecticide resistance in whitefly populations throughout the region so as to understand the level of resistance and the underlying mechanisms and the effect of the insecticides on natural enemies of whiteflies. Such knowledge would help in the development and implementation of appropriate IPM packages for the whitefly/disease control.
- Strengthening of a global network to address whitefly and whitefly-transmitted virus problems within the framework of the System-Wide Whitefly IPM Project needs to be done.

(See also the reports on the Biosystematics Unit, Animal Rearing and Quarantine Unit, Population Ecology and Ecosystems Science Department and the 'Models for IPM in Vegetables' project.)

Development of Environmentally Friendly Management Methods for Red Spider Mites in Smallholder Tomato Production Systems

Background, approach and objectives

Tomato is one of the most important vegetables in eastern and southern Africa, yet yields in smallholder production systems are far below the crop's potential. Among the reasons are low quality seeds, non-availability of inputs, sub-optimal crop husbandry and a large number of pests and diseases. Red spider mites (RSM) are among the most serious pests of tomatoes in eastern and southern Africa. Current control practices involve weekly applications of highly toxic acaricides with long pre-harvest intervals, which result in pesticide contamination of the farmers' produce and the environment. The development of non-pesticide-based management methods should reverse this situation.

The main areas of research are the study of the bio-ecology of the mites, the development of IPM methods, investigations on classical biological control of *Tetranychus evansi* Baker & Pritchard and use of mite-resistant varieties. Collaborative research involving active participation of local research organisations in Kenya, Zimbabwe, Malawi, Namibia, Mozambique, Zambia and South Africa as well as a large training component, helps to ensure maximum benefit at minimum cost.

Participating scientists: *B. Löhr*, M. Knapp, I. Sarr, I. Nzuma* (*Project Leader)

Assistants: *B. Muia, M. Kungu*

Donors: *Ministry of Economic Co-operation and Development (BMZ), Germany*

Collaborators: • *Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya* • *Department of Research & Specialist Services, Harare, Zimbabwe* • *Makoka Agricultural Research Station, Thondwe, Malawi* • *Mashare Agricultural Development Institute, Rundu, Namibia* • *National Irrigation Research Station, Mazabuka, Zambia* • *National Agricultural Research Institute, Maputo, Mozambique* • *Plant Protection Research Institute, Pretoria, South Africa* • *Agritex, Harare, Zimbabwe* • *Escola Superior de Agricultura 'Luiz de Queiroz', University of São Paulo, Brazil*

Work in progress

1. CO-ORDINATION AND PLANNING

Planning meetings with collaborators from Zimbabwe, Malawi, Mozambique, Namibia and Zambia were held in May 1998 in Pretoria and September 1999 in Harare to co-ordinate the project activities in the region. In 1998, it was discovered that there are actually two different RSM species: *Tetranychus evansi* in southern Africa and *Tetranychus urticae* (Koch) in Kenya. This led to the shift of major activities to the southern part of the region, since *T. evansi* causes much greater damage on tomatoes.

2. SURVEY OF TOMATO PRODUCTION SYSTEMS AND DISTRIBUTION OF RSM AND NATURAL ENEMIES IN EASTERN AND SOUTHERN AFRICA

Work is in progress to explore the severity of RSM damage and the distribution of different RSM species and their natural enemies in eastern and southern Africa. The most important species on tomatoes in the southern part of the project area (Zimbabwe, Namibia, Mozambique, Zambia and Malawi) is *Tetranychus evansi*. This species is specific to Solanaceae and was probably introduced to Africa from South America. Most indigenous predators do not feed on it, but in Malawi and Zimbabwe, a staphylinid beetle, *Oligota* sp. was found preying on *T. evansi*. In Kenya, *T. urticae*, a species with worldwide distribution and a wider host range, is the predominant species. This explains the higher severity of mite attack on tomatoes in southern Africa compared to Kenya. Contacts with the University of São Paulo in Brazil have been initiated for investigations on a classical biological control approach to control the exotic species, *T. evansi*.

A questionnaire was designed to investigate tomato growing practices of farmers in Kenya, Zimbabwe, Namibia, Mozambique, Zambia and Malawi. Results of 115 farms surveyed in semi-arid districts of Kenya show clearly that RSM are only a problem in areas where farmers treat their crops frequently with broad spectrum insecticides. In other

Table 2. Pesticides used by Kenyan farmers to control RSM in tomatoes

Active ingredient	Trade name(s)	Class	Farmers (%)*
Dicofol	Kelthane	Acaricide	32.3
Dimethoate	Dimethoate, Rogor, Danadin, Tafgor	Insecticide/Acaricide	16.9
Bifenthrin	Brigade	Insecticide/Acaricide	13.8
Cypermethrin	Polytrin	Insecticide	12.3
Lambda-cyhalothrin	Karate	Insecticide	9.2
Sulphur	Thiovit	Fungicide/Acaricide	9.2
Permethrin	Ambush	Insecticide	7.7
Tetradifon	Tedion	Acaricide	6.2
Propargite	Omite	Acaricide	6.2
Omethoate	Folimat	Insecticide/Acaricide	4.6
Diazinon	Diazinon	Insecticide/Acaricide	4.6
Endosulfan	Thiodan	Insecticide/Acaricide	4.6
Azocyclotin	Peropal	Acaricide	3.1
Malathion	Malathion	Insecticide/Acaricide	3.1
Deltamethrin	Decis	Insecticide	3.1
Carbosulfan	Marshal	Insecticide	3.1
Mancozeb	Penncozeb	Fungicide	3.1
Dicofol	Mitigan	Acaricide	1.5
Amitraz	Mitac	Acaricide/Insecticide	1.5
Quinalphos	Ekalux	Insecticide/Acaricide	1.5
Pirimiphos-methyl	Actellic	Insecticide/Acaricide	1.5
Fenitrothion	Sumithion	Insecticide	1.5
Cyromazin	Trigard	Insecticide	1.5
Propineb	Antracol	Fungicide	1.5
Dimethomorph	Acrobat	Fungicide	1.5
Copper	Copper	Fungicide	1.5

*Sum is more than 100%, because some farmers use more than one pesticide.

areas, the mites are controlled by their natural enemies.

Out of the farmers interviewed, 47% knew about RSM and 32% regarded them as a problem. The farmers used a total of 30 different pesticide brands with 27 different active ingredients to control the mites. Only 5 of these active ingredients are specific acaricides, 1 is an acaricide with additional insecticidal activity, 6 are insecticides with some activity against mites, 1 is a fungicide with activity against mites, 7 are insecticides and 4 are fungicides (Table 2). Only 3% of the farmers knew that natural enemies could help to control RSM.

The identification of the natural enemies is still in progress, but it is already obvious that predatory mites (Phytoseiidae), Staphylinid beetles (*Oligota* sp.) and predatory bugs (Anthocoridae) play a major role.

The survey was completed in Zambia and Mozambique in December 1999, but the data are not yet analysed. In Zimbabwe, the survey will be continued after the end of the rainy season.

3. TESTING OF RESISTANCE OF TOMATO ACCESSIONS TO RSM

A rapid method for the greenhouse screening of tomato germplasm for resistance to *T. urticae* was developed and the screening of commercial varieties started. Tomato plants were grown until the fourth true leaf developed. The second true leaf was then isolated by putting cotton wool around the petiole and smearing the cotton wool with insect glue. Five adult females of *T. urticae* were put on the isolated leaf with a fine brush. After 12 days, motile stages and eggs were counted separately. Money Maker, a variety which is susceptible to *T. urticae* and widely planted in Kenya, was taken as a standard. Several

Table 3. Tomato accessions with significantly lower numbers of *T. urticae* motile stages and/or eggs compared to the standard variety (Money Maker) after 12 days

Variety	Motile stages (%)	Eggs (%)
Money Maker	100.0	100.0
Cal-J	64.7*	36.3*
Roma	56.5*	17.4*
Marglobe	37.8*	23.4*
Marmande	62.8*	47.2*
94 RT 330	61.7*	67.4
EC 1193	82.8	27.5*
Continental Michel	40.4*	29.4*
Azad Konti	79.7	47.7*
C.No.153	62.2	47.7*
ARP 365-1	55.1*	112.0
EC 1154	50.9*	154.88
94 RT 348	19.5*	117.7
Early Pearson	42.4*	42.3*

Data shown as percentage of the standard.
* Indicates significant differences to the standard variety (Student-Newman-Keuls-Test, P=0.05).

varieties showed significantly lower reproduction rates compared to Money Maker (Table 3).

4. CONTROL OF *TETRANYCHUS URTICAE* WITH DIFFERENT NEEM FORMULATIONS

Four commercial neem formulations available in Kenya were tested for their efficacy in controlling *T. urticae*: Neemros WP (neem seed powder, 0.5% azadirachtin); Neemroc EC (water miscible oil formulation, 0.03% azadirachtin); Saroneem (alcoholic extract, 1% azadirachtin) and Neemroc-Combi (enriched oil, 0.5% azadirachtin). Mitac (amitraz) was used as a standard acaricide for comparison. A combination of Neemroc and Mitac was also tested, arising from a recommendation from a flower grower who reported good results with this combination in his greenhouses.

Neemroc caused high mite mortality in leaf disc tests at a concentration of 25 ml/l (Table 4). Trials with potted tomatoes in a greenhouse also showed significantly lower mite numbers on plants treated with Neemroc compared to the untreated control and other neem formulations. Mite numbers in Neemroc treatments were as low as on plants treated with Mitac.

Table 4. Mortality of *T. urticae* after 24 hours at different concentrations of neem products (3 replications, leaf discs 25 mm diameter, 15 adult females per disc)

Treatment	Concentration	Mortality (%) (mean ± SE)
Neemros	0 g/l	0 c
	20 g/l	33.3 ± 10.2 ab
	25 g/l	55.6 ± 8.0 a
	30 g/l	13.3 ± 7.7 bc
	35 g/l	26.7 ± 7.7 abc
Neemroc	0 ml/l	2.23 ± 2.23 b
	10 ml/l	24.6 ± 11.7 b
	15 ml/l	65.1 ± 18.4 a
	20 ml/l	93.2 ± 0.13 a
	25 ml/l	95.6 ± 4.4 a
Saroneem	0 ml/l	4.40 ± 4.4 c
	5.0 ml/l	23.6 ± 5.3 bc
	5.5 ml/l	36.6 ± 8.9 ab
	6.0 ml/l	64.3 ± 9.9 a
	6.5 ml/l	67.0 ± 6.4 a
Neemroc Combi	0 ml/l	0 b
	0.1 ml/l	20.0 ± 7.7 ab
	0.5 ml/l	33.3 ± 7.7 ab
	1.0 ml/l	53.3 ± 15.4 a
	1.5 ml/l	57.8 ± 17.4 a
Mitac T5 (ml/l)	0 ml/l	6.7 ± 3.8 d
	1.0 ml/l	25.9 ± 12.5 cd
	1.5 ml/l	56.8 ± 5.5 bc
	2.0 ml/l	92.5 ± 4.4 a
	2.5 ml/l	85.8 ± 10.9 ab
Mitac + Neemros	0 ml/l + 0 g/l	4.4 ± 4.4 b
	1 ml/l + 20 g/l	63.7 ± 15.6 a
	1 ml/l + 25 g/l	78.9 ± 4 a
	1 ml/l + 30 g/l	90.0 ± 4 a
	1 ml/l + 35 g/l	97.7 ± 2.3 a

For each product, means followed by a common letter are not significantly different ($P = 0.05$, Ryan-Einot-Gabriel-Welsch Multiple Range Test).

5. SPATIAL AND TEMPORAL DYNAMICS OF *TETRANYCHUS URTICAE* IN TOMATO FIELDS

Initial studies on the spatial and temporal distribution of RSM in tomato fields in Kenya show that mite densities are highest in the lower part of the plants (Table 5). The trial was artificially infested with mites because no natural infestation occurred. A tomato field (25 x 25 m) was divided in 25 strata of equal size (5x5m). Sampling was done at weekly intervals. At each sampling occasion 2 plants per stratum were sampled. The tomato plants were divided in 3 strata (top, middle, bottom) and 2 leaves per strata were taken. Leaves were brought to the lab where males were counted with the help of a microscope. Mite numbers increased with time, but were generally very low throughout the trial (Figure 5).

Table 5. Mean density of the different stages of *T. urticae* mites on different tomato canopy layers in a smallholder tomato field

RSM stages/leaf	Canopy layers: Bottom*	Middle*	Top*
Eggs	3.27 a	2.61 b	2.22 c
Immatures	2.22 a	1.76 a	0.86 b
Adult females	0.52 a	0.47 a	0.26 b
Adult males	0.18 a	0.09 b	0.03 c

*Within a column, means followed by a common letter are not significantly different ($P = 0.05$, Student-Newman-Keuls Test).

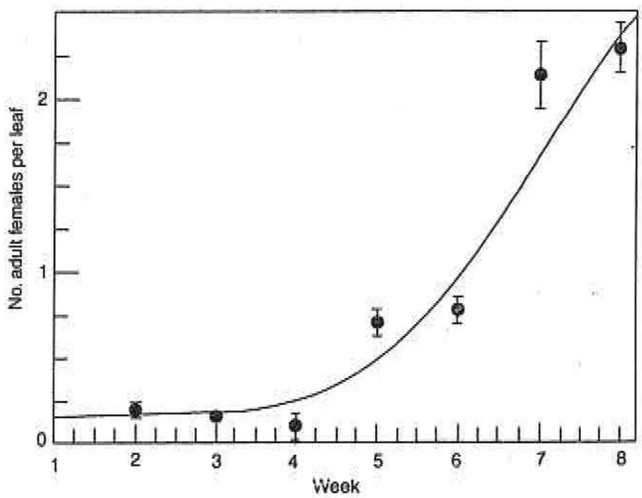

Figure 5. Development of the population of adult female *T. urticae* in a smallholder tomato field (weekly sampling starting from 19 May 1999)

Output

Conferences attended

Knapp M. (1998) First African Acarology Symposium, Pretoria, South Africa, 24–27 November 1998. Paper presented, 'Development of environmentally friendly management methods for red spider mites in smallholder tomato production systems in eastern and southern Africa'.

Knapp M., Agong, S.G., Löhr, B. (1998) Second National Horticulture Seminar, JKUAT, Nairobi, Kenya, 14–15 January 1998. Paper presented, 'Development of environmentally friendly management methods for red spider mites in smallholder tomato production systems in eastern and southern Africa'.

Capacity building

ARPPIS students

Ivy Nzuma: The bio-ecology of red spider mites *Tetranychus evansi* (Acari: Tetranychidae) on tomatoes in Zimbabwe. (University of Zimbabwe)

Ibrahima Sarr: The bio-ecology and control of red spider mites *Tetranychus urticae* (Acari: Tetranychidae) on tomatoes in Kenya. (Kenyatta University)

MSc student

Sophia S. Kashenge: Comparative efficacy of neem (*Azadirachta indica*) and amitraz (Mitac) against two spotted spider mites (*Tetranychus urticae*) on tomatoes (*Lycopersicon esculentum*). (Completed in 1999). (Sokoine University of Agriculture, Tanzania)

Training course

A training course 'Mites on Tomatoes: Collecting, Preserving, Identification and Control', conducted by the ARC Plant Protection Research Institute, Pretoria was organised jointly with GTZ-IPM Horticulture for 7 participants from 4 countries in Eastern and Southern Africa.

(See also the reports on Neem and 'Models for IPM in Major Vegetable Crops'.)

Microbial Control of Thrips in Flowers with an Entomopathogenic Fungus

1. DEVELOPMENT OF A FUNGUS-BASED PESTICIDE FOR THE MANAGEMENT OF THRIPS IN FLORICULTURAL CROPS

Background, approach and objectives

Thrips are one of the major constraints to floricultural production worldwide. They are currently controlled by repeated application of synthetic insecticides. Reliable alternatives for thrips control are not commercially available and this situation prevents the development of alternative control strategies for other pests as well: as long as thrips need repeated pesticide applications, the use of natural enemies for the control of red spider mites, aphids and other cut flower pests is impossible. Less harmful and yet effective alternatives to synthetic pesticides have to be developed, due to environmental and worker safety concerns in international markets.

Research at ICIPE has identified a highly pathogenic strain of *Metarhizium anisopliae* (Metsch.) Sorok. which attacks the three thrips species of importance to floricultural production: *Megalurothrips sjostedti* Trybom, *Frankliniella occidentalis* (Pergande) and *Thrips tabaci* Lindeman (Figure 1). The objective of this industry co-funded project was to compare the performance of the fungus to generally used thrips control measures in chrysanthemum, carnation and rose production.

Participating scientists: *N. K. Maniania*, S. Ekesi, M. Knapp (*Project Leader)*

Assistant: *E. Wesonga*

Donors: *• The Fresh Produce Exporters Association of Kenya (FPEAK) • Kenya Flower Council (KFC) • ICIPE Core Fund donors (Development Agencies of Switzerland, Sweden, Norway and Denmark)*

Collaborators: *• Yoder Farm • Finlay Flowers • Kijabe Flowers (all in Kenya)*

Work in progress

1.1 FIELD EXPERIMENTS

Field evaluation of the fungus product Metathripol, developed from *M. anisopliae*, was first carried out at Yoder Farm (Embu) on chrysanthemum cuttings (1997–1998), and later on two farms selected by FPEAK and KFC: Finlay Flowers in Kericho raising carnations (1998–1999) and Kijabe Flowers in Naivasha raising

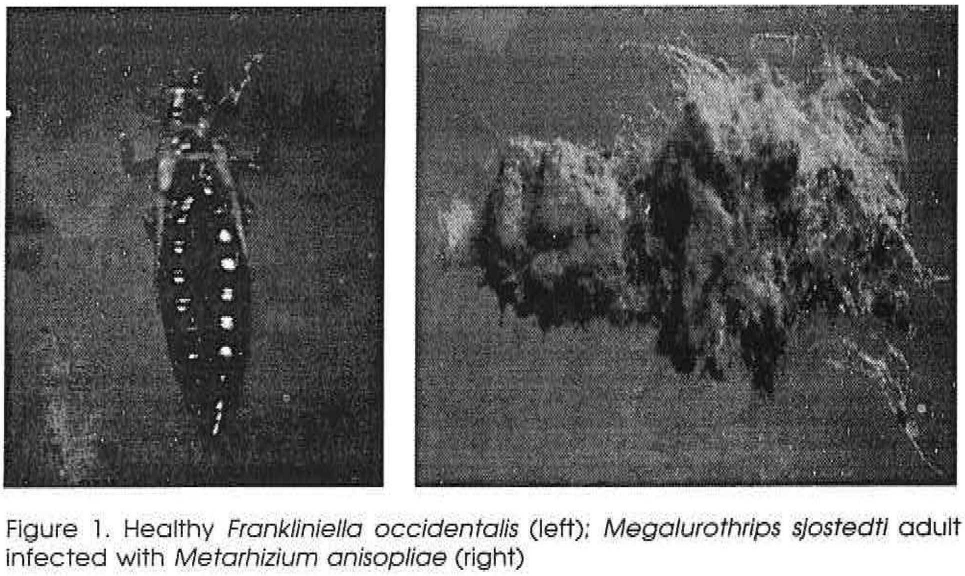

Figure 1. Healthy *Frankliniella occidentalis* (left); *Megalurothrips sjostedti* adult infected with *Metarhizium anisopliae* (right)

roses (1999). All treatment applications were done by the farm's technical staff following ICIPE guidance.

At Yoder Farm, two trials were conducted. In the first trial, chrysanthemum variety Bright Yellow Mayshoesmith was planted in 4 x 1 m plots (24 rows) with an intra- and inter-row spacing of 15 and 40 cm, respectively. The treatments consisted of:

(a) *M. anisopliae* applied weekly
(b) *M. anisopliae* applied bi-weekly
(c) Lannate® (Methomyl 90 WP) applied weekly
(d) Lannate applied bi-weekly
(e) Control (water spray).

The fungus was applied at the rate of 1×10^{13} conidia/ha and Lannate was applied at the growers recommended rate of 440 g a.i./ha of the commercial formulation. The experiments were laid down in a randomised complete block design with three replications. Results from the trial revealed that control of adult thrips was achieved with *M. anisopliae*, while Lannate performed better on the larval stage.

An attempt was therefore made in the second trial to compare both control agents at high and reduced doses in order to obtain control of both stages. Prior to this field trial, bioassays had been conducted to study the compatibility between *M. anisopliae* and Lannate. The different concentrations of insecticide tested did not have any inhibitory effect on germination and fungal growth. Chrysanthemum variety Honey Charm, highly susceptible to thrips, was used in the second trial. The plant was established in plots of 1.6 x 1.1 m (8 rows). Plant spacing was similar to the previous trials. Nine treatments were applied:

(i) *M. anisopliae* applied at 1×10^{12} conidia/ha
(ii) *M. anisopliae* applied at 1×10^{13} conidia/ha
(iii) Lannate applied at 440 g a.i./ha
(iv) Lannate applied at 44 g a.i./ha
(v) *M. anisopliae* applied at 1×10^{12} conidia/ha + Lannate at 440 g a.i./ha
(vi) *M. anisopliae* applied at 1×10^{12} conidia/ha + Lannate at 44 g a.i./ha
(vii) *M. anisopliae* applied at 1×10^{13} conidia/ha + Lannate at 440 g a.i./ha
(viii) *M. anisopliae* applied at 1×10^{13} conidia/ha + Lannate applied at 44 g a.i./ha
(ix) Control (water spray)

The experiment was replicated three times in a randomised complete block design.

Conidia were suspended in water for spray application in all trials. In all the trials, treatments were started when the plants were 3 weeks old and continued at weekly or bi-weekly intervals. The fungus and the chemical insecticide were applied with a separate motorised knapsack sprayer at an output of 1000 litres/ha. Spray applications during all trials were performed in the evenings between 1700 and 1830 hours.

To sample for thrips, 20 cuttings were randomly excised from each plot into a vial containing 30% alcohol. The samples were brought to ICIPE's laboratory and cuttings were dissected and washed to separate insects from the plant parts, and later counted. The first sample of cuttings was taken 24 hours prior to treatment and subsequently at weekly intervals.

At Finlay and Kijabe farms, treatments were applied on commercial productions at the rate described earlier using the usual spray application equipment (1000-litre output). The farms' technical staff also collected efficiency data.

1.1.1 *Yoder Farm experimental results*

During the first trial, larval and adult thrips population density taken before spray application varied from 12–18 thrips/20 cuttings and 10–16 larvae/20 cuttings, respectively. At 7 days after treatment (DAT), a significant reduction in thrips population density was observed in both the fungal and Lannate-treated plots as compared with the control: larvae (F=9.86; d.f.=4,8; P=0.0071) and adults (F=12.7; d.f. =4,8; P=0.0231). Similar differences among treatments were also observed for larvae and adults at 14 DAT and 28 DAT. *Metarhizium anisopliae* applied weekly out-performed all other treatments in bringing down adult population density. Likewise, weekly application of Lannate was superior in reducing larval population density compared to the other treatments.

In the second trial, a reduction in adult and larval thrips population density receiving fungal, Lannate or a combination of the fungus and Lannate treatment was clearly evident at 7 DAT: adults (F=13.5; d.f.=8,16; P=0.0024) and larvae (F=11.7; d.f.=8,16; P=0.0046) (Table 1.1.1a). Two treatment combinations (*M. anisopliae* 1×10^{13} conidia/ha + Lannate 440 g/ha and *M. anisopliae* 1×10^{13} conidia/ha + Lannate at 44 g/ha) were superior to all other treatments in reducing both adults and larval thrips populations at 14 and 21 DAT (Tables 1.1.1a and 1.1.1b).

We have shown that Metathripol can effectively control thrips in a variety of flower crops. This can improve plant protection practices through the use of non-chemical approaches to red spider mite and aphid problems.

1.1.2 *Finlay and Kijabe farm experiments*

All reports indicate that Metathripol is as effective as the standard insecticide treatment (Tables 1.1.2a and 1.1.2b).

1.2 EFFECT OF COMMONLY USED PESTICIDES ON METATHRIPOL

Thrips are not the only pests in horti- and floricultural crop production systems. Pathogens, spider mites and other insects may be controlled by chemical pesticides. It is therefore of paramount importance to study the compatibility between these pesticides and Metathripol. After consultation with growers, 19 fungicides, five insecticides and two acaricides were evaluated *in vitro* in the laboratory for their side

Table 1.1.1a. Effect of *Metarhizium anisopliae* and Lannate application on larval population of *Frankliniella occidentalis* on chrysanthemum

Treatment	Days after treatment (No. of larvae)			
	0	7	14	21
M. anisopliae 1 x 10^{12} conidia/ha	34.7 ± 2.1 a	21.7 ± 2.3 b	13.8 ± 2.5 b	12.0 ± 1.6 b
M. anisopliae 1 x 10^{13} conidia/ha	40.7 ± 1.3 a	29.3 ± 3.5 b	13.7 ± 2.7 b	12.7 ± 2.1 b
Lannate 440 g/ha	43.7 ± 9.8 a	14.0 ± 1.8 c	8.0 ± 0.7 c	8.1 ± 1.1 c
Lannate 44 g/ha	40.0 ± 2.8 a	20.0 ± 2.1 b	15.1 ± 0.9 b	13.1 ± 1.5 b
M. anisopliae 10^{12} + Lannate 440 g/ha	39.3 ± 8.7 a	10.1 ± 0.8 c	5.7 ± 1.1 c	5.3 ± 0.8 c
M. anisopliae 10^{12} + Lannate 44 g/ha	32.3 ± 2.3 a	10.1 ± 1.1 c	6.1 ± 0.7 c	6.3 ± 0.4 c
M. anisopliae 10^{13} + Lannate 440 g/ha	44.7 ± 2.6 a	5.3 ± 0.7 d	2.0 ± 0.4 d	1.0 ± 0.2 d
M. anisopliae 10^{13} + Lannate 44 g/ha	43.3 ± 8.7 a	6.1 ± 1.1 d	2.7 ± 0.2 d	1.3 ± 0.1 d
Control (water)	45.5 ± 1.8 a	48.1 ± 2.3 a	37.1 ± 4.5 a	38.3 ± 3.4 a

Means within a column followed by the same letter are not significantly different by Student-Newman-Keuls' test at P=0.05.

Table 1.1.1b. Effect of *Metarhizium anisopliae* and Lannate application on adult population of *Frankliniella occidentalis* on chrysanthemum

Treatment	Days after treatment (No. of adults)			
	0	7	14	21
M. anisopliae 1 x 10^{12} conidia/ha	24.3 ± 2.1 a	10.3 ± 1.2 b	15.2 ± 2.1 b	11.3 ± 1.1 b
M. anisopliae 1 x 10^{13} conidia/ha	27.7 ± 3.8 a	12.0 ± 1.1 b	10.8 ± 2.1 b	6.7 ± 0.7 c
Lannate 440 g/ha	28.7 ± 1.6 a	10.0 ± 0.8 b	10.3 ± 0.4 b	6.8 ± 0.2 c
Lannate 44 g/ha	33.3 ± 1.7 a	13.7 ± 0.5 b	12.3 ± 0.7 b	12.1 ± 0.8 b
M. anisopliae 10^{12} + Lannate 440 g/ha	20.0 ± 2.1 a	11.0 ± 1.1 b	10.3 ± 0.9 b	6.0 ± 0.5 c
M. anisopliae 10^{12} + Lannate 44 g/ha	33.3 ± 1.9 a	11.2 ± 1.8 b	13.7 ± 0.2b	11.0 ± 0.1b
M. anisopliae 10^{13} + Lannate 440 g/ha	28.7 ± 0.5 a	8.7 ± 0.3 b	6.0 ± 0.1 c	2.7 ± 0.2 d
M. anisopliae 10^{13} + Lannate 44 g/ha	34.3 ± 1.2 a	7.3 ± 0.2 b	6.7 ± 0.4 c	2.1 ± 0.1 d
Control (water)	34.3 ± 1.5 a	22.1 ± 1.1 a	22.0 ± 2.1 a	18.7 ± 3.1 a

Means within a column followed by the same letter are not significantly different by Student-Newman-Keuls' test at P=0.05.

Table 1.1.2a. Mean number of thrips/cutting following 8 weekly applications of Metathripol and chemical insecticide (Lannate) on carnations at Finlay Flowers, Kericho

Treatment	Larvae	Adults
Metathripol	1.1	0.4
	0.8	0
	0.6	0
	1.2	0
	0.8	0.4
Mean	0.9	0.2
Lannate	0.4	0.2
	0.3	0.4
	0.6	0.6
	0.4	0.6
	0.2	0.2
Mean	0.4	0.4

Table 1.1.2b. Mean number of thrips/flower following 2 weekly applications of Metathripol and chemical insecticides (Lannate) on roses at Kijabe Flowers, Naivasha

Treatment	Larvae	Adults
Metathripol	1.1	0.9
	0.5	0.7
	1.4	0.9
	0.1	0.4
Mean	0.9	0.7
Lannate	0.3	0.3
	0.5	0.4
	0.7	0.3
	0.7	0.5
Mean	0.6	0.4

effects on Metathripol. The fungus was exposed to different rates of application of the chemical pesticides (1/10 and the recommended rate) over different periods of time (less than 2, 24 and 48 hours).

Results showed that the insecticides and acaricides tested did not have any effects on Metathripol. Out of the fungicides tested, 16 out of 21 did not have inhibitory effects on the fungus, including Benomyl (Benlate).

1.3 EFFECT OF METATHRIPOL ON THE PREDATORY MITE, *PHYTOSEIULUS PERSIMILIS*

This predatory mite is widely used for the control of spider mites in horticultural crops worldwide. Predatory mites are being reared at ICIPE and their use could be the next step in the improvement of pest control activities, especially in roses and strawberries. The effect of Metathripol was therefore investigated in the laboratory by spraying three concentrations of the fungus (10^5, 10^6 and 10^7 conidia/ml) directly on the predator mites or by placing them on treated leaves. The application of the fungus did not have any effect on the predator mite.

Output

Publications

Ekesi S., Maniania N.K., Ampong-Nyarko K. and Onu I. (1998) Potential of the entomopathogenic fungus *Metarhizium anisopliae* (Metsch.) Sorokin for control of the legume flower thrips, *Megalurothrips sjostedti* (Trybom) on cowpea in Kenya. *Crop Protection* 17, 661–668.

Ekesi S., Maniania N.K., Ampong-Nyarko K. and Onu I. (1999) Effect of temperature on germination, radial growth and pathogenic activity of *Metarhizium anisopliae* (Metschnikoff) Sorokin and *Beauveria bassiana* (Balsamo) Vuillemin on *Megalurothrips sjostedti* (Trybom). *Biocontrol Science and Technology* 9, 177–185.

Ekesi S., Maniania N.K., Ampong-Nyarko K. and Onu I. (1999) Effects of temperature and photoperiod on development and oviposition of the legume flower thrips, *Megalurothrips sjostedti*. *Entomologia Experimentalis et Applicata* 93, 149–155.

Ekesi S., Maniania N.K., Ampong-Nyarko K. and Onu I. (1999) Effect of intercropping cowpea with maize on the performance of *Metarhizium anisopliae* against the flower thrips, *Megalurothrips sjostedti*. *Environmental Entomology* 28, 1154–1161.

Ekesi S., Maniania N.K., Onu I. and Löhr B. (1998) Pathogenicity of entomopathogenic fungi (Hyphomycetes) to the legume flower thrips, *Megalurothrips sjostedti* (Trybom) (Thysanoptera: Thripidae). *Journal of Applied Entomology* 122, 629–634.

Ekesi S., Maniania N.K. and Onu I. (1998) Antibiosis and antixenosis of two cowpea varieties to the legume flower thrips, *Megalurothrips sjostedti* (Trybom) (Thysanoptera: Thripidae). *African Crop Science Journal* 6, 49–59.

Maniania N.K., Saxena K.N. and Odulaja O. (1998) Influence of three sorghum cultivars on the activity of *Metarhizium anisopliae* (Metsch.) Sorok. against *Chilo partellus* (Swinhoe). *Insect Science and Its Application* 18, 45–52.

Conferences attended

Ekesi S., Maniania N.K., Ampong-Nyarko K. and Onu I. (1999) 32nd Meeting of the Society for Invertebrate Pathology, University of California at Irvine, 22–27 August 1999, USA. Paper presented, 'Effect of intercropping cowpea with maize on the performance of *Metarhizium anisopliae* against *Megalurothrips sjostedti* and some predators.

Langewald J., Bokonon Ganta A., Gitonga W., Kooyman C., Maniania N.K. and Moore D. (1999) 32nd Meeting of the Society for Invertebrate Pathology, University of California at Irvine, 22–27 August 1999, USA. Paper Presented, 'Developing *Metarhizium anisopliae* for termite control in Africa.

Maniania N.K. (1998) Workshop on Microbial Control of Termites in Africa, 13–15 October 1998. Paper presented, 'Termite control with *Metarhizium anisopliae*: Facts'.

Maniania N.K. (1998) Workshop on 'Microbial Control of Storage Pests', 30 November–3 December, 1998, Cotonou, Benin.

Maniania N.K. and Lux S. (1998) African Fruit Fly Initiative Donor Meeting, 16–18 February 1998. Paper presented, 'Exploration for fruit fly pathogens and evaluation of their potential for fruit fly control in Africa'.

Maniania N.K., Ekesi S. and Mwangi F. (1998) Pathfast International Floriculture Seminar, 15–17 March 1998, Nairobi, Kenya. Paper presented, 'Prospects of entomopathogenic fungi for biological control of thrips in floriculture'.

Maniania N.K., Ekesi S., Ampong-Nyarko K. and Sithanantham S. (1998) FPEAK Seminars, Hortec 1998, 18–20 March 1998, Nairobi, Kenya. Paper presented, 'Prospects of entomopathogenic fungi for biological control of thrips in horticulture'.

Maniania N.K., Ekesi S., Ampong-Nyarko K. and Sithanantham S. (1998) VIIth International Colloquium on Invertebrate Pathology and Microbial Control, IVth International Conference on *Bacillus thuringiensis*, 23–28 August 1998, Sapporo, Japan. Paper presented, 'Metathripol, *Metarhizium anisopliae*-based bioinsecticide for biological control of thrips on vegetable and flower in Africa'.

Research proposals

Towards biologically intensive pest management: *Metarhizium anisopliae* for the management of thrips in high value horticulture. Funded by the Fresh Produce Exporters Association of Kenya (FPEAK) and the Kenya Flower Council (KFC).

Development of a *Metarhizium anisopliae*-based biopesticide for control of thrips in East Africa. Joint proposal with CABI Bioscience, UK and the Royal Veterinary University, Copenhagen, Denmark.

Capacity building

PhD students

S. Ekesi was awarded the PhD degree in insect pathology at Ahmadu Bello University, Nigeria. The research topic was 'Variability of pathogenic activity of entomopathogenic fungi towards the legume flower thrips, *Megalurothrips sjostedti*, and their potential for biological control'.

E. Aloo is carrying out research on the 'Evaluation of *Bacillus thuringiensis* and botanical extracts for the IPM of African armyworm, *Spodoptera exempta*'. Registered at Makerere University.

S. Dimbi is conducting research on the 'Evaluation of the potential of entomopathogenic fungi for the management of African Tephritidae fruit flies, *Ceratitis rosa* and *C. cosyra* in Kenya. Registered at Kenyatta University.

Impact

The Fresh Produce Exporters Association of Kenya (FPEAK) and Kenya Flower Council (KFC) have been impressed by the performance of Metathripol, the *Metarhizium anisopliae*-based product and have given a grant for large-scale field trials in the farms. There is increasing demand from the growers to purchase the product.

A pilot plant is needed to produce the product for large-scale trials.

(See also the reports on the Entomopathology Unit.)

Awareness Building and Facilitating the Use of Neem as a Source of Natural Pesticides and Other Useful Products in Sub-Saharan Africa

A. NEEM FOR MANAGEMENT OF HORTICULTURAL CROP PESTS

Background, approach and objectives

In the coming millennium, nature, humanity and technology must work in harmony to produce more food for the growing populations in developing countries. The challenge is to increase yields in production systems, reduce post-harvest losses, and improve human health, animal health and the environment. The challenge is particularly relevant to Africa, where a high percentage of people suffer from malnutrition and other ailments, many of which are arthropod-borne. The food production and health technologies need to be economically efficient, ecologically sound, equitable and ethical. Over the past decade, the neem tree, *Azadirachta indica* A. Juss (Meliaceae), which is widespread in Asia and Africa, has attracted the attention of researchers worldwide as a source of natural pest control materials which are not only novel in their modes of action, but also environmentally safe. The tree also has multiple uses in herbal medicine, toiletries, as a source of firewood and timber, as a soil quality enhancer and in reforestation programmes.

The use of simple products made from neem seed is an attractive option. However, the dearth of information on methods of seed processing, extraction, and formulation of bioactive constituents and application have been major constraints to the use of neem materials 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 eastern Africa and thereby safeguard the environment within ICIPE's 4-H paradigm for sustainable development. This goal is being achieved by imparting hands-on training on how to use neem by conducting field trials and demonstrations. This is being done with the participation of the scientific and farming communities and entrepreneurs and in collaboration with national, regional and international programmes.

In 1998 and 1999, laboratory studies and field trials on management of pests affecting kale, tomato and banana were conducted at ICIPE's Mbita Point Field Station, and in farmers' fields. The phytotonic effect of neem on selected crops was also investigated.

Participating scientists: *R. C. Saxena (Project Coordinator), T. Musabyimana (PhD student)*

Assistants: *E. L. Kidiavai, N. O. Owino*

Donor: *Government of Finland, UNEP*

Collaborators: • *ICRAF* • *KARI*

Work in progress

1. NEEM SEED DERIVATIVES FOR CONTROL OF THE DIAMONDBACK MOTH

1.1 SETTLING RESPONSE

The diamondback moth (DBM), *Plutella xylostella* (L.), a major pest of cruciferous crops such as cabbage and kale (*Brassica oleracea* L. subsp. *acephala*), has become resistant to most synthetic insecticides and *Bacillus thuringiensis*. Spray application of neem seed extract (NSE) to kale leaves (a popular green eaten as accompaniment to starch dishes in East Africa) repelled the DBM larvae and deterred feeding. In 1998 and 1999, further laboratory tests and field trials were conducted with NSE and azadirachtin-rich neem extractive (NE). In choice tests, significantly fewer 3rd-instar DBM larvae settled on kale leaf discs treated with NSE or NE than on control discs treated with water. The higher the concentration of NSE or NE, the stronger the repellent effect. In contrast, the settling response of DBM larvae was almost equal when they were given a choice of water-treated control leaf discs only.

1.2 FEEDING RESPONSE

In the free-choice test, DBM larvae fed and excreted significantly less on leaf discs treated with NSE or NE than on water-treated, control leaf discs, as indicated by smaller areas of leaf discs consumed and by

Table 1.2. Leaf area consumed by 3rd-instar *Plutella xylostella* larvae and dry weight of faeces excreted in 18 hours (as indicator of feeding activity) when confined to kale leaf discs treated with neem seed extract (NSE) or water (control) under no-choice conditions

Treatment	Leaf area (cm²) eaten/20 larvae	Dry wt (mg) of faeces /20 larvae
NSE 1%	5.05 ± 02.0 c	4.86 ± 0.76 c
NSE 2%	3.50 ± 0.54 b	4.12 ± 1.04 b
NSE 3%	2.34 ± 0.38 a	2.13 ± 0.55 a
Control	5.67 ± 0.23 d	7.59 ± 0.80 d

In a column, means followed by the same letter are not significantly different ($P > 0.001$; REGW multiple range test); means ± SE of 10 reps.

correspondingly lower weights of dried faeces. The higher the concentration of NSE or NE, the greater the reduction in feeding and excretion. Even under the no-choice test, DBM larvae fed significantly less from NSE-treated leaf discs than from water-treated discs (Table 1.2). Also, the weight of dried excreta was significantly less on neem-treated discs than on control discs.

1.3 PUPATION AND LONGEVITY

Pupation was significantly less ($P \leq 0.001$) when 3rd-instar DBM larvae were confined for 24 hours on NE-treated kale plants and then reared on untreated plants. The pupae that developed from larvae which had been exposed to neem treatment weighed significantly less and fewer normal adults emerged from them than in the control. The longevity of male and female moths which emerged from pupae developing from larvae exposed to 0.3% NE treatment was significantly less than in the control.

1.4 REPRODUCTION

In treatments with 0.2 and 0.3% NE, emerged females deposited significantly fewer eggs than in the control, while hatchability of eggs was reduced in all NE treatments.

In another test of carry-over effect, fewer eggs were generally laid by females when crossed with males from the control or NE treatment. As a result of the carry-over effect, the hatchability of eggs was also significantly reduced in most crosses.

When given a choice of neem-treated kale plants and water-treated plants, the DBM females laid significantly fewer eggs on neem-treated plants (Table 1.4). The higher the concentration of NSE or NE, the greater the reduction in egg laying. Even under no-choice tests, the females deposited fewer eggs on NSE- or NE-treated plants than on control plants ($P \leq 0.001$).

Hatchability was inhibited when DBM eggs were sprayed with NSE or NE. The higher the concentration of NSE or NE, the greater the inhibitory effect on

Table 1.4. Ovipositional response of *Plutella xylostella* females given a choice of kale plants sprayed with neem seed extract (NSE) or water (control) and with neem extractive (NE) or water

Treatment	Eggs laid in 24 h (no.)	Treatment	Eggs laid in 24 h (no.)
NSE 1%	76.2 ± 10.92 bc	NE 0.1%	40.5 ± 3.08 c
NSE 2%	41.1 ± 4.26 ab	NE 0.2%	23.5 ± 1.70 b
NSE 3%	15.6 ± 2.64 a	NE 0.3%	13.3 ± 1.48 a
Control	120.8 ± 5.16 c	Control	65.7 ± 2.86 d

In a column, means followed by the same letter are not significantly different ($P > 0.001$; REGW multiple range test); means ± SE of 10 reps;
Each rep had 10 gravid females.

hatchability, with NSE at 3% reducing it to 13.6 ± 1.20% and NSE 1% to 58.5 ± 2.74%.

1.5 YIELD GAIN FROM USE OF NEEM

Three field trials were conducted in the 1997 and 1998 cropping seasons. In the 1997 trial, DBM infestation was consistently lower in plots sprayed with NSE or NSE+ ajwan (*Pimpinella anisum*), or with Cypermethrin than in untreated control plots (Table 1.5). Fewer larvae, pupae, and pupal cases were recorded at 4, 5, 6, 7 and 8 (WT) in plots sprayed with 20% NSE, 20% NSE + ajwan, or with Cypermethrin than in unsprayed plots.

At 9 WT, DBM infestation in control plots decreased due to almost total decimation of the crop; DBM infestation increased in insecticide-treated plots and remained low in neem-treated plots. The yield of marketable kale leaves was significantly higher in NSE- or insecticide-treated plots than in control plots due to lower DBM infestation (Table 1.5). However, the net gain was higher when the crop was sprayed with NSE.

In the 1998 field trial conducted at Site #1, significantly lower ($P \leq 0.001$) DBM infestation was recorded in plots sprayed with 20% NSE, 0.3% NE or Cypermethrin than in untreated plots. However, the lowest pest infestation occurred in NSE-sprayed plots. The highest yield of marketable kale leaves and the highest net gain were obtained in plots sprayed with 20% NSE. Yield differences in other treatments were not significant. Also at Site #2, similar results were obtained with respect to DBM infestation, spider density, yield of marketable leaves, and the net gain, confirming the superiority of NSE-treatment over other treatments.

Our in-depth laboratory studies and three multi-location field trials have shown that even a recalcitrant pest like *P. xylostella* is highly vulnerable to neem treatments. Not only was the pest repelled and its feeding activity strongly inhibited on neem-treated collards, but mere exposure to neem treatment during the larval stage had a strong carryover effect on subsequent growth and development, adult longevity

Table 1.5. Comparison of *Plutella xylostella* infestation, foliage yield and net gain in kale crop sprayed with neem seed extract (NSE), NSE + ajwan (a natural antioxidant), or with Cypermethrin. MPFS, Kenya

Treatment[1]	DBM[2] (no.)	Yield[3] (kg/ha)	Treatment[4] cost (US$/ha)	Yield value[5] – cost of treatment (US$/ha)
NSE 20%	41.8 ± 6.89 a	14043 ± 1577 a	12.0	2328.3
NSE 20% + ajwan	51.0 ± 9.98 a	13737 ± 1497 a	13.0	2709.7
Cypermethrin	45.2 ± 7.21 a	13972 ± 1931 a	21.6	2308.9
Control	109.2 ± 14.86 b	6630 ± 741 b	0.0	1105.0

In a column, means followed by the same letter are not significantly different ($P > 0.001$; REGW multiple range test); means ± SE of 5 replications.
[1]Using ULV applicators, NSE, NSE + ajwan, or Cypermethrin 5%EC (0.05 kg a.i./ha) was applied six times at 10 l/ha at 3, 4, 5, 6, 7 and 8 WT.
[2]DBM collected from 20 randomly plucked leaves on six sampling dates.
[3]Total yield based on foliage harvested on six sampling dates. 1US$ = KSh 60;
[4]Cost of treatment includes only the cost of NSE, NSE + ajwan, or Cypermethrin applied during cropping season; cost of neem seed = US$ 0.50/kg; cost of Cypermethrin = US$ 36/l.
[5]Cost of collard leaves = US$ 0.17/kg (source: Market Information Branch, Ministry of Agriculture, Kenya).

and fecundity, and hatchability of eggs. Compared with the usual output of eggs ensuing from crosses between *P. xylostella* females and males in the control group, crosses of normal females with normal males reared from individuals briefly exposed to neem treatments during the 3rd larval instar, or even mating them with normal untreated moths, did not realise the full reproductive potential, resulting in hatchability failures in most crosses.

In field trials, the yield of kale leaves with ULV spray applications of 20% NSE with or without ajwan, the antioxidant, was as good as or better than Cypermethrin applications. On the other hand, because of the lower cost of NSE treatment, the net gain was always higher with NSE than with Cypermethrin. ULV spray applications of azadirachtin-rich 0.3% NE, though similar to Cypermethrin, were generally inferior to treatment with NSE 20%, indicating that besides azadirachtin, other constituents in NSE seem to have a synergistic effect against the pest.

2. NEEM FOR BANANA PEST MANAGEMENT

Background, approach and objectives

Banana, *Musa* spp. is the world's second most traded and widely consumed tropical fruit after citrus. Worldwide, the banana weevil, *Cosmopolites sordidus* (Germar), and the parasitic nematode complex, especially *Radopholus similis* (Cobb), *Pratylenchus goodeyi* Sher & Allen, and *Meloidogyne* spp., cause severe yield losses in bananas. They often occur together in the same plant and are associated with similar damage symptoms. The weevil larvae intensively tunnel in the corm and occasionally bore into the pseudostem, while the nematodes damage the roots and corm, resulting in poor plant growth.

Synthetic pesticides such as Furadan have been used successfully for the control of *C. sordidus* and nematodes, but they are expensive, hazardous to human health and the environment and generally enhance pest resistance. So far, little effort has been made at developing a sustainable banana pest management technology using inexpensive plant materials that can substitute for toxic insecticides. We therefore evaluated the potential of neem seed materials for management of the banana weevil and banana parasitic nematodes in trials conducted in farmers' fields in Kenya.

Work in progress

Trials were conducted during May 1996–Feb. 1999 at Oyugis and Kabondo in western Kenya, a prime banana growing area where *C. sordidus* and *P. goodeyi* are the major pests. The suckers of 'Nakyetengu,' a cooking-type triploid banana (AAA-EA) were used. 'Nakyetengu' is popular in the East African highlands, but highly susceptible to the weevil and the nematodes. We tested the efficacy of neem seed powder (NSP) and neem cake (NC). NSP (with 4000 ppm azadirachtin-A) was prepared by pounding the neem seeds, while NC (with ~5800 ppm azadirachtin-A) was obtained by cold-pressing seeds in an oil expeller. Furadan 5G, a synthetic insecticide/nematicide, was used as a positive check.

2.1 FREQUENCY OF NEEM APPLICATION

To determine the optimal frequency of effective applications of NSP, unpared banana suckers were planted in 100-litre capacity drums containing soil mixed with ~5 kg of composted farmyard manure (FYM). NSP was incorporated into the soil around the base of plants at 100 g/drum at planting time and then at 1-, 2-, 3-, 4-, 5- and 6-month intervals. At 40 days after planting, each plant was infested with 5 pairs of newly emerged female and male banana weevils and with a mixed population of nematodes (>90% *P. goodeyi*) by pouring a suspension of 2000 nematodes into the soil around the plant.

Table 2.1. Effects of neem seed powder (NSP) application at different intervals on nematode and weevil density and their damage to banana plant height, girth and biomass, 12 months after planting in drums at MPFS

Treatment	Necrosis index (0–4)	Nematodes (no./100 g roots)	Weevils (no./drum)	PCI outer (%)	Plant height (cm)	Plant girth (cm)	Root density (1–5)	Plant biomass (kg)
Once a month	1.8 ± 0.7 ab	888 ± 168 a	2.2 ± 0.3	10.0 ± 4.4 a	110 ± 5 a	43 ± 1.5 a	4.0 ± 0.3 a	15.2 ± 6.1 ab
Once in 2 months	1.4 ± 0.5 a	2592 ± 488 a	3.1 ± 1.2	10.0 ± 3.2 a	97 ± 3.2 ab	39 ± 1.1 a	4.0 ± 0.3 a	16.9 ± 7.9 a
Once in 3 months	1.2 ± 0.3 a	1896 ± 252 a	2.3 ± 0.9	11.6 ± 3.7 a	105 ± 6.4 ab	38 ± 2.5 ab	3.8 ± 0.4 ab	15.3 ± 5.2 ab
Once in 4 months	2.4 ± 1.2 ab	2880 ± 558 a	2.1 ± 1.1	11.4 ± 4.1 a	96 ± 2.3 ab	36 ± 2.2 ab	3.8 ± 1.0 ab	15.1 ± 7.1 ab
Once in 5 months	2.6 ± 1.8 ab	6036 ± 854 b	2.0 ± 0.8	19.6 ± 9.4 abc	95 ± 2.5 ab	37 ± 1.9 b	3.5 ± 1.5 bc	13.4 ± 4.1 ab
Once in 6 months	3.0 ± 2.5 b	7428 ± 1322 b	2.1 ± 1.2	33.2 ± 11.7 bc	87 ± 5.3 b	33 ± 1.3 b	2.6 ± 1.9 bc	11.7 ± 6.1 ab
Untreated	3.2 ± 2.1 b	13558 ± 1238 c	3.2 ± 2.2	52.0 ± 16.3 c	89 ± 5.1 b	31 ± 1.4 b	2.4 ± 2.0 bc	8.3 ± 4.2 b

In a column, means followed by the same letter are not significantly different at $P<0.05$ level by Tukey's test; means ± SE of 5 replications.

At 12 months after planting, banana plants were uprooted and for each treatment, the root density was evaluated on a 1–5 scale (1 = no root; 5 = abundant roots). Pest density and damage were evaluated following standard procedures. Regardless of the frequency of application, compared with the untreated control, application of NSP significantly reduced the weevil and nematode damage (Table 2.1). However, the lowest nematode population was recorded when NSP was applied once a month or in 2-, 3-, or 4-monthly intervals. The weevil density did not differ among treatments, but larval damage was greater when NSP was applied once in 5- or 6-month intervals. Monthly application of NSP resulted in significantly taller plants with bigger girth. Also, increased frequency of NSP application tended to increase the root density and plant biomass.

2.2 RATE OF APPLICATION

The effective rates of NSP or NC application were determined in farmers' fields in Oyugis (low soil fertility and high pest infestation) and in Kabondo (fertile soil with moderate pest infestation). At both locations, unpared 'Nakyetengu' suckers were planted at 3 x 3 m spacing in April 1997 and applied with NSP or NC at various rates at planting and then at 4-month intervals. Furadan was applied at planting and then at 6-month intervals.

During the first crop, within the same site, regardless of the rates of neem application, the population of nematodes and weevil damage were both significantly less than in untreated controls, but weevil density did not differ among treatments (Table 2.2a). However, pest infestation and damage varied from one site to another with respect to initial pest population; in neem-treated plants, nematodes decreased by 88–97% at Kabondo and by 47–93% at Oyugis. At Kabondo, there was no significant difference among the number of fingers/bunch and the fruit yield from plants applied with the neem materials at different rates (Table 2.2b). However, application of NC at 80 g/mat led to production of significantly more fingers/bunch. Similarly at Oyugis, fruit yield in NSP-treated or NC-treated plants was significantly greater than in control plants. Both at Kabondo and Oyugis, Furadan used alone or together with NC equally increased the banana fruit yield as with neem treatments.

2.3 PEST DAMAGE

Compared with the first crop, during the second crop cycle, neem applications continued to suppress the nematode population below the economic threshold level (~10,000 nematodes/100 g of roots), while the nematode population continued to build up in untreated plants (Table 2.3a). On the other hand, nematode density was significantly higher in Furadan-treated plants than in plants treated with NC + Furadan mixture.

Table 2.2a. Effects of neem seed powder (NSP), neem cake (NC), Furadan or combination of NC and Furadan applied at different rates on nematode and weevil density and their damage to banana grown in a fertile soil with moderate pest infestation (Kabondo) and in a poor soil at high pest infestation (Oyugis)

	Kabondo				Oyugis			
Treatment (g/mat)	Necrosis index (0-4)	Nematodes (no. /100 g root)	Weevils (no./ plot)	PCI (%)	Necrosis index (0-4)	Nematodes (no./100 g root)	Weevils (no./ plot)	PCI (%)
NSP60	0.0 ± 0.0 a	1860 ± 862 a	3.5 ± 3.6	0.1 ± 1.6 a	1.3 ± 0.6 a	4200 ± 600ab	3 ± 0.7	5.0 ± 1.4 ab
NSP80	0.3 ± 0.1 a	780 ± 409 a	1.7 ± 2.8	0.8 ± 0.6 a	1.4 ± 0.9 a	12300 ± 754c	3 ± 0.7	2.5 ± 1.6 a
NSP100	0.1 ± 0.1 a	1920 ± 999 a	2.0 ± 2.4	0.1 ± 0.1 a	1.8 ± 0.2 a	2100 ± 574a	3 ± 0.4	1.0 ± 0.7 a
NC60	0.6 ± 0.3 ab	1440 ± 391 a	2.7 ± 3.5	2.0 ± 1.2 a	1.4 ± 0.7 a	8200 ± 295bc	3 ± 0.7	4.5 ± 1.9 ab
NC80	0.2 ± 0.1 a	580 ± 145 a	5.0 ± 1.6	0.5 ± 0.4 a	1.5 ± 0.4 a	9600 ± 979bc	3 ± 0.5	4.2 ± 2.6 ab
NC100	0.2 ± 0.1a	1860 ± 716 a	1.7 ± 1.5	0.1 ± 0.1 a	1.0 ± 0.0 a	13150 ± 2275c	4 ± 0.5	0.7 ± 0.4 a
Furadan 60	0.5 ± 0.1ab	1080 ± 634 a	1.7 ± 1.7	2.8 ± 1.3 a	1.0 ± 0.3 a	13300 ± 1300c	2 ± 0.8	6.7 ± 2.9 ab
NC+Furadan	0.3 ± 0.1 ab	720 ± 1064 a	0.2 ± 0.5	4.3 ± 1.4 a	1.2 ± 0.2 a	9600 ± 979bc	2 ± 0.4	12.0 ± 4.9 ab
Control	1.1 ± 0.5 ab	16680 ± 2910 b	2.7 ± 0.9	12.0 ± 3.3 b	2.7 ± 0.4 b	31200 ± 2019d	3 ± 0.7	26.0±13.2 b

In a column, means followed by the same letter are not significant at $P<0.05$ level by Student-Neuman-Keuls test; means ± SE of 4 replications.

Table 2.2b. Effects of neem seed powder (NSP), neem cake (NC), Furadan or combination of NC and Furadan applied at different rates against the banana weevil and parasitic nematodes complex on the banana fruit yield and crop cycle at Kabondo and Oyugis

	Kabondo			Oyugis		
Treatment (g/mat)	Fingers (no./bunch)	Fruit yield (t/ha)	Crop cycle (days)	Fingers (no./bunch)	Fruit yield (t/ha)	Crop cycle (days)
NSP60	125.1 ±4.6 ab	15.4 ± 0.8 ab	455 ± 17	61 ± 13.6	6.0 ± 2.5 ab	534 ± 3
NSP80	126.0 ±4.9 ab	18.2 ± 0.8 a	467 ± 21	60 ± 17.4	7.5 ± 2.2 ab	543 ± 32
NSP100	114.5 ±4.8 ab	15.0 ± 0.8 ab	459 ± 27	83 ± 8.10	11.0 ± 1.1 a	485 ± 11
NC60	126.3 ±7.6 ab	18.3 ± 1.0 a	451 ± 19	66 ± 8.60	6.0 ± 2.4 ab	542 ± 26
NC80	129.6 ±5.2 a	17.8 ± 0.9 ab	460 ± 15	45 ± 5.30	3.6 ± 0.7 b	509 ± 24
NC100	125.1 ±3.9 ab	16.8 ± 0.7 ab	468 ± 22	82 ± 2.70	9.2 ± 0.9 ab	542 ± 22
Furadan 60	118.5 ±5.6 ab	15.4 ± 0.8 ab	446 ± 14	53 ± 0.80	5.0 ± 0.7 ab	515 ± 18
NC+ Furadan*	116.3 ±4.0 ab	15.2 ± 1.3 ab	469 ± 19	57 ± 9.10	5.9 ± 1.3 ab	540 ± 22
Control	96.3 ±5.6 b	12.2 ± 0.7	466 ± 17	43 ± 3.00	0.08 ± 0.02 c	541 ± 45

In a column, means followed by the same letter are not significant at $P<0.05$ level by Student-Neuman-Keuls test; means ± SE of 4 replications.
*NC+Furadan (30 g : 30 g).

Table 2.3a. Effects of application of neem seed powder (NSP), neem cake (NC), Furadan or combination of NC and Furadan at different rates on banana pest infestation and damage, crop cycle and fruit yield. Kabondo. (second crop)

Treatment (g/mat)	Necrosis index (0-4)	Nematode (no./ 100 g roots)	Weevils (no./plot)	PCI outer (%)	Crop cycle (days)	Fruit yield (kg/ha)
NSP60	0.3 ± 0.2 ab	3533 ± 333 ab	3.0 ± 0.6 b	0.0 ± 0.0 a	541 ± 12 ab	19864 ± 2142 ab
NSP80	0.0 ± 0.0 a	2667 ± 675 a	0.2 ± 0.2 a	0.7 ± 0.7 a	531 ± 7.5 ab	24438 ± 1565 a
NSP100	0.0 ± 0.0 a	1800 ± 268 a	0.8 ± 0.5 ab	0.0 ± 0.0 a	570 ± 6.4 b	19873 ± 2740 ab
NC60	0.0 ± 0.0 a	2233 ± 167 a	1.8 ± 0.6 ab	0.2 ± 0.2 a	490 ± 3.1 a	24622 ± 1270 a
NC80	0.5 ± 0.2 ab	4733 ± 949 ab	2.1 ± 0.9 ab	0.0 ± 0.0 a	535 ± 8.0 ab	26978 ± 1789 a
NC100	0.0 ± 0.0 a	3530 ± 313 ab	1.0 ± 0.4 ab	2.3 ± 1.5 ab	569 ± 9.0 b	18682 ± 2142 ab
Furadan 60	0.8 ± 0.3 ab	7273 ± 219 b	0.5 ± 0.2 a	3.0 ± 1.0 ab	573 ± 10.0 b	15070 ± 550 b
NC+Furadan*	0.3 ± 0.2 ab	2800 ± 252 a	0.5 ± 0.5 a	1.2 ± 0.7 a	502 ± 15.0 a	24017 ± 764 a
Control	1.1 ± 0.4 b	29533 ± 1574 c	0.3 ± 0.3 a	5.6 ± 2.0 b	543 ± 6.0 ab	15326 ± 1907 b

In a column, means followed by the same letter are not significantly different at $P<0.05$ level by Student-Neuman-Keuls Test; means ± SE of 4 replications.
*NC+Furadan (30 g : 30 g).

Table 2.3b. Effects of application of neem seed powder (NSP) and neem cake (NC) at rates of 200, 300, or 400 g/plant on the banana weevil and nematode infestation, their damage and the fruit yield at MPFS. First crop

Treatment (g/mat)	Necrosis index (0–4)	Nematodes (no. /100 g roots)	Weevils (no./plot)	PCI outer (%)	Fingers (no. / bunch)	Fruit yield (t/ ha)
NSP200	2.1 ± 1.7 a	2800 ± 800 bc	3 ± 1.5	14 ± 1.0ab	93.5 ± 6.5 a	12.8 ± 2.6 a
NSP300	1.2 ± 0.9 a	480 ± 120 a	4 ± 0.9	15 ± 0.0ab	101.0 ± 0.0 a	11.1 ± 0.0 a
NSP400	0.7 ± 0.2 a	1200 ± 346 ab	3 ± 1.9	4 ± 0.5a	84.0 ± 18.2 a	10.2 ± 1.9 a
NC200	0.5 ± 0.5 a	4400 ± 400 c	4 ± 0.6	11 ± 2.3ab	68.6 ± 19.5 a	7.7 ± 3.2 a
NC300	1.0 ± 0.7 a	5066 ± 267 c	5 ± 1.4	8 ± 2 ab	79.3 ± 11.7 a	9.2 ± 1.9 a
NC400	0.0 ± 0.0 a	3200 ±1058 bc	3 ± 0.7	7 ± 0 ab	50.0 ± 0.0 a	6.5 ± 0.0 a
Control	3.2 ± 1.3 b	34666 ± 705 d	4 ± 0.5	48 ± 27 b	26.0 ± 6.0 b	4.2 ± 0.7 b

In a column, means followed by the same letter are not significantly different at $P<0.05$ level by Student-Neuman-Keuls test; means ± SE of 3 replications.

The weevil density and larval damage remained negligible in various neem treatments. Plants treated with NSP at 60 or 100 g/mat or with NC at 80 g/mat were totally free from larval damage. Compared with the control, fruit yield was higher in all treatments, except in Furadan-treated plants. NC+Furadan treatment produced 1.5 times heavier bunches during the second than during first crop. The crop cycle differed among treatments.

Application of neem materials at >100 g/mat was tested in a field at MPFS, where each planting hole received ~10 kg of FYM before planting unpared 'Nakyetengu' suckers. NSP or NC was applied at 200, 300 or 400 g/mat at planting and thereafter at 6-month intervals. Standard cultural methods, such as weeding, de-suckering at flowering, removal of dried leaves and male flowers, propping of plants, etc. were practised throughout the duration of the trial. Pest density and nematode damage were evaluated 2–3 weeks before and after application of NSP, NC or Furadan for each treatment. The weevils trapped were counted and removed from the field and the damage at harvest was assessed. At flowering, plant height, plant girth at 100 cm above the ground level, and the number of suckers were recorded. Bunches were harvested when the fruits had become more rounded and the fruit yield was recorded. Pest infestation and damage was reduced at all rates of neem application, resulting in significantly increased fruit yields. The higher rates of application caused most of the plants to dry up or develop 'chokethroat' (Table 2.3b).

2.4 NET GAIN AND OVERALL BENEFITS OF USE OF NEEM

Compared with the untreated control grown in good soil at Kabondo, application of neem materials generally conferred a net gain of greater than US$ 500/ha only with the second harvest, while application of Furadan alone led to a loss of about US$ 827/ha (Tables 2.4a, 2.4b). In poor soil and high pest infestation at Oyugis, neem treatments resulted in an economic gain over the control in the first crop; the use of Furadan led to a loss of US$ 622/ha. Application of neem materials at >200 g/mat did not confer any economic return (Table 2.4c).

Our results have indicated that application of NSP once in 1, 2, 3 or 4 months effectively controlled the banana weevil and the parasitic nematodes. Thus, application of NSP once in 4 months or thrice a year is of practical and economic significance. The control of banana pests using neem seed derivatives was often accompanied by increased banana plant growth and vigour, particularly during the second crop, and rendered banana plants less attractive to the weevil and nematodes, hence less susceptible to pest damage. The crop cycle was shortened by neem treatments. Banana plants treated with NSP or NC were harvested 27–56 days earlier than untreated plants at Oyugis. A similar trend was also recorded in the second crop at Kabondo.

Our findings show that neem materials can effectively replace the use of toxic and expensive pesticides for the management of banana pests and give attractive economic returns in increased yields. This awareness needs to be created all over the world, and more so in Africa, where banana growers suffer huge losses due to poor pest control.

3. NEEM SEED DERIVATIVES AGAINST TOMATO PESTS

The fruit borer, *Helicoverpa armigera* (Hübner) and the root-knot nematodes, *Meloidogyne* spp. seriously limit tomato yields. In field trials conducted at MPFS in 1998, soil incorporation of powdered neem seed at 3 g/plant at planting reduced nematode damage (Figure 3). ULV spray applications of 20% NSE at 10 litres/ha at 10-day intervals controlled the borer damage better than that obtained with Cypermethrin. Compared with untreated or insecticide-treated plots, the yield of marketable tomatoes was higher in neem-treated plots (Figure 3).

4. NEEM EFFECTS ON COWPEA POD BUGS

Several species of pod bugs infest cowpeas at the podding stage and cause considerable damage. Fewer pod bug, *Clavigralla* (synonym: *Acanthomia*) *tomentosicollis* nymphs settled on cowpea pods treated

Table 2.4a. Cost-effectiveness of neem seed powder (NSP), neem cake (NC), Furadan or combination of NC and Furadan applied at different rates against weevils and nematodes in bananas at Kabondo (fertile soil and moderate pest infestation) and Oyugis (poor soil at high pest infestation). First crop

			Kabondo				Oyugis			
Treatment[1] (g/mat)	Product[2] cost (US$/ha)	Total [4] cost (US$/ha)	Yield (kg/ha)	Yield[5] value (US$/ha)	Net gain (US$/ha) Total	Net gain (US$/ha) Over control	Yield (kg/ha)	Yield [5] value (US$/ha)	Net gain (US$/ha) Total	Net gain (US$/ha) Over control
NSP60	264	336	15391	1539	1203	-13	5957	596	260	179
NSP80	352	424	18241	1824	1400	184	7537	754	330	249
NSP100	440	512	14941	1494	982	-234	10903	1090	578	497
NC60	396	468	18270	1827	1359	143	5957	596	128	47
NC80	528	600	17765	1777	1177	-39	3597	360	-240	-321
NC100	660	732	16821	1682	950	-266	9152	915	183	102
Furadan 60	114	1202	15400	540	338	-878	4987	499	-703	-784
NC+Fur.[3]	964	1036	15240	1524	488	-728	5830	583	-453	-534
Control	0	0	12155	1216	1216	0	812	81	81	0

[1]In a year, NSP, NC, or NC+Furadan was applied at 3-monthly intervals, while Furadan was applied three times at 4-monthly intervals.
[2]The cost of NSP, NC, or NC+Furadan treatment was US$ 72/ha, while Furadan alone costed US$ 54/ha as it was applied only 3 times a year.
[3]NC+Furadan (30 g : 30 g).
[4]Approximate cost of Furadan at US$ 5.8/kg; NSP at US$ 1/kg; NC at US$ 1.5/kg; cost of labour (11 man days) for applying neem or Furadan US$ 18/ha;
[5]Price of banana fruit at US$ 0.1/kg.

Table 2.4b. Cost-effectiveness of neem seed powder (NSP), neem cake (NC), Furadan or combination of NC+Furadan application against nematodes and weevils in bananas at Kabondo. Second crop

Treatment (g/plant)	Applications (no./year)	Product[1] cost (US$/ha)	Application cost (US$/ha)[2]	Total cost (US$/ha)	Yield (kg/ha)	Yield[3] value (US$/ha)	Net gain (US$/ha)	Net gain over control (US$/ha)
NSP60	3	198	54	252	19864	1986	1734	201
NSP80	3	264	54	318	24438	2444	2126	593
NSP100	3	330	54	384	19873	1987	1603	70
NC60	3	297	54	351	24622	2462	2111	578
NC80	3	396	54	450	26978	2698	2248	715
NC100	3	495	54	549	18682	1868	1319	-214
Furadan 60	2	765	36	801	15070	1507	706	-827
NC+Furadan[4]	3	723	54	777	24017	2402	1625	92
Control	0	0	0	0	15326	1533	1533	0

[1]Cost of Furadan at US$ 5.8/kg; NSP at US$ 1/kg; NC at US$ 1.5/kg;
[2]Cost of labour (11 man days) for applying neem or Furadan at US$ 18/ha;
[3]Price of banana fruit at US$ 0.1/kg.
[4]NC+Furadan (30 g : 30 g)

Table 2.4c. Cost-effectiveness of neem seed powder (NSP) and neem cake (NC) application at high rates (200 to 400 g/mat) in bananas against the banana weevil and nematodes at MPFS. First crop

Treatment (g/plant)	Applications (no./year)	Product[1] cost (US$/ha)	Application[2] cost (US$/ha)	Total cost (US$/ha)	Yield (kg/ha)	Yield[3] value (US$/ha)	Net gain (US$/ha) Total	Net gain (US$/ha) Over control
NSP200	2	440	36	476	14135	1414	938	859
NSP300	2	660	36	696	6207	620	-76	-155
NSP400	2	880	36	916	6149	615	-301	-380
NC200	2	660	36	696	6578	658	-38	-117
NC300	2	990	36	1026	7921	792	-234	-313
NC400	2	1320	36	1356	4790	479	-877	-956
Control	0	0	0	0	794	79	79	0

[1]The cost of NSP or NC, was US$ 72/ha.
[2]Cost of labour (11 man days) for applying neem at US$ 18/ha;
[3]Price of banana fruit at US$ 0.1/kg.

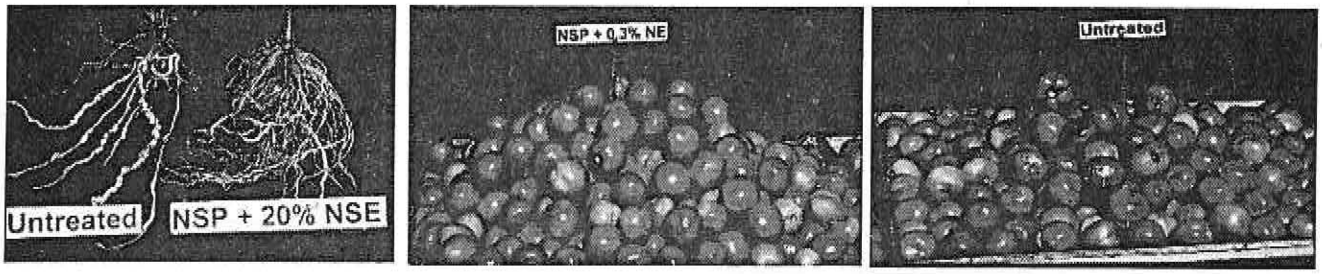

Figure 3. Galled and gall free roots of tomato plants from untreated and neem-treated plots (left); relatively less damaged and heavily damaged tomato harvested from neem-treated (centre) and untreated plots (right) respectively. MPFS, 1998

with 1–3% NSE or 0.1–0.3% NE. The growth and development of nymphs was disrupted when 2nd instar nymphs, exposed for 24 hours to neem-treated pods, were subsequently reared on untreated cowpea pods. Also, the pod bug females reared on neem-treated pods laid fewer eggs than the females reared on untreated pods.

5. PHYTOTONIC EFFECT OF NEEM

We earlier reported that crop plants treated with neem seed derivatives were generally more robust and more vigorous than untreated control plants. In the 1999 long rainy season, we tested whether neem's phytotonic effect persisted even when crops were grown in fields without the application of fertilisers. In trials conducted at MPFS, we found that maize plants developing from seed treated with 5% NE for 24 hours were more than 1.5 times taller (119 cm) than control plants (68 cm) developing from untreated maize at 7 weeks after emergence (WE). Compared with the grain yield of 2.06 t/ha in the control, the yield from neem-treated maize plants was 2.62 t/ha.

Likewise, sorghum plants developing from seed treated with 5% NE were more than 1.5 times taller (127 cm) than the control plants (77 cm) at 7 WE. Grain yield from NE-treated sorghum plants was 1.93 t/ha, while that from untreated plants was 0.95 t/ha. In tomato crops, fertilised with calcium-ammonium nitrate, the phytotonic effect of neem was evidenced in vigorous crop growth, early flowering and fruiting, and higher marketable fruit yield (10.6 t/ha) over that (8.3 t/ha) in the untreated control. The effect of fertiliser application on the enhancement of the phytotonic effect of neem is being evaluated in maize and sorghum crops.

B. BUILDING NEEM AWARENESS

Building awareness of neem's potential in target and non-target countries of Africa is being accomplished in the Project through dissemination and exchange of information, distribution of neem flyers and publications, and giving invited lectures in schools, NGOs, and other fora. Attractive bill-boards stating *'Neem for Rural Health and Prosperity'*, installed at strategic locations in Kenya are generating much interest among rural communities and creating awareness of neem's potential. The Project participated in a Farmers' Field Day held at MPFS in July 1999. More than 300 farmers and government officials visited the neem stall, where the Project staff explained and demonstrated the uses of various neem products for pest management and other uses. The Project also participated in the Kisumu and Mombasa Agricultural Shows in August 1999.

About 637 persons had been trained by November 1997. However, due to persistent demands from individuals and various organisations, a seventh training workshop on *'How to Grow and Use Neem'* was announced in *The Daily Nation* and *The East African* in July 1999. More than 400 applications and nominations were received; 42 candidates were selected and given hands-on training in the seventh workshop, which was held at MPFS, 14–23 Nov. 1999. Participation of women and representatives of environment-conscious NGOs was given priority.

Output

Publications

Khan Z. R. and Saxena R. C. (1998) Host plant resistance to insects, pp. 118–154. In *Critical Issues in Insect Pest Management* (Edited by G. S. Dhaliwal and E. A. Heinrichs). Commonwealth Publishers, New Delhi, India.

Musabyimana T. and Saxena R. C. (1999) Efficacy of neem seed derivatives against nematodes affecting banana. *Phytoparasitica* 27, 43–49.

Saxena R. C. (1998) Botanical pest control, pp. 155–179. In *Critical Issues in Insect Pest Management* (Edited by G. S. Dhaliwal and E. A. Heinrichs). Commonwealth Publishers, New Delhi, India.

Saxena R. C. (1998) "Green revolutions" without blues: Botanicals for pest management, pp. 111–127. In *Ecological Agriculture and Sustainable Development*, vol. 2 (Edited by G. S. Dhaliwal, N. S. Randhawa, R. Arora and A. K. Dhawan). Indian Ecological Society, Ludhiana and Centre for Research in Rural and Industrial Development, Chandigarh, India.

Saxena R. C. (1999) Building awareness and facilitating the use of neem as a source of natural pesticides in sub-Saharan Africa. *Phytoparasitica* 27, 177–181 (Guest Editorial).

Saxena R. C. (1999) Neem for ecological pest and vector management and environmental conservation. Dr S. Pradhan Memorial Lecture, Indian Agricultural Research Institute, New Delhi. 31 pp. (Souvenir).

Saxena R.C., Owino N.O. and Kidiavai E.L. (In press) Behavioural and physiological effects of neem seed extract and extractive on the diamondback moth and its management in collard. *J. Econ. Entomol.*

Singh R. P. and Saxena R. C. (Eds) (1999) *Azadirachta indica* A. Juss. *Proc. Int. Neem Conf.*, Queensland, Australia. Oxford & IBH, New Delhi, 322 pp.

Neem fliers

'Yien Miluongo in Mwarubaine' 'Neem': Berne Ne Pinje Mapod Dongore (Dholuo version of *The Neem Tree: Its Potential for Developing Countries*), 4 pp., ICIPE Science Press, Nairobi.

'L'Azadire d'Inde 'Neem': Son Potentiel Dans Les Pays en Developpment (French version of *The Neem Tree: Its Potential for Developing Countries*), 4 pp., ICIPE Science Press, Nairobi.

'A árvore Neem': O seu potencial para os paises em desenvolvimento'(Portuguese version of *The Neem Tree: Its Potential for Developing Countries*), 4 pp., ICIPE Science Press, Nairobi.

'Neem for Low-cost Management of Flower Thrips in Cowpea'. ICIPE Science Press (In Press).

'Neem Seed Derivatives for Management of Banana Weevil and Parasitic Nematodes'. ICIPE Science Press (In Press).

Conferences/workshops attended, lectures

Musabyimana T. and Saxena R. C. (1998) International Symposium on Banana and Food Security, Douala, Cameroon, 10–14 November 1998. Paper presented, 'Potential of neem (*Azadirachta indica*) seed derivatives for the management of parasitic nematodes and the banana weevil complex'.

Musabyimana T. and Saxena R. C. (1999) World Neem Conference, University of British Columbia, Vancouver, Canada, 19–21 May 1999. Paper presented, 'Use of neem seed derivatives for sustainable banana pest management'.

Saxena R. C. and Musabyimana T. (1998) 3rd International Congress on Allelopathy in Ecological Agriculture and Forestry, Dharwad, India, 18–21 August 1998. Paper presented, 'Neem for sustainable management of plant parasitic nematodes affecting banana and tomato'.

Saxena R. C. (1998) Joint Annual Meeting of Entomological Society of America and American Phytopathological Society, Las Vegas, 8–12 November 1998. Paper presented, 'Powdered neem seed or cake as a low-cost input for management of *Chilo partellus* (Lepidoptera: Pyralidae) in maize and sorghum crops'.

Saxena R. C. (1998) International Conference on Pest and Pesticide Management for Sustainable Agriculture, Kanpur, 11–13 December 1998. Paper presented, 'Neem for ecological pest management and environmental conservation'.

Saxena R. C. (1999) World Neem Conference, University of British Columbia, Vancouver, Canada, 19–21 May 1999. Paper presented, 'Development of neem for plant protection and medicinal uses in Africa'.

Saxena R.C. (1999) 'Neem for ecological pest management and environmental conservation' at the World Bank, Washington DC, 25 May 1999.

Dr S. Pradhan Memorial Lecture on neem at the Indian Agricultural Research Institute, New Delhi, 18 Aug. 1999.

Recognition and awards

1998. Distinguished Achievement Award to R. C. Saxena for his outstanding contribution and valuable service in the field of Pest Management given at the International Pest and Pesticide Management Conference for Sustainable Agriculture, Kanpur, India, 11 Dec.

1998. Meritorious recognition of the Project 'Building Awareness and Promoting the Use of Neem for Improving the Living Environment and Mitigating Rural and Urban Poverty in Sub-Saharan Africa' under 1998 Dubai International Award for Best Practices to Improve the Living Environment.

Proposals

Awareness building and facilitating the use of neem as a source of natural pesticides and other useful products for promoting rural prosperity in sub-Saharan Africa. 19 pp. + Annex.

Promoting the use of neem seed derivatives for sustainable control of banana weevil and parasitic nematodes for augmenting yields of organic banana in sub-Saharan Africa. 6 pp.

Capacity building

Three students in the Project completed their requirements for MPhil and PhD degrees at Moi and Kenyatta universities and the University of Addis Ababa. Another student attached to the Project is about to complete his MPhil dissertation on neem.

ARPPIS PhD students

- PhD project: Biological effects of neem seed derivatives on the management of the maize stalk borer *Busseola fusca* (Fuller) in pest management (H. Tekie, University of Addis Ababa, Ethiopia)
- PhD project: The potential of neem derivatives for management of maize pests with special reference to *Sitophilus zeamais* (Motsch.) (K. M. Kega, (Coleoptera: Curculionidae) Kenyatta University)

DRIP scholars

- MPhil project: 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 (Z. Ngalo Otieno-Ayayo, Moi University)
- PhD project: Neem seed for the management of the banana weevil, *Cosmopolites sordidus* Germar (Coleoptera: Curculionidae) and banana parasitic nematode (T. Musabyimana, Kenyatta University)

Impact

With growing awareness, more individuals, communities, and entrepreneurs are becoming interested in planting neem and in collecting, processing, and marketing of neem seed and neem products. More than 75 Kenyan schools, churches and other institutions in Suba, Homa Bay, Migori, Kisii, Kisumu, Molo, Naivasha and Nairobi are involved in planting neem trees. Roadside planting of neem is gaining popularity in Suba and Homa Bay Districts near ICIPE's MPFS.

During recent visits to Tanzania and Uganda in September 1999, it was found that some of the trainees under the project have facilitated large-scale planting of neem trees by the local peasantry. In Kwimba Reforestation Project in Mwanza, Tanzania, more than 600,000 neem trees have been planted on homesteads and in plantations in the past 5 years.

Likewise, in a Refugee Rehabilitation Centre at Adjumani, northern Uganda, more than 200,000 neem trees have been grown in pure stands and in mixed plantations. In all these locations, neem has been thriving, a testimony to its versatility and hardiness. Children and elderly women and men collected about 3 tonnes of neem seed and large neem nurseries have been established at several locations at Adjumani. In 1998, about 140 litres of neem oil was produced by crushing surplus seed using locally devised machinery. The oil has been sold among local inhabitants and is in great demand for treating various skin infections (foot rot, ringworm, scabies), lice, burn wounds, bruises, etc. in humans and against ticks in livestock.

Neem cake is being used primarily for crop protection. Planting of neem in these remote areas has created employment and income-generating activities, where none existed before. Another former trainee in Meru, Kenya has started producing and marketing quality neem products which are in great demand, even in the city of Nairobi.

The economic returns and environmental services rendered by a neem tree in its lifetime of over 200 years has been estimated at US$ 25,000. At this rate, the returns of the ICIPE-Finland-UNEP Neem Awareness Project already runs into the millions of dollars. The impact of the Neem Awareness Project transcends the target countries of Africa. Many countries in Latin America, Europe, the Middle East, and Southeast Asia are interested in our activities.

(See also the reports on 'Models for IPM in Vegetables' project, 'Biological Control of Stemborers' project, Ticks report, and the Behavioural and Chemical Ecology Department.)

Socioeconomic Evaluation of Technologies for the Control of Pests and Diseases of Banana in Banana-based Cropping Systems

Background, approach and objectives

Bananas are the world's fourth most important staple food crop after rice, wheat and maize. In the Great Lakes Regions of East and Central Africa, they are the most important food staple. In Uganda, banana is of strategic importance to food security. About 75% of farmers allocate 40% of cropped land to banana production, mostly for home consumption. Productivity is decreasing however, due to three mutually reinforcing factors, namely pests and diseases, declining soil fertility and socioeconomic factors such as labour, infrastructure and marketing problems. There is a high regional variability in the net impact of these constraints. Whereas banana production has declined substantially in the traditional mainstay East and Central producer regions, it has expanded appreciably in the southwestern region.

In response to these trends and constraints, a series of measures were taken, including the development of a research agenda by the Uganda National Banana Research Programme (UNBRP) of the Uganda National Agricultural Research Organisation (NARO), the International Institute of Tropical Agriculture (IITA) and the African Highland Initiative (AHI). In 1997 the collaboration was extended to the International Centre of Insect Physiology and Ecology (ICIPE) to provide an input in farmer participatory research and technology adoption with special reference to IPM.

Participating scientists: *J.W. Ssennyonga*, E. Katungi*
(Project Leader)*

Assistants: *J.M. Muchiri*

Donor: *Rockefeller Foundation*

Collaborators: *• Uganda National Banana Research Programme of NARO • International Institute of Tropical Agriculture, Uganda*

Work in progress

1. ASSESSMENT OF CURRENT BANANA PRODUCTION IN TWO DISTRICTS IN UGANDA

1.1 APPROACHES AND METHODOLOGY

The consensus among researchers is that cultural control of pests and diseases of banana offer the best hope for increased production. Farmers are widely using most of the conventional cultural controls. Against this background, socioeconomic work under the ICIPE/NARO/IITA collaboration has focused on cultural control at benchmark sites representing (a) relatively high banana production and productivity (BPP) with incipient decline, and (b) severe decline in BPP.

Specifically, the investigations sought to provide an understanding of farmers' decision-making processes regarding banana pest and disease control (BPDC). The aim was to determine: (a) BPDC chosen, abandoned temporarily or for good, or taken up again; (b) the criteria used; (c) the factors influencing the decisions; and (d) the results obtained and why.

We hypothesised that five factors were crucial for an understanding of farmers' strategies and decisions regarding banana production in general and IPM practices in particular:

(i) The role bananas play in the production systems and economy is of utmost importance. This role pertains to the part bananas play in farmers' production goals, food security and related strategies and their (banana) contribution to cash income. Farmers adopt different strategies depending on whether bananas are their own principal food staple or a commercial commodity.

(ii) The availability and allocation of production resources, money, land, labour, farm implements and inputs.

(iii) Farmers' knowledge of banana pests and assessment of associated losses relative to those caused by other constraints, are critically important.

(iv) Economic factors, namely costs, benefits, benefit/cost ratios and affordability, greatly influence farmers' production and IPM decisions.
(v) The institutional factors that influence farmers' decisions such as policy, marketing and road infrastructures.

A total of 65 farmers were randomly selected from four parishes in the district of relatively high banana production and productivity (BPP). With the help of local council officials, a list of villages in each parish was obtained. In line with the accepted view that farmers in different farming systems have different technological needs, we grouped the sample farmers into three socioeconomic strata (SS). We used 8 criteria suggested to us by the farmers themselves. These are: (a) quality of residential house, (b) livestock owned, size of banana farm(s), (c) size of coffee plantation(s) (d) off-farm employment, (e) food security, (f) ownership of crop processing equipment, and (g) ownership of motor vehicle(s). On the basis of these criteria, the 65 households were grouped into the 3 SS levels as follows: top (12), middle (20), bottom (33).

1.1.1 *Data analysis*

Interpretive analysis was used for data obtained by use of unstructured interviews. Survey data were analysed by a variety of quantitative methods. Budgeting techniques were used to measure the comparative advantage of various crops in terms of income earned and returns to family labour. Multi-regression and cross tabulation were used for quantitative analysis. Regression analysis was used to determine factors affecting yield, while cross tabulation and Chi-square techniques were used to determine the relationships among selected variables. Similar conceptual and methodological approaches were used for the study in the district with severe decline in the BPP, but the sample was enlarged to 120 farms.

1.2 IMPORTANCE OF BANANAS

The vital role of bananas in the economy is shown in five major ways:

- 57% of cropped area is under banana.
- 75% of producers consume over 70% of the bananas they grow on their plots. This is due not only to their preferences, but also to market forces; traders supplying bananas to urban markets do not buy small bunches.
- The wide range in cultivars grown also reflects the uses to which bananas are put: as food staple, beer brewing, dessert and roasting. A notable gap in the data presented is the information on processed products such as handicrafts, which would increase greatly the viability of banana growing.
- Bananas contribute 68 and 38% of cash income from crops and total household income, respectively.
- Farmers in the bottom SS attach far less significance (30.3%) to banana as a source of cash income compared to 55 and 67% for the middle and top SS, respectively.

1.3 RESOURCES AVAILABILITY AND ALLOCATION

Information on cash income, labour, land, farming implements and inputs reveals a chain of mutually reinforcing trends. Cash income is critical to the purchase of inputs, farm implements and hired labour, however involvement in off-farm enterprises takes male labour away from the farm. Furthermore, labour hiring is not affordable by farmers in the bottom stratum which has a ratio of hired to family labour of only 0.27 for banana IPM work. Ironically, due to labour constraints, households in this stratum, despite having a mean land holding of only 0.87 ha, are unable to put even a quarter % of this land under cultivation. This group has also low use of labour-intensive practices and a high incidence of pest damage. Information presented on the low level, especially of purchased inputs, further highlights the dilemma for low income banana growers. One way out of this predicament is the search for locally available sources of inputs, which is what some farmers are doing. They are experimenting with the use of urine and other concoctions as fertilisers. Entomological research should also play its part.

1.4 KNOWLEDGE ISSUES

Farmers' heightened perceptions of banana pests and associated losses do not translate into knowledge intensity, which is so critical for IPM. Farmers have a poor understanding of key banana weevil controls such as paring (3%), hot water treatment (34%), pseudostem trapping (12%), and the use of resistant cultivars. The biology of weevils and associated damage are also poorly understood especially by men. For example, 58% of farmers think that the larva is a different insect from the adult weevil. Farmers' assessment of the efficacy of cultural controls presents challenges to the extension. High proportions of farmers are not sure of the efficacy of most of the practices they are using: mulch placement, use of ash, corm covering, and splitting pseudostems, among others. Only sanitation practices such as the removal of sheath (45%) and corms (35%), together with the use of chemicals (Furadan) (35%) are rated as very effective. This was why we looked into factors which shape farmers' perceptions. Farmers (albeit only 37%) with thorough knowledge of weevils got the information from fellow farmers. Women understand weevil biology and damage better than men. However, the crux of the matter is not so much what farmers *know* as what they *do*.

1.5 IPM USAGE

In general, usage of pest control methods is low, especially for direct weevil control such as trapping

(19%). What is more, abandonment is also relatively high due to a combination of high costs, chemicals and labour intensity of some of the cultural practices (trapping and use of compost). A closely related issue is the intensity with which practices are used. Direct pest control such as trapping and hot water treatment (HWT) are not intensively used due to costs and labour constraints. Sanitation practices, the most intensively used, are not as effective as controls. As expected, farmers in the bottom stratum use IPM practices at the lowest level of intensity.

The major challenge is to demonstrate the efficacy of these controls to farmers so that they can address the issues of finding the labour and money to implement them. We also examined nine factors influencing the use of IPM practices. Risk was negatively correlated with mulch placement (-0.335, significant at 1%) and corm removal (-0.289), practices that do not directly control weevils, but contribute to plant vigour and productivity. The age of farmers was also associated with the use of clean planting material, ash, split pseudostems and mulch. In general, older farmers practise sanitation methods. Age was also negatively correlated with direct pest controls. Other important factors include education (positive for all practices) and household size. Extension agencies need to target their dissemination efforts to these social and economic factors.

1.6 ECONOMIC ANALYSIS

Banana production in general and IPM practices in particular require significant resource inputs, especially labour and farm inputs. However, benefit/cost ratios are higher than those estimated for any other crop grown in the area except coffee. In fact, even farmers who invest in sanitation practices alone realise a benefit/cost ratio of 1.48 (Table 1.6). This shows that banana production is, as farmers themselves confirmed, good business. More work still needs to be done to estimate the benefit/cost ratios of other IPM combinations so that several optimal options can be made available for farmers in the various socioeconomic strata. Entomological research should also focus on clusters of IPM practices, rather than individual ones.

1.7 FACTORS INFLUENCING BANANA PRODUCTIVITY

Damage level was found to be significant at 0.01 with a coefficient of -1522.2 . This means that an increase in weevil damage level by 1% reduces yield by 1522.2 kg/per acre. Similarly, damage level was negatively correlated (-0.43) with banana bunch size that was significant at 0.01. Damage level and accessibility to any road were also negatively correlated (-0.35) and significant at 0.01. Accessibility by road enables farmers to access markets which makes them more interested in higher yields than those who do not have access to roads. Likewise, distance from the tarmac road to the farm is important in determining yield from the farm. Distance was significant at 10% with a coefficient of -279.92. The negative effect means that the further the farm is from the tarmac road, the poorer are the yields. This implies that farms far from the tarmac roads lack market incentives to manage banana plantations well. Distance from the tarmac road, was negatively correlated with education level (-0.37), banana cropped area (-0.33), bunch size (-0.38) and yield (-0.36), all significant at 0.1.

Off-farm income (0.0038) was found to have a positive effect on yield and significant at 10%. A positive effect from off-farm income means that part of this income is invested in banana production. Farm income, gender, total farm area, number of cattle, age and education levels of the farmer, showed a positive insignificant relationship with yield as expected. On the other hand, extension exposure indicated a negative effect on yield. This was in contrast with the expected relationship. When extension exposure was removed from equation 1 to produce equation 2, adjusted R increased from 0.387 to 0.402, implying

Table 1.6. Benefit/cost analysis of banana production under different IPM regimes compared to other crops

Variable	Banana Case 1	Banana Case 2	Banana Case 3	Coffee	Maize	Beans	Sweet potatoes	Cassava	Groundnuts
Gross income[1]	531	747	1368	1022	272	386	390	494	452
Variable costs[1]	73	314	741	276	73	85	80	80	
Total costs[1]	359	614	1104	559	288	325	372	397	380
Gross margin[1]	458	433	627	746	199	301	310	414	347
Net income[1]	172	133	264	463	-16	61	18	97	72
Return to family labour[2]	720	654	755	1620	489	668	557	373	684
Benefit/cost ratio (BCR)	1.48	1.22	1.24	1.83	0.94	1.10	1.05	1.24	1.19

Case 1: Management involving mainly sanitation practices.
Case 2: Sanitation + mulching.
Case 3: Sanitation + grass mulch + manure.
[1]In '000 Ushs/ha.
[2]In '000 Ushs/hour.
(Exchange rate, 1US$=UShs 1200.)

that exposure to extension does not explain variation in yield.

1.7.1 *Institutional factors*

Policy, extension, road and marketing infrastructures have an important bearing on banana production and IPM adoption, but fall outside the competence of researchers. Nevertheless, it is worthwhile pointing out the relevance of institutional factors. For example, improving rural road infrastructure and extension services both of which have negative correlations with banana productivity, is best addressed at policy level. It may be worth suggesting that since conventional methods have negative results, alternative approaches such as farmer-to-farmer extension, which have worked exceptionally well in Indonesia, Philippines and other countries, could be considered.

1.7.2 *Gender*

Women provide the bulk of banana production and IPM work, but collected information shows that men control most of the resources such as land, labour, inputs and cash income from bananas, even when women sell 70% of the bananas. Women also have a low weevil damage level in banana farms they manage, compared to men whose banana farms have high (63%) weevil damage. Men and women use IPM controls for different purposes. Gender is important, but not significantly for banana productivity. This is yet another matter which policy makers in collaboration with other change agents should address at the level of society. Those engaged in the R&D of IPM need to target technologies to gender differences.

1.7.3 *Cluster analysis*

We need to carry out further cluster analysis to address the fact that farmers use IPM practices in combination. The case studies presented in this report highlight aspects of this issue. Cluster analysis will probably unravel the existence of optimal options of integrated IPM practices suitable for the different socioeconomic strata.

1.8 INTEGRATION

The information presented in this report highlights the need for integration at two levels. First, one of the objectives of benchmark sites is the generation of integrated databases. A modest start has been made at Kisekka benchmark where socioeconomic and some entomological data sets have been collected from the same farms. This has facilitated the determination of the three-way relationships between socioeconomic parameters and pest/damage levels on the one hand, and each of these and productivity, on the other. The integration can be strengthened further by collecting soil and disease data sets from the same farms. Second, interventions will also have to be integrated and targeted to the needs of the three socioeconomic strata identified in this study. A delicate balance has to be struck between considerations of the efficacy of IPM practices on the one hand, and their costs and farmers' needs for food and cash on the other.

Outputs

Publications

Ssennyonga J. W., Bagamba F., Gold C., Tushemereirwe W. K., Karamura E. B. and Katungi E. (1999) Understanding current banana production with special reference to integrated pest management in southwestern Uganda. In *Mobilising IPM for Sustainable Banana Production in Africa* (Edited by E. A. Frison, C. S. Gold, E. B. Karamura and R. A. Sikora). Proceedings of a workshop on banana IPM held in Nelspruit, South Africa, 23–28 November 1998. International Network for the Improvement of Banana and Plantain, Montpellier, France.

Conferences attended

Ssennyonga J. W. (1998) Workshop on Baseline Data Collection and Management for Research on Banana Production and Pest Management in East, Central and Southern Africa, organised by Banana Research Network for East and South Africa (BARNESA), 16–19 February 1998, Kampala, Uganda. Paper presented, 'Socioeconomic approaches to the generation of baseline information: Illustrations from socioeconomic baseline information for the development of low-cost, safe tick controls'.

Ssennyonga J. W. (1998) Workshop on Mobilising IPM for Sustainable Banana Production in Africa, organised by INIBAP, 23–28 November 1998, Nelspruit, South Africa. Paper presented, 'Understanding current banana production with special reference to IPM in southwestern Uganda'.

Ssennyonga J. W. (1998) Workshop on Farmer Participatory Banana Technology Testing in Uganda, organised by the Uganda National Banana Research Programme and the International Development Research Centre (IDRC), 15–19 February, Kampala, Uganda. Papers presented, (a) 'Approaches to farmer participatory research on banana production and pest management', (b) 'The role of sociology in research on banana production and pest management'.

Capacity building

PhD students

Dorothy M. Wanyama, supervised by J.W. Ssennyonga, P. Chitere, R. M. Ocharo and Z. Khan is carrying out field work in Kitale, western Kenya, on 'Socioeconomic factors influencing technology adoption: The case of maize stemborer control ir Trans Nzoia District, western Kenya'.

Impact

Results were used as a basis for launching on-farm adoptive research managed and financed by researchers with farmer participation, starting in May 1999. Similarly, provisional results form the basis for interventions currently being planned for the district experiencing severe decline in production. The ICIPE's socioeconomist is chairman of the committee set up to prepare action plans for the interventions.

J. W. Ssennyonga was appointed to the Steering Committee of Banana Research Network for East and South Africa (BARNESA) in 1999.

J. W. Ssennyonga was co-opted in 1999 by UNBRP to provide a backstopping input into the IDRC-funded Outreach On-farm Farmer Participatory Banana Technology Testing in Uganda.

(See also the reports under the Molecular Biology and Biochemistry Unit and the Social Sciences Unit.)

AGRICULTURAL RESEARCH

PLANT HEALTH MANAGEMENT

STAPLE FOOD CROP PESTS

Three projects centering on the management of insect pests, weeds and diseases affecting cereal crops are included in the Staple Food Crop Pests Sub-Division. A project on habitat management is examining novel approaches to controlling cereal stemborers and *Striga* in maize and sorghum. 'Push-pull' strategies have been developed which use certain plants to repel stemborers from cereal fields, and other plants to attract and trap them outside of the field. The plants used to repel or attract the stemborers are forages, which have a high value in farming systems where livestock are maintained. When planted between maize rows, the forage legume *Desmodium* has been shown to suppress *Striga hermonthica*, an extremely harmful parasitic weed found in many parts of Africa. Current research is focused on understanding the mechanism by which *Desmodium* controls *Striga*.

A second activity is a collaborative project between ICIPE and the Kenya Agricultural Research Institute, which has the objective of increasing the understanding of the epidemiology of maize streak virus (MSV). Within this larger project, ICIPE is focusing on the biology of MSV and its leafhopper vectors (*Cicadulina* spp.) with a view to understanding the uneven spread of MSV disease in nearly uniform susceptible maize types grown in different agroecological zones of Kenya. Results from this project clearly indicate that several species of *Cicadulina* are involved in MSV transmission, but that their vectorial capacity varies, even between populations of the same species collected from different locations. Another interesting finding, observed through successive adjacent plantings of maize, is that the progeny of *Cicadulina* breeding in a maize crop are not an important source of spread of the disease to later-planted maize.

The last activity in the Sub-Division is the programme on classical biological control of the exotic stemborer *Chilo partellus*. An exotic parasitic wasp introduced by the project in 1993 is now well established in southern Kenya, and its population has increased each year since the first releases. In 1998/99, average parasitism across more than 60 sites in the southern coastal zone was 9%, and at some sites was greater than 40%. The project is now working with governments in several countries in eastern and southern Africa to replicate the work done in Kenya. Parasitoids have been released in Uganda, Mozambique, Somalia, Malawi, Zambia, Zimbabwe and Zanzibar, and there is evidence of establishment in Mozambique, Uganda and Tanzania.

Plant Health Division

STAPLE FOOD CROP PESTS

New Integrated Stemborer and *Striga* Management Systems in Subsistence Maize Farming for Africa

Background, approach and objectives

Among the most important biotic constraints to maize production are lepidopteran stemborers, which feed inside plant stems, and the parasitic weeds belonging to the genus *Striga*, which compete with the maize plant for water and nutrients. Reducing the losses caused by these pests through improved management strategies could significantly increase maize production, and result in better nutrition and purchasing power of maize growers. To put stemborer and striga weed control within the reach of African farmers, simple and inexpensive measures need to be developed that are tailored to the diversity of African cropping systems. A sustainable solution would be an integrated approach that simultaneously addresses both of these major problems.

The new approaches being developed as part of a habitat management programme for controlling stemborers and striga weed in maize-based cropping systems make use of a 'push-pull' strategy. This involves trapping stemborers on highly susceptible trap plants (the pull) and driving them away from the crop using repellent intercrops (the push). Plants which both repel stemborers and inhibit striga weed have also been identified. On-farm trials confirmed that these approaches, conducted separately and together, give significant yield increases and are acceptable to subsistence farmers.

The habitat management approach is suitable for small- to medium-scale farmers in Africa practising mixed agriculture. The strategy will also serve as a model for the management of other pests in Africa and beyond. The Project is being undertaken in different agroecologies in Kenya. Recommendations from this Project are demonstrated to farmers through on-farm trials conducted in collaboration with KARI and Ministry of Agriculture Livestock Development and Marketing (MOALDM).

The overall objective of the Project, now in Phase II (1998–2001), is to promote further the adoption by farmers of new stemborer and striga weed control technologies, including the integration of trap and repellent plants in a sustainable push-pull strategy, while continuing to assess their potential and limits.

Participating scientists: Z. R. Khan*, W. Overholt, A. Hassanali (*Project Coordinator)

Technical staff: P. Chiliswa, N. Dibogo, S. Mokaya, S. Ogechi, A. Ndiege, J. O. Ogoro*, *(deceased in 1998)

Donor: *Gatsby Charitable Foundation*

Collaborators: • *Kenya Agricultural Research Institute (KARI)* • *Ministry of Agriculture Livestock Development and Marketing (MOALDM), Government of Kenya* • *Institute for Arable Crops Research (IACR)-Rothamsted, UK*

Work in progress

1. MANAGEMENT OF STRIGA WEED USING FODDER LEGUMES

Field trials were conducted in Suba District of Kenya, where *Striga hermonthica* is a serious limitation to the cultivation of cereals. Maize was intercropped with five species of legumes: cowpea (*Vigna unguiculata*), soybean (*Glycine max*), sun hemp (*Crotolaria juncea*), greenleaf (*Desmodium intortum*) and silverleaf (*Desmodium uncinatum*) in alternate rows. A control plot of maize mono was also included. The six treatments were completely randomised and planted in 6 replications in a six by six quasi-complete Latin Square Design. Each treatment plot was 6 x 6 m. The maize variety used was the susceptible, medium maturity, commercial hybrid 511, recommended for mid-altitude regions with moderate rainfall. The trials were planted during the long and short rainy seasons (March to July and September to December) of 1998 and long rains of 1999.

Intercropping maize with the fodder legumes, *D. uncinatum* and *D. intortum* significantly reduced striga infestation when compared to maize monocrop (Figure 1). Reduction in striga infestation by intercropping maize with the two species of *Desmodium* was significantly greater than by intercropping the maize with soybean, sun hemp and

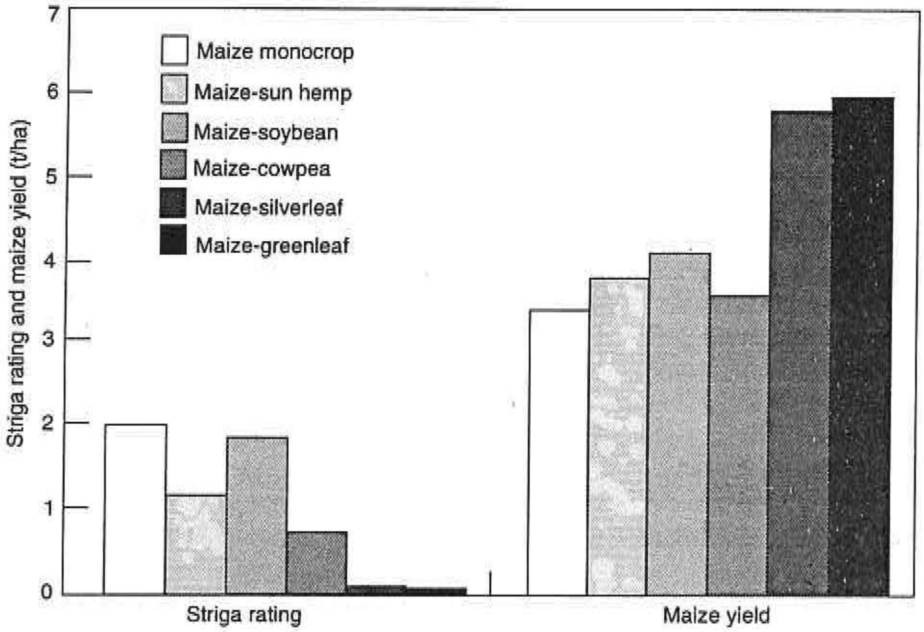

Figure 1. Striga rating and yield of maize in plots intercropped with legumes (long rains 1998)

cowpea, and gave an associated significantly higher growth of maize.

We are also examining other species of *Desmodium* for their striga-inhibitory and stemborer-repellent effects and their adaptability under various agroecosystems. 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. PUSH-PULL STRATEGIES FOR CONTROL OF STEMBORERS

Napier grass and Sudan grass, two widely used commercial fodder grasses, can provide natural control to stemborers by acting as trap plants for the pests 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 defence mechanism against crop borers. When the larvae enter the stem, the plant produces a gummy substance, which causes the death of the pest. Napier grass or Sudan grass, when planted around maize fields, can decrease 'stemborer infestation on maize and thus increase crop yield (See *ICIPE 1995–1997 Annual Scientific Report*). Planting Sudan grass around maize fields also increases the efficiency of natural enemies.

Previous work has also shown that intercropping maize with non-traditional hosts and non-host companion plants produces a marked impact in reducing stemborer infestation on maize. Planting maize into an already-established crop of molasses grass (*Melinis minutiflora*) and silverleaf (*D. uncinatum*) significantly reduces stemborer incidence (See *ICIPE 1995–1997 Annual Scientific Report*).

The Project has now developed fully integrated 'push-pull' or stimulo-deterrent diversionary strategies. 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. The integrated push-pull strategies also incorporate increased parasitism of stemborers caused by one of the intercrops, molasses grass. The leguminous intercrop silver leaf also reduced damage to maize by striga very considerably and this aspect has been developed for integration with stemborer control in the areas where both pests are found to pose serious constraints to maize production.

In a push-pull field trial at ICIPE, Sudan grass was planted as a border around a maize field, and maize was intercropped with silverleaf, *D. uncinatum*. Sudan grass was used as a trap plant for stemborers. Stemborer and striga weed infestations and maize yields were compared with a control plot where maize monocrop was grown. The push-pull strategy significantly reduced stemborer and striga infestation on maize and significantly increased maize yield (Table 2).

Table 2. Comparison of means of stemborer damage, striga rating, yield and yield parameters from a 'push-pull' trial (long rains 1998)

Parameter	Maize+Sudan grass+*Desmod.*	Maize mono	Difference
Stemborer damage (%)	11.1	22.0	-10.9
Striga rating*	0.1	2.4	-2.3
Plant ht. (cm)	260.7	233.6	27.1
Yield (t/ha)	6.7	5.2	1.5

*Striga rating on 1–9 scale.

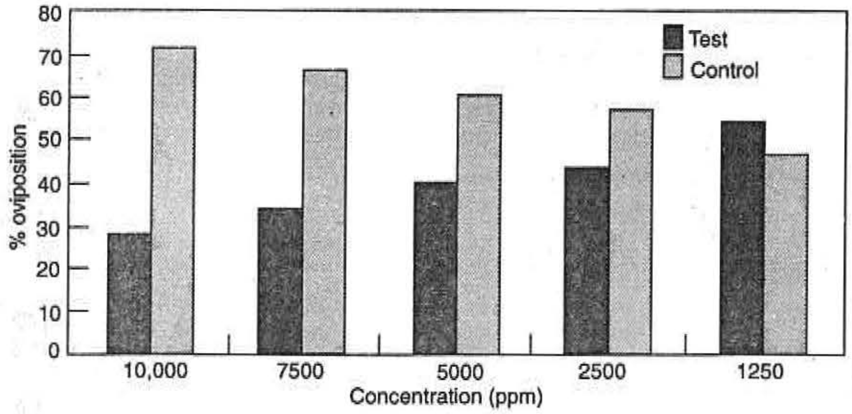

Figure 3. *Busseola fusca* oviposition bioassay using steam distilled oil of *Melinis minutiflora*

3. SEMIOCHEMICALS FROM *MELINIS MINUTIFLORA*

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, especially from the molasses grass, *M. minutiflora*. The volatile oil obtained by hydrodistillation of the molasses grass deterred oviposition of *Chilo partellus*, demonstrating that the volatile semiochemicals play a major role in oviposition deterrence of stemborers on the grass (See *ICIPE 1995–1997 Annual Scientific Report*).

In this review period, a similar study was conducted with *Busseola fusca*. *Melinis minutiflora* oil extract was tested for *B. fusca* ovipositional deterrence in various concentrations (1250, 2500, 5000, 7500 and 10,000 ppm) dissolved in hexane. The test chemical was applied to a surrogate stem ovipositor at the rate of 100 ml per surrogate stem (see *ICIPE 1994 Annual Scientific Report*), aiming where the insect places its ovipositor. After the solvent evaporated (30 min after application), treated and control (treated with hexane only) surrogate stems were placed in a wire mesh cage. Three gravid *B. fusca* females were then released in each cage, and oviposition on the extract-treated and the control surrogate stems was recorded after a period of 12 hours. The results presented in Figure 3 demonstrate a strong ovipositional deterrence with increasing concentration of the oil. On *B. fusca*, (*E*)-β-ocimene and α-terpenolene were found to be the major electrophysiologically active compounds in *M. minutiflora* airborne volatiles. Ovipositional bioassays against *B. fusca* are in progress.

4. ON-FARM TRIALS OF STEMBORER AND STRIGA WEED MANAGEMENT IN KENYA

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 were 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 KARI and extension staff from MOALDM also work very closely with ICIPE scientists in implementing on-farm trials. During 1998 and 1999, the on-farm trials continued. In 1999, the on-farm trials consisted of 150 farmers in Trans Nzoia district and 60 in Suba District. In both years, the farmers were selected by nomination by the farming community.

Community mobilisation was undertaken with the help of KARI staff, agricultural extension agents and local administrative leaders. Meetings were convened at four villages. The primary objectives of

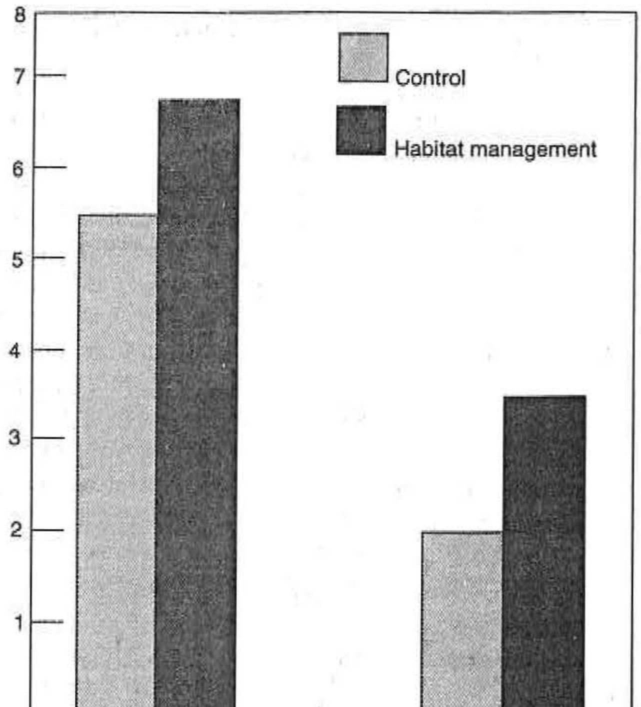

Figure 4. Average yield advantages of habitat management technologies in Kenya, 1999 in on-farm trials

these meetings were to create awareness on the use of fodder plants for management of stemborers and to select farmers for participation in the on-farm trials.

In Trans Nzoia, the farmers who used Napier grass as trap plant for stemborers in 1998 participated in fully-integrated 'push-pull' trials during 1999. The farmers had a choice of using *D. uncinatum* or *M. minutiflora* as repellent plants with napier grass. New farmers selected in 1998 used napier grass as a trap plant. Increase in maize yield was recorded in most of the on-farm trials where farmers used napier grass or a combination of napier grass with a repellent plant (Figure 4).

In Suba District, the farmers who used *D. uncinatum* as a method of stemborer and striga control and napier grass for stemborer control in 1998, participated in fully-integrated 'push-pull' trials during 1999. Similar selection procedures 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. The results of on-farm trials in Suba District are summarised in Figure 4.

4.1 FARMERS' PERCEPTIONS ON HABITAT MANAGEMENT

Habitat management strategies can confer various benefits to farmers who practise them. The most important contributions are increased grain yield, higher milk production and reduction in levels of pest and weed infestation from participating farms. These benefits translate into improved food security,

Table 4.1. Benefits of using habitat management practices in on-farm trials in Kenya, 1998

	Percentage of farmers	
Perceived benefit to the farmer+	Trans Nzoia (n = 50)	Suba (n = 24)
Reduced stemborer infestation	98	88
Acquired knowledge on new feeding techniques	92	Not elicited[1]
Increase in availability of animal fodder	68	83
Increase in maize yield	44	92
Increase in milk yield	32	33
Reduced soil erosion	22	Not elicited
Reduced maize lodging due to strong wind	20	Not elicited
Acquired knowledge in new animal fodders	16	Not elicited
Reduced budget in buying insecticides	14	4
Improved animal health	12	Not elicited
Reduced striga infestation	No striga	63
Income from sale of napier and *Desmodium*	Not elicited	4

+These responses were drawn from open-ended questionnaires.

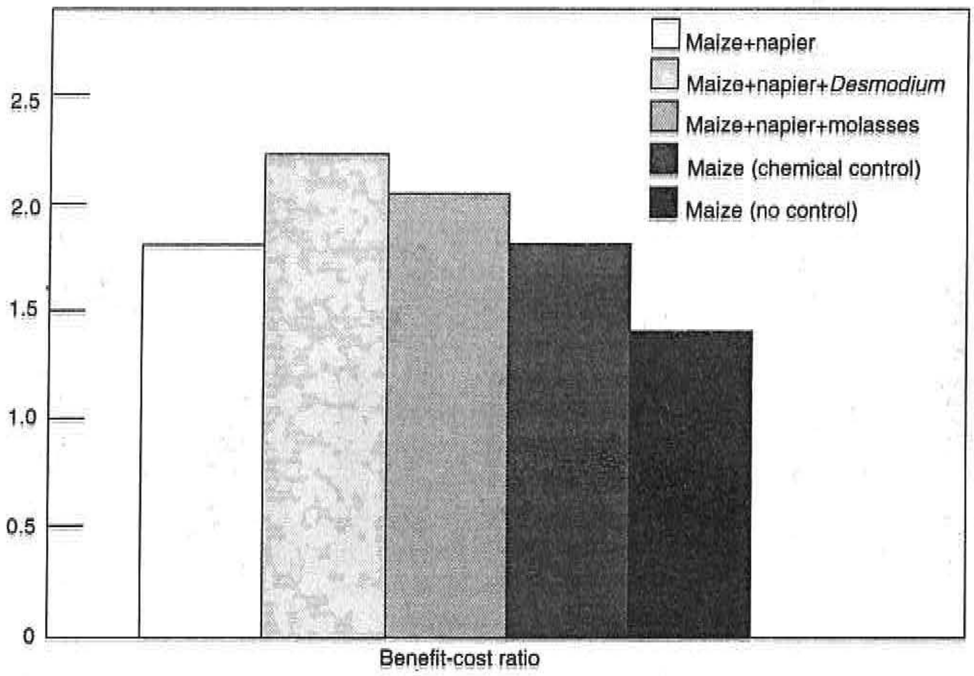

Figure 4.2. Economics of habitat management technology (1998)

higher farm incomes and contribute to the sustainability of low-input agriculture. Fifty farmers in Trans Nzoia District and 24 farmers in Suba District who participated in on-farm trials in 1998 were interviewed for their perceptions towards the habitat management strategies and the effectiveness of using this innovation as a stemborer and/ or striga control method. Results from both the districts are presented in Table 4.1.

4.2 BENEFIT-COST RATIO

Evaluating returns to investments in habitat management strategies is key in the ex-ante assessment of the feasibility of these technologies in contributing to farm income and improved welfare. As a preliminary step towards the economic feasibility of the various habitat management strategies, data on various components of income (benefits) and costs was gathered from Trans Nzoia District in 1998 and analysed for options in different agroecological and socioeconomic settings. Comparisons were made with farmers who used pesticides for stemborer control. Results showed the highest benefit-cost ratio for the farmers who used both napier grass and *Desmodium* in a 'push-pull' strategy (Figure 4.2). Similar data need to be collected from different places and different types of farmers, including women farmers, in order to assess yield or income stability or variability over time. This is to assist in generating estimates of economic returns under different weather regimes (i.e. good vs. bad seasons) in various agroecologies for different types of farmers.

5. WOMEN'S PARTICIPATION IN HABITAT MANAGEMENT

Women's contribution to agricultural production in eastern African countries is significant. Despite variations across cultural and socio-political backgrounds, women contribute enormously towards agricultural resource allocation decisions. During 1999, women farmers and members of women groups were invited to ICIPE's Mbita Point Field Station for a one-day workshop on the role of women in habitat management strategies for controlling stemborers and striga weed. The aim of the workshop was to provide information about the technology to women farmers, to get first-hand information from them about their contributions to the habitat management strategies and to help develop their potential in sustaining and diffusing the technology. A pre-coded focused questionnaire was administered to capture information on various activity profiles for cultivation of maize, napier grass and *Desmodium* and for animal production undertaken by men, women and children. The information related to napier and *Desmodium* cultivation is summarised in Figures 5a and 5b. The information will be valuable in future training to identify a target group for a specific activity in habitat management.

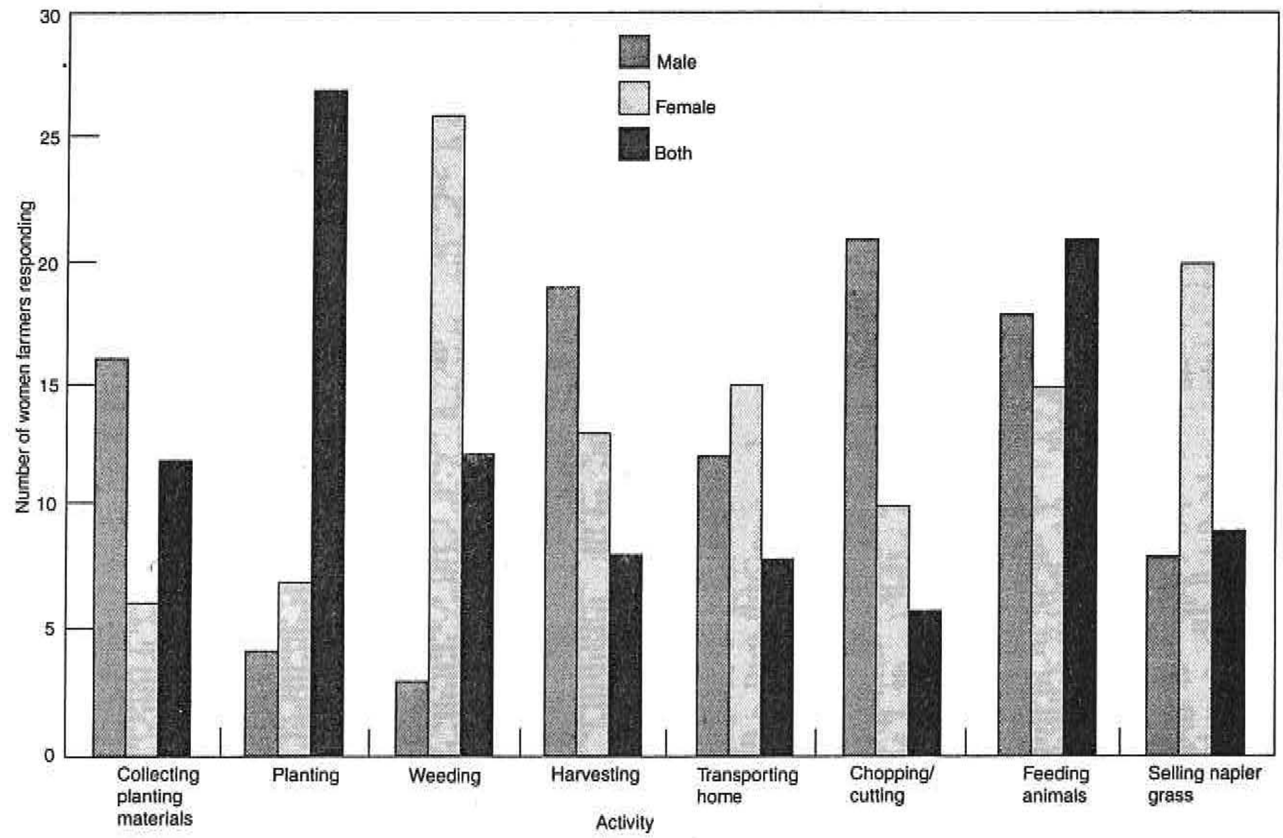

Figure 5a. Role of women in use of napier grass as a trap plant for stemborers in habitat management strategies

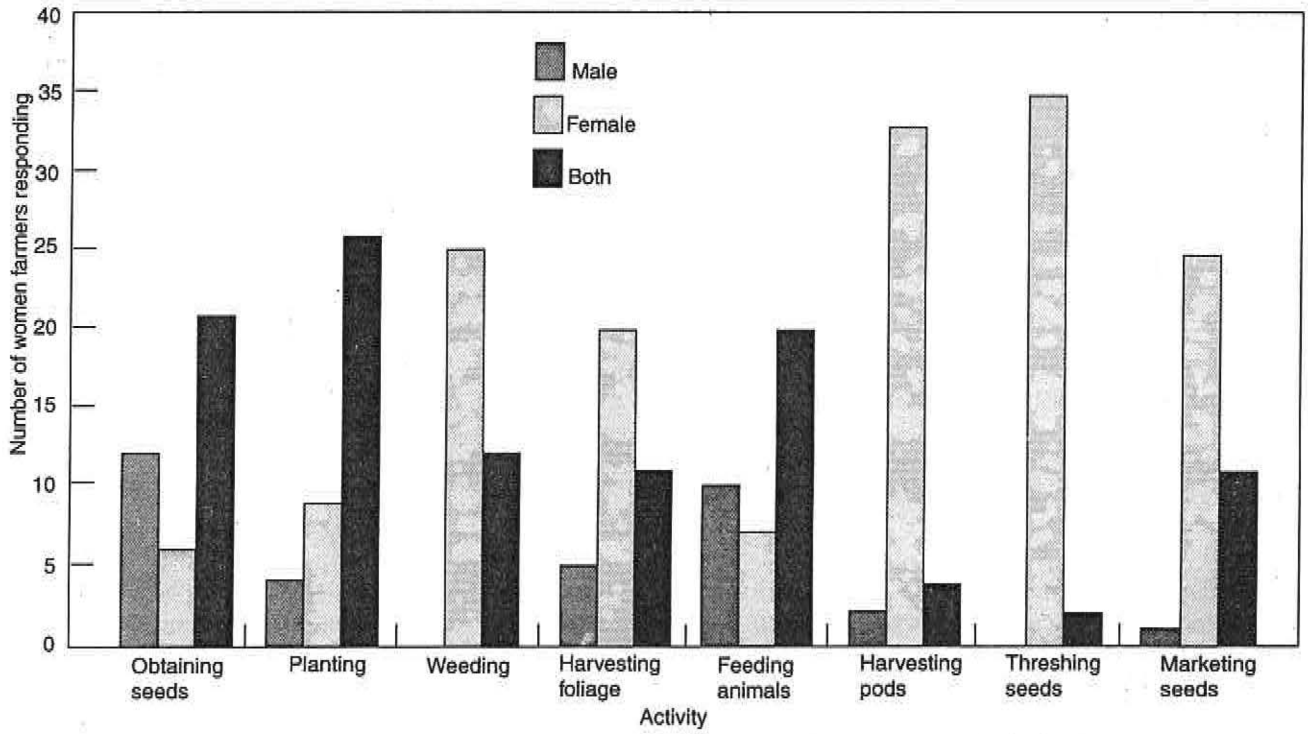

Figure 5b. Role of women in use of *Desmodium uncinatum* in habitat management strategies to control stemborers and striga weed

Output

Publications

Khan Z. R. (1998) Habitat management strategies for control of insect pests in Africa: A novel approach to IPM for the twenty-first century, pp. 53–64. In *Ecological Agriculture and Sustainable Development*, Vol. 2 (Edited by G. S. Dhaliwal, N. S. Randhawa, R. Arora and A. K. Dhawan). Indian Ecological Society and Centre for Research in Rural and Industrial Development, Ludhiana, India.

Khan Z. R. and Saxena R. C. (1998) Host plant resistance to insects, pp. 118–154. In *Critical Issues in Insect Pest Management* (Edited by G. S. Dhaliwal and E. A. Heinrichs). Commonwealth Publishers, New Delhi.

Pathak M. D. and Khan Z. R. (1998) Management of rice stemborers in Asia, pp. 227–238. In *Tropical Entomology: Proceedings of the 3rd International Conference on Tropical Entomology* (Edited by R. K. Saini). ICIPE Science Press, Nairobi.

Polaszek A. and Khan Z. R. (1998) Host plants, pp. 3–10. In *African Cereal Stem Borers: Economic Importance, Taxonomy, Natural Enemies and Control* (Edited by A. Polaszek). CAB International, UK.

Conferences organised

Habitat Management Strategies for Suppression of Cereal Stemborers and Striga Weed, 19 September 1998, Institute of Agricultural Research, Addis Ababa, Ethiopia (Funded by BBSRC and Gatsby Charitable Foundation).

Conservation of Gramineae and Associated Arthropods for Sustainable Agricultural Development in Africa, ICIPE, Nairobi 23–25 November 1998, funded as a PDF-Block A by the Global Environment Facility through UNEP (To develop a project proposal for funding).

International Workshop on Habitat Management Strategies for Control of Stemborers and Striga Weed in Maize-Based Farming Systems in Africa, 27–30 June 1999, ICIPE's Mbita Point Field Station, Mbita Point.

Conferences attended

Khan Z. R. (1998) International Workshop on the Management of Cereal Stemborers in Africa, Nairobi, Kenya, 12–13 October, 1998. Paper presented, 'Use of wild host plants in cereal stemborer and striga management'.

Khan Z. R. (1998) The 6th Eastern and Southern Africa Regional Conference, 21–25 September 1998, Institute of Agricultural Research, Addis Ababa, Ethiopia. Paper presented, 'Maize production technology for the future: Challenges and opportunities'.

Khan Z. R. (1998) Annual Meeting of the Entomological Society of America, 8–12 November, 1998, Las Vegas, USA.

Khan Z. R. (1999) Annual Meeting of the Entomological Society of America, 12–16 December, 1999, Atlanta, GA, USA.

Proposals written

Implementation of habitat management strategies for stemborer and striga suppression in maize-based farming systems in eastern Africa. To be submitted for funding through ASARECA jointly with national programmes.

Mechanism of *Striga* suppression in maize-*Desmodium* intercrop. Submitted to Rockefeller Foundation.

'Push-pull' strategies for management of stemborers and striga weed in Lake Victoria Basin of East Africa. Submitted to USAID.

Conservation of gramineae and associated arthropods for sustainable agricultural development in Africa submitted to UNEP for funding by the Global Environment Facility

Project proposals funded in 1998 and 1999

'New integrated stemborer 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.

'Mechanism of striga suppression in maize–*Desmodium* intercrop'— funded by Rockefeller Foundation.

Capacity building

Training has been a very strong component of the Gatsby-funded Project. Several MSc and PhD students from different countries are working under the project (Table A).

During the trials, the project also organised several training activities for farmers and extension staff in Trans Nzoia and Suba Districts (Table B). 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 and on-farm technology trials. The views expressed by the farmers during the training session were taken into account and variations incorporated where appropriate. In some of the training workshops, an exchange of MOA staff and farmers from the two districts was facilitated to allow exchange of experiences. In addition to the training sessions, field days were also held in each on-farm trial site of Trans Nzoia and Suba Districts to give an opportunity to a large cross-section of farmers in the project areas, to observe and assess the technology under evaluation. Several hundred farmers from the project sites took part in field days.

Impact

The integrated strategy of stemborer and striga weed control developed under this project is potentially attractive to farmers, because it manifests the following important features which render it distinctively more advantageous than some other methods:

- **Food security.** Intercropping or mixed cropping of maize, grasses and fodder legumes has enabled farmers/users to increase crop yield to improve food security. This feature of the technology is suitable to mixed farming conditions, which are prevalent in eastern Africa.

Table A. Students trained under Gatsby Project during 1998–1999

Name	Country	Start date	Completion date	Title/ Degree
Patrick J. Mbugi	Kenya	1995	1999	Movement of *Chilo partellus* (Lepidoptera: Pyralidae) and *Busseola fusca* (Lepidoptera: Noctuidae) adults between cultivated and wild habitats (PhD)
Linnet S. Gohole	Kenya	1997	Continuing	Effects of molasses grass (*Melinis minutiflora*) on parasitisation of cereal stemborers in cereal-based cropping systems (PhD)
Philip Berry	UK	1998	1998	Population dynamics of stemborers in on-farm trials (MSc)
Nathalie King	UK	1999	1999	Population levels of stemborers and their parasitoids on wild grasses under different push-pull strategies
Muniru K. Tsanuo	Kenya	1997	Continuing	*Striga hermonthica* seed germination stimulant/ inhibitors exuded by roots of selected fodder legumes (PhD)
Dorothy Wanyama	Kenya	1998	Continuing	Adoption by farmers of habitat management technologies in Trans Nzoia (PhD)
Mohamad Hassan Mahmud	Somalia	1998	Continuing	Interaction between striga and stemborers (PhD)

Table B. Training activities, farmers' meetings and visits during 1998–1999

Date	Location	Target group	Topics
January 1998	Suba District, MPFS	Participating and non-participating farmers	1. Stemborer life cycle, 2. Management of stemborers and striga weed by use of habitat management strategies
February 1998	Trans Nzoia District, Kitale County Council Hall	As above (January, 1998, MPFS)	1. Stemborer life cycle, 2. Establishment of napier grass, *Desmodium* and molasses grass in an integrated approach, 3. Need for farmers training in technology development, 4. Role of farmers in adaptive research project, 5. 1998 Trial designs
March 1998	Trans Nzoia District, KARI, Kitale	Divisional and locational agricultural extension staff	Collecting socioeconomic data from Trial farmers fields
July 1998	Suba District, MPFS	Participating Project farmers	Eight Trans Nzoia farmers and extension officers visited Suba district to familiarise themselves with both on-station and on-farm Gatsby Project research activities
September 1998	Trans Nzoia District	Participating and non-participating farmers, Nongovernmental Organisations (NGOs), Teachers, Chiefs	1. Utilisation of wild host plants for the management of stemborers, 2. Stemborer life cycle, 3. Napier utilisation
October 1998	Trans Nzoia	As above	Eight Suba farmers visited Trans Nzoia district to familiarise themselves with both on-station and on-farm Gatsby Project research activities
October 1998	Trans Nzoia District	Participating and non-participating farmers	1. Stemborer life cycle, 2. Napier grass, *Desmodium* and molasses grass establishment and utilisation,3. Role of farmers in adaptive research, 4. Recruitment of 1999 Project farmers
December 1998	Trans Nzoia District	Participating Project farmers	Meeting to discuss and evaluate the technology on on-farm farmer managed trials
February 1999	Suba District	Extension staff	Training of Suba District extension staff on communication skills
March 1999	Suba District	Women farmers	Gender training on habitat management strategies
May 1999	Trans Nzoia District	Extension staff	Training of Trans Nzoia District extension staff on communication skills
August 1999	Suba District	Participating and non-participating farmers	Raising awareness of 'Tembea na Majira' Kiswahili Radio Programme
September 1999	Trans Nzoia District	Participating and non-participating farmers	Raising awareness of 'Tembea na Majira' Kiswahili Radio Programme
September 1999	Trans Nzoia District	Extension staff	Training on setting up on-farm trials for year 2000
November 1999	Trans Nzoia District	Participating farmers	Evaluation of on-station trials by farmers at KARI, Kitale
December 1999	Suba District	Senior Agricultural Officers from Trans Nzoia	Training visit to ICIPE's Mbita Point Field Station

- **Livestock production.** Habitat management strategies have contributed to increased livestock production (milk and meat) by availing more fodder and crop residues, especially on small farms where competition for land is quite high. It has been demonstrated by the Project that intercropping of forage legumes with cereal crops can improve the quantity and quality of livestock feeds on smallholder farms in various sub-Saharan African countries. The Project has assisted farmers in the semi-arid Suba District of Kenya to acquire 'grade' cattle in a bid to help them meet the district milk shortfall of 40%.
- **User-friendly technology.** The proposed technology introduces practices which are already familiar to farmers in Africa. The approach has affinity to the common agricultural practice of multiple cropping (a system that is based on the diversity of crops, rather than a monocrop) and is based on the use of economically valuable plants. The cultivation of napier grass for livestock fodder and soil conservation is being encouraged in eastern Africa and is already widely practised.
- **Exploiting biodiversity.** This habitat management approach embodies maintenance of species diversity, i.e. by intercropping different plants to avoid the pest problems associated with monoculture. The beneficial effects of field margin habitats in supporting greater arthropod

biodiversity and in enhancing natural enemy populations within adjacent cereal fields is well known.

- **Sustainability.** In this approach, the full integration of several crop protection approaches creates 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.
- **Protecting fragile environments.** Higher crop yields and improved livestock production, resulting from habitat management strategies, are helping support rural households under the existing stressful socioeconomic and agroecological conditions. Thus, there will be less motivation for human migration to fragile environments in search of cultivable land.
- **Income generation and gender empowerment.** These habitat management strategies can contribute considerably towards enhancing farm incomes and gender empowerment through sale of farm grain surpluses, fodder and *Desmodium* seed, especially for women farmers/groups and rural youth groups. The cultivation of napier grass and *Desmodium* for livestock fodder and for soil conservation is being encouraged in Trans Nzoia and is already widely applied.
- **Technology transfer.** Farmers (80%) participating in on-farm trials want to extend the technology to larger areas of their farms. The Project intends to reach about 500 more Kenyan farmers in farm trials up to the year 2001.

Over the next five years, ICIPE plans to test the habitat management technology in three other African countries—Ethiopia, Uganda and Tanzania—in collaboration with national agricultural research systems. Recognising the important role of women in subsistence farming, ICIPE is ensuring that women benefit from on-farm trials and training opportunities. The Project organised an international workshop at ICIPE's Mbita Point Field Station. The workshop helped in stimulating interest among researchers and extension staff that would lead to a regional project to test the results of habitat management strategies in different agroecologies and eventually to be adopted by small scale farmers.

- **Media attention and publicity.** The interest created by this project has earned it a recent mention in international reputable publications—*New Scientist* (24 October, 1998, page 25) and *National Geographic* (February 1999, pages 82–83). During 1998 and 1999, field trials were visited by several donors, notable among them are Rockefeller Foundation, USAID and United Nations Development Programme. Maize scientists from Ethiopia, Kenya, Tanzania, Sudan, South Africa and Uganda also visited the trials. The Project's recommendations are reaching 5 million Kenyan farmers through one of the most popular Kiswahili soap opera radio programmes entitled 'Tembea na Majira' on which ICIPE works closely with Media Trust based in Nairobi.

(See also reports on Biodiversity and Conservation, Biosystematics Unit, Behavioural and Chemical Ecology Department.)

Biological Control of Cereal Stemborers in Eastern and Southern Africa

Background, approach and objectives

The exotic spotted stemborer, *Chilo partellus* invaded Africa from Asia sometime in the early part of this century, and now occurs throughout eastern and southern Africa. In many of the colonised areas, *Ch. partellus* is considered to be one of the most important pests of maize and sorghum. The approach being followed in this ICIPE project is classical biological control, in which coevolved natural enemies from the native Asian home of *Ch. partellus* are collected and introduced into the area of invasion.

Classical biological control strives to re-establish in the invaded area the ecological balances that occur in the native home. Thus far, one exotic natural enemy, *Cotesia flavipes*, has been successfully established in Africa. *Cotesia flavipes* is a gregarious endoparasitoid which attacks *Ch. partellus* and other stemborers throughout much of Asia. The material introduced into Africa originated from collections made at several locations in Pakistan and India.

The ICIPE Project is a regional initiative which has established close collaborative activities with national programmes in Kenya, Uganda, Ethiopia, Zambia, Malawi, Zimbabwe, Mozambique, Tanzania and Zanzibar. In each country, surveys are conducted to determine areas where the exotic stemborer is dominant. *Cotesia flavipes* is then mass released, either by ICIPE or the national programme at the target sites. By the end of 1999, releases had been made in Kenya, Uganda, Somalia, Mozambique, Malawi, Zimbabwe, Zanzibar and Zambia.

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

Collaborators: *• Wageningen Agricultural University • IITA • ICRISAT • NARS/Universities in Kenya, Uganda, Ethiopia, Zanzibar, Zambia, Zimbabwe, Malawi, Mozambique and Tanzania*

Work in progress

1. ESTABLISHMENT AND EVALUATION OF *COTESIA FLAVIPES* IN KENYA

1.1 POPULATION DYNAMICS OF *COTESIA FLAVIPES*

The exotic parasitoid *Cotesia flavipes* was first released in Africa in the coastal area of Kenya in 1993, and this region has received the most attention in monitoring the spread and increase of the parasitoid population. In 1998 and 1999, surveys were expanded inland to Voi, located about 160 km northwest of Mombasa, and from Voi westward towards Taveta near the Tanzanian border. All of the fields were sampled five times in the long rainy season and three times in the short rainy season. *Cotesia flavipes* was found at more than 80% of the sites sampled (Table 1.1), indicating that the population had spread throughout the area. Spatial interpolation of the spread and population increase, based on parasitoid densities found at sampling sites from 1994 to 1998, are shown in Figure 1.1. In comparison to 1997, there was a marked increase in parasitisation of *Chilo partellus* in 1999, with average parasitisation in Kilifi District of 12.5%, and ranging as high as 66.2% (Table 1.1).

1.2 RELATIONSHIP BETWEEN STEMBORER SPECIES COMPOSITION AND PARASITISATION BY *CO. FLAVIPES*

Cotesia flavipes is established in much of southern Kenya, where there is variation in the stemborer species composition from area to area (Table 1.2). In the southern low altitude coastal area are found *Ch. partellus*, *Ch. orichalcociliellus* and *Sesamia calamistis*, with *Ch. partellus* being predominant. Mean parasitisation by *Co. flavipes* in the coastal area reached 9.5% in fields where *Ch. partellus* was dominant. In fields where the proportion of *Ch. partellus* was less

Table 1.1. Parasitisation of *Chilo partellus* by *Cotesia flavipes* in 14 Districts of Coast Province

Year	Season	Statistics	Kilifi	Kwale	Voi	Taita/Taveta
1998	Long rains	No. of sampling sites	15	15	14	17
		No. of sites with Cf	13	10	13	16
		Mean parasitism (%)	9.4	2.6	16.7	14.9
		Maximum parasitism	43.3	9.1	47.1	35.4
1998	Short rains	No. of sampling sites	20	30	-	-
(98LR sites)		No. of sites with Cf	16	22	-	
-		Mean parasitism (%)	7.9	4.2	-	-
		Maximum parasitism	22.7	15.9	-	-
1999	Long rains	No. of sampling sites	39	46	-	36
(98SR sites)		No. of sites with Cf	30	36	-	34
		Mean parasitism (%)	7.7	3.9	-	12.32
		Maximum parasitism	66.2	29.3	-	52.7

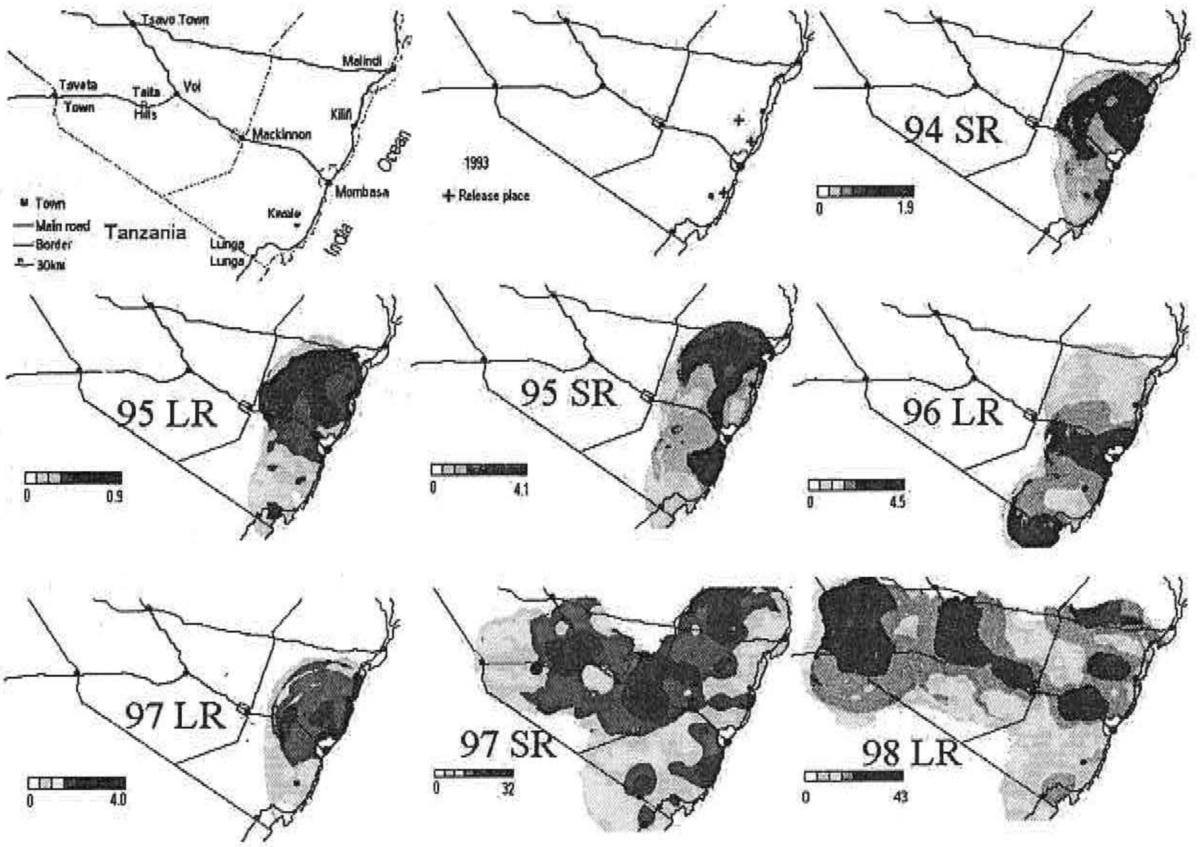

Figure 1.1. Distribution and density of *Cotesia flavipes* in the Coastal Province of Kenya from 1994 to 1998

Table 1.2. Stemborer composition and parasitism by *Co. flavipes*

Area	Coastal area	Eastern area	Western area
Districts	Kilifi, Kwale Kiboko,Taita	Katumani, Ithokwe	Kuja, Mbita, Ungoye
Data collection	1996–1998	1996–1998	1995–1996
Composition	Cp 63%	Cp 85%	Cp 72%
	Co 25%	Co <1%	Sc 3%
	Sc 10%	Sc 9%	Bf 12%
		Bf 3%	Es 12%
Cf parasitism	6.4%	9.8%	2.2%

Cp= *Chilo partellus*, Co= *Chilo orichalcocielellus*, Sc = *Sesamia calamistis*, Bf= *Busseola fusca*, Es= *Eldana saccharina*, Cf = *Cotesia flavipes*.

than 40%, parasitisation was only about 1.7%. In the Eastern Province, *Busseola fusca* occurred in half of the sampled fields, and in these fields, parasitisation by *Co. flavipes* was about 4.0%. In fields without *B. fusca*, average parasitisation by *Co. flavipes* reached 11.6%. In western Kenya, *Ch. partellus*, *B. fusca*, *S. calamistis* occur in most fields and *Eldana saccharina* is less common. Average parasitisation by *Co. flavipes* was only 2.1%, and even lower in fields where *E. saccharina* was found.

1.3 BIODIVERSITY OF STEMBORER PARASITOIDS

From 1992–1998, 4159 parasitoids in 25 species were recovered from identified stemborers in the Coast Province (Table 1.3). In addition to the 25 species, another 6 species, *Dolichogenidia fuscivora*, *Meteorus* sp., *Rhaconotus scirpophagae*, *Glyptapanteles africanus* (Hymenoptera: Braconidae) and *Pimpla* sp. (Hymenoptera: Ichneumonidae) were recovered from unidentified stemborers. Out of the 25 species, 22 were reared from *Ch. partellus*, 15 from *S. calamistis*, 14 from *Ch. orichalcociliellus* and 6 from *B. fusca*. In coastal Kenya, *B. fusca* only occurs in the Taita Hills, a high elevation area of Taita/Taveta District. The high diversity of native parasitoids which were recovered from the exotic stemborer is interesting and suggests that the majority of parasitoids which attack gramineous stemborers tend to be more habitat-specific than host-specific. Three species, *Co. sesamiae*,

Table 1.3. Diversity of parasitoids attacking larvae and pupae of four stemborers in the Coast Province of Kenya, 1992–1998

Parasitoid species	*Sesamia calamistis*	*Chilo orichalcociliellus*	*Chilo partellus*	*Busseola fusca*	Total parasitoids	Percent of total
Braconidae						
Cotesia sesamiae	282	211	1852	4	2349	56.48
Cotesia flavipes	24	108	1030	4	1166	28.04
Chelonus curvimaculatus	0	8	28	0	36	0.87
Stenobracon rufa	1	1	25	0	27	0.65
Bracon sesamiae	1	1	22	0	24	0.58
Macrocentrus sp.	1	2	18	0	21	0.50
Glyptapanteles maculitarsis	0	0	13	0	13	0.31
Amyosoma nyanzaense	1	0	9	0	10	0.24
Stenobracon sp.	1	0	2	0	3	0.07
Dolichogenidea polaszeki	1	0	0	1	2	0.05
Meteorus sp.	0	0	1	0	1	0.02
Ichneumonidae						
Dentichasmias busseolae	1	10	83	0	94	2.26
Syzeuctus sp.	2	31	35	0	68	1.64
Xanthopimpla sp.	1	1	5	0	7	0.17
Temelucha sp.	0	0	2	0	2	0.05
Pristomerus sp.	1	0	0	0	1	0.02
Chalcididae						
Psilochalsis soudanensis	0	1	14	1	16	0.38
Brachymeria olethria	0	0	3	0	3	0.07
Antrocephalus mitys	0	0	1	0	1	0.02
Eurytomidae						
*Eurytoma braconidis**	0	1	0	1	2	0.05
Eurytoma orzivora	0	0	1	0	1	0.02
Euophidae						
Pediobius furvus	77	29	102	3	211	5.07
Bethylidae						
Goniozus indicus	4	19	46	0	69	1.66
Ceraphronidae						
*Aphanogmus fijiensis**	0	0	1	0	1	0.02
Tachinidae						
Sturmiopsis parasitica	1	22	8	0	31	0.75
Unparasitised individuals	9792	16,982	76,963	428	104,165	-
Total parasitised	399	445	3301	14	4159	-
No. of parasitoid species	15	14	22	6	57	-
Total parasitism	3.92	2.6	4.1	3.17	3.84	-
Total hosts	10,191	17,427	80,264	442	108,324	-

*Hyperparasitoid.

Co. flavipes and *Pediobius furvus*, were reared on four stemborer species. *Cotesia sesamiae* appeared in all seasons and in all regions sampled from 1992 to 1998 and *Co. flavipes* occurred in all seasons and regions since 1997. Together, these two species accounted for 84.5% of the parasitoids recovered.

The recoveries of *Co. flavipes* from *B. fusca* are surprising as previous laboratory and field studies clearly indicated that *Co. flavipes* could not develop in this stemborer. It appears that the population of *B. fusca* which occurs in the Taita Hills may be susceptible to *Co. flavipes*. Other species of secondary abundance (recovered > 20 times) were *Dentichasmias busseolae, Goniozus indicus, Syzeuctus* sp., *Chelonus curvimaculatus, Sturmiopsis parasitica, Stenobracòn rufa, Bracon sesamiae* and *Macrocentrus* sp. The remaining species were rare and only found in one or a few seasons.

Two hyperparasitoids were reared from *Cotesia* spp. cocoons, *Aphanogmus fijiensis* and *Eurytoma braconidis*. The number of hyperparasitoids are under-represented in the dataset as most of the attached hosts were not identified.

1.4 RELEASE OF *COTESIA FLAVIPES* IN THE EASTERN PROVINCE

Cotesia flavipes was released in maize plots in Katumani, Ithookwe and Kiboko during the short rains of 1997. In the long rains of 1998, surveys were conducted at the three sites to examine the population dynamics of stemborers and their natural enemies and to determine whether *Co. flavipes* had successfully colonised fields and survived through the dry period between the rainy seasons. The most prevalent stemborer at the three sites was *Ch. partellus*, followed by *S. calamistis* and *Cryptophlebia leucotreta*. Larval parasitoids recovered from maize at Katumani in descending order of abundance were *Co. flavipes, Co. sesamiae, Chilonis curvimaculatus, Co. ruficrus, Tetrastichus* sp., *Venturia* sp., an unknown dipteran and *Nyereria* sp.

Pupal parasitoids recovered included *Dentichasmias busseolae, Pediobius furvus, Brachymeria olethria* and unidentified Pteromalids. A hyperparasitoid, *Aphanogmus fijiensis*, was recovered from *Cotesia* spp. at each of the three sites.

2. USE OF GIS FOR PREDICTION OF EVENTUAL DISTRIBUTION OF *CHILO PARTELLUS* IN AFRICA

As a relatively recent introduction into Africa, *Ch. partellus* is spreading to invade new areas of the continent. Recent unconfirmed reports indicate that *Ch. partellus* is now in Angola, and possibly northern Namibia. A prediction of where *Ch. partellus* may eventually establish in Africa would be useful information for national programmes in countries

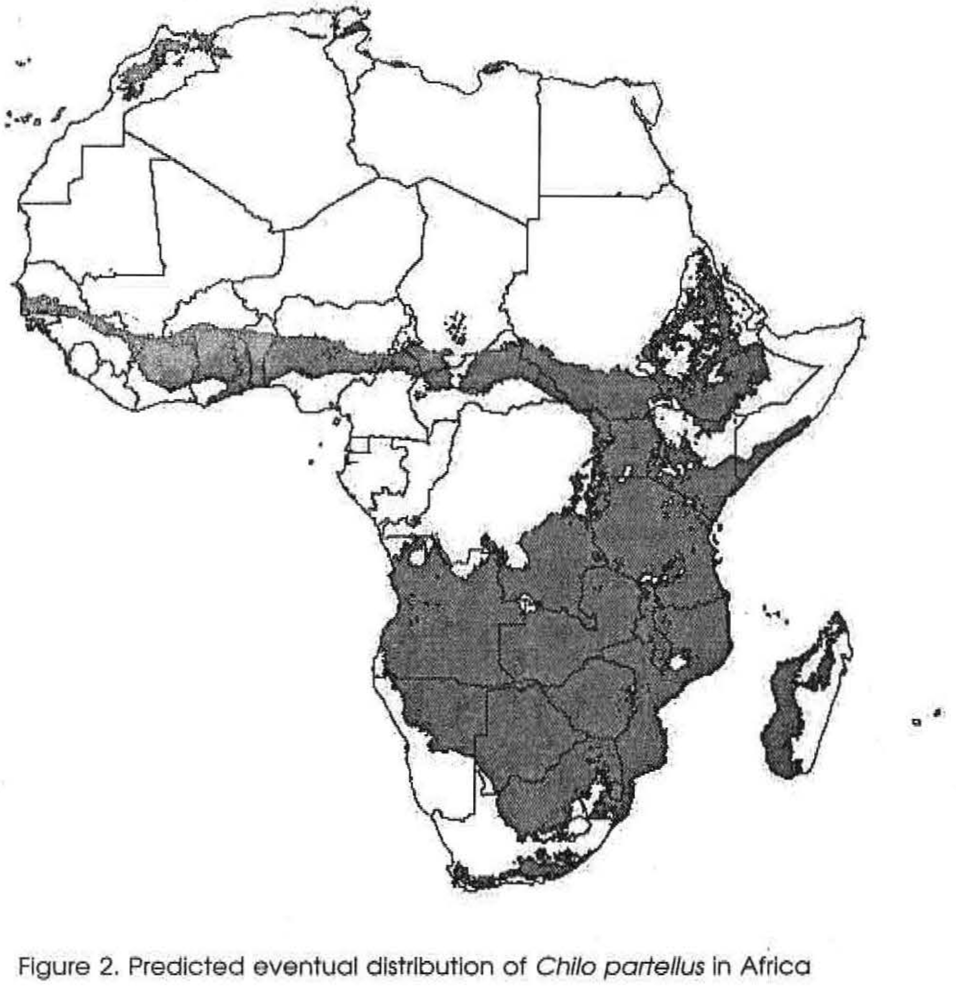

Figure 2. Predicted eventual distribution of *Chilo partellus* in Africa

not yet invaded. In collaboration with Texas A&M University, we are using geographic information systems (GIS) to locate areas in Africa which have climates similar to areas where *Ch. partellus* is already established. Initially, the climate parameters included in the analyses were precipitation, evapotranspiration and average maximum and minimum temperatures.

Using data on stemborer occurrence in Kenya, Uganda, Mozambique, Zambia, South Africa, Ethiopia, Lesotho and Somalia, the predicted eventual distribution of *Ch. partellus* is shown in Figure 2. There are some obvious problems with this prediction; for example, Zambia and Zimbabwe are completely covered, which we know is not the case. Additionally, the distribution includes areas in central and northern Kenya where we do not have any evidence that *Ch. partellus* occurs. These anomalies suggest that either we have left out some important climatic or biotic parameters in the analysis (e.g. competition with indigenous stemborers), or that various geographic populations of *Ch. partellus* are adapted to different conditions. This work will continue in 2000.

3. FOREIGN EXPLORATION FOR ADDITIONAL NATURAL ENEMIES OF *CHILO PARTELLUS*

A visit was made to India in December 1998 to collect *Sturmiopsis inferens* and more *Co. flavipes*. *Sturmiopsis inferens* is often regarded as the second most important parasitoid of *Ch. partellus* in India, after *Co. flavipes*. This tachinid parasitoid has a different life history and attack strategy from *Co. flavipes*, and thus, may provide complementary mortality of stemborers, rather than directly competing with *Co. flavipes*. A second objective of the trip was to collect *Co. flavipes* isofemale lines, which will be required for release in Zanzibar in 1999 (see section 16.7on Zanzibar). The 4-week visit to India resulted in the laboratory colonisation at ICIPE of approximately 40 new *Co. flavipes* isofemale lines. Unfortunately, only 5 *S. inferens* were collected during the visit. Due to lack of both males and females at the same time, a culture could not be initiated. However, during the same trip it was observed that the pupal parasitoid, *Xanthopimpla stemmator*, was quite abundant. Efforts are now being made to import *X. stemmator*.

4. EFFECT OF MULTIPLE PARASITISM BY *COTESIA SESAMIAE* EX-KITALE AND *COTESIA FLAVIPES* ON *BUSSEOLA FUSCA*

The exotic parasitoid *Co. flavipes* is established in western Kenya where *B. fusca* is commonly found. This is a surprising finding because previous work had shown that *Co. flavipes* could not develop in *B. fusca* (see section 1.1 on population dynamics of *Co. flavipes*). Moreover, laboratory experiments conducted earlier in the project indicated that *Co. flavipes* would search for and attack *B. fusca* — a behaviour considered to lead to the death of the progeny. Thus, we hypothesised that *Co. flavipes* would not establish in areas where *B. fusca* was abundant. One area of research we had not explored, but that could increase the possibility of *Co. flavipes* establishing in areas where *B. fusca* occurs, is the outcome of multiple parasitism of *B. fusca* by *Co. flavipes* and the indigenous parasitoid, *Co. sesamiae*.

A study was initiated using *Co. sesamiae* originating from Kitale, and *Co. flavipes*, to parasitise the same *B. fusca* larva. Results showed that *Co. flavipes* stinging alone was not able to successfully parasitise *B. fusca* larvae, because all its eggs were encapsulated. On the other hand, *Co. sesamiae* collected from the western part of Kenya successfully parasitised its habitual host, *B. fusca*. However, successful parasitism of *B. fusca* by *Co. flavipes* was possible when the same host was already parasitised by *Co. sesamiae* (Figure 4.).

Our laboratory tests also indicated that larvae of *B. fusca* that were stung by the two parasitoids within a 2-hour-interval were successfully parasitised by both parasitoids. In the presence of eggs and

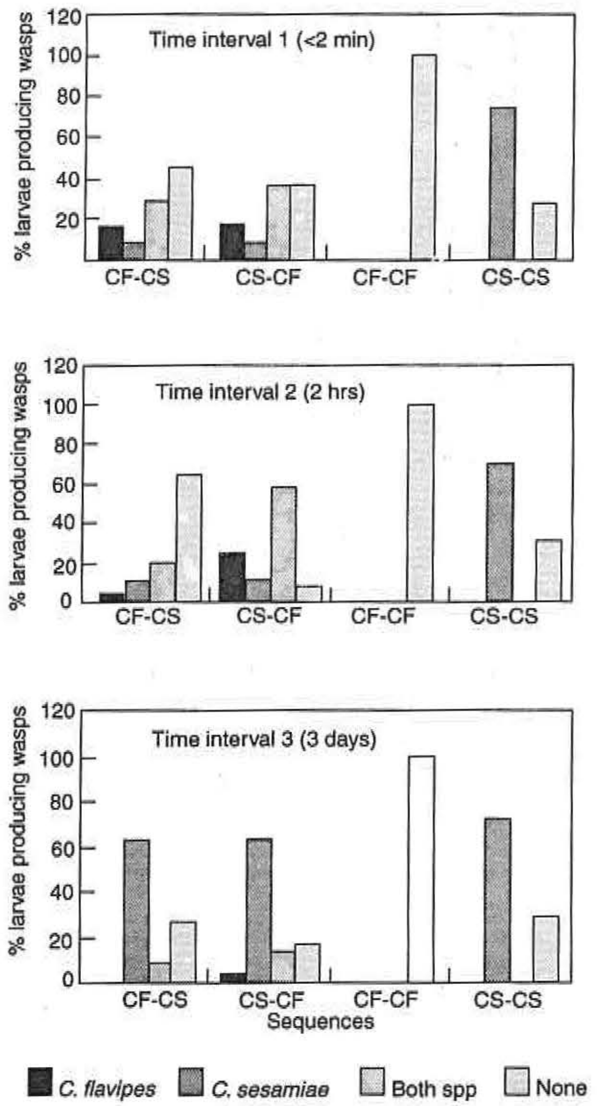

Figure 4. Percentage of hosts producing different parasitoid species after ovipositions at different time intervals and in different sequences. Cf=*Cotesia flavipes*, Cs=*Cotesia sesamiae*

substances injected at oviposition by *Co. sesamiae*, *Co. flavipes* was able to hatch and develop on *B. fusca*. However, the chances for *Co. flavipes* to escape encapsulation were reduced when the time interval between oviposition by the two parasitoid species increased. In larvae producing both parasitoid species, we observed that *Co. flavipes* individuals outnumbered *Co. sesamiae* individuals, suggesting that *Co. flavipes* may out-compete *Co. sesamiae* in the host.

5. DIVERSITY OF *COTESIA SESAMIAE* IN KENYA

Cotesia sesamiae is the most common larval parasitoid of stemborers in many areas of sub-Saharan Africa, where it attacks a variety of noctuid and pyralid stemborers in gramineous crops. As indicated earlier, in nearly all surveys in Kenya, *Co. sesamiae* was the most abundant parasitoid before the introduction of *Co. flavipes*, and still remains the most important natural enemy in higher elevation areas where the indigenous stemborer *Busseola fusca* predominates. This is likely to remain the case as *Co. flavipes* is not able to develop in *B. fusca*. A study conducted earlier by the project showed the unexpected result that the *Co. sesamiae* population from the Kenya coast was unable to develop in *B. fusca*. This suggests that there may be at least two biotypes of the parasitoid in Kenya. Presence of symbiotic microorganisms, such as the bacteria *Wolbachia* sp. that cause male sterility in one or both directions in reciprocal crosses,

Table 5.1a. Percentage parasitism by *Cotesia sesamiae* and *Co. flavipes* from sampling sites at the Kenya coast

Location	No. plants sampled	No. borers	Host borer	No. Cs	No. Cf	% Parasitism	
						Cs	Cf
South Coast							
Mwaluvanga	20	133	Sc,Cp	1(Sc)	7(Cp)	0.7	5.2
Eshu	20	39	Cp	0	1	0	2.5
Kikoneni	20	30	Cp	0	1	0	3.3
Mrima	20	75	Cp	2	0	2.7	0
Mpongwe	27	25	-	0	0	0	0
Msambweni	31	52	Cp	1	0	1.9	0
Bahakanda	35	30	-	0	0	0	0
Nwandeo	30	42	Cp	0	2	0	4.8
Maneawani	30	21	Cp	0	4	0	19
North Coast							
Mkapuni	31	76	Sc	2	0	2.6	0
Kawala	21	9	-	0	0	0	
Kaloleni	32	70	Cp	4	0	5.7	0
Mtwapa	41	27	Cp	3	0	11.1	0
Malindi	20	4	-	0	0	0	0
Matano manne	53	46	Cp	1	0	2.2	0

Sc=*Sesamia calamistis*, Cp=*Chilo partellus*, Cs=*Cotesia sesamiae*, Cf=*Cotesia flavipes* Bf=*Busseola fusca*

Table 5.1b. Percentage parasitism by *Cotesia sesamiae* and *Co. flavipes* during the second survey

Location	No. plants sampled	No. borers	Host borer	No. Cs	No. Cf	% Parasitism	
						Cs	Cf
S. Coast	199	278	Cp	2	0	0.7	0
N. Coast	169	356	Sc, Cp	4	2	1.2	0.6
Voi	149	429	Cp	1	15	0.2	3.5
Taveta	66	75	Cp	0	4	0	5.3
Kibwezi	88	418	Cp	0	7	0	7.0
Muranga	38	107	Cp	0	5	0	4.5
Nakuru	107	307	Bf	1	0	0.3	0
Kericho	23	19	Bf	0	0	0	0
Kisumu	64	146	Cp	0	2	0	1.5
Vihiga	12	22	Bf	1	0	4.5	0
Kakamega	4	1	-	0	0	0	0
Webuye	11	8	Bf	1	0	12.5	0
Bungoma	38	3	-	0	0	0	0

Sc=*Sesamia calamistis*, Cp=*Chilo partellus*, Cs=*Cotesia sesamiae*, Cf=*Cotesia flavipes*, Bf=*Busseola fusca* characterise biotypes. Biotypes have serious implications for pest management and biological control, as failure to recognise distinct populations can have costly consequences. For example, ICIPE is currently supplying IITA in Benin with *Co. sesamiae* from Kenya for trials against *B. fusca* and other stemborers in West Africa; if the wrong biotype is sent, then the work in Benin would fail.

5.1 SURVEY OF *COTESIA* SPP. PARASITOIDS IN THE COASTAL AREA OF KENYA

The aim of our work was to identify different biotypes of *Co. sesamiae* in Kenya, study the distribution of *Wolbachia* infection among *Co. sesamiae* populations in East and Southern Africa, and the role of *Wolbachia* in the mating compatibility of some populations of *Co. sesamiae*. To understand and quantify the diversity of *Co. sesamiae* in Kenya, field collections from different areas in Kenya were initiated in 1998 to examine the diversity of populations, their host ranges and their abilities to interbreed. A follow-up survey was carried out during the growing seasons (from 30 October to 12 June 1999). Two surveys were carried out:

(1) Concentrated on the North and South Coast of Kenya. Locations sampled are indicated in Table 5.1a. These sites were specifically selected in areas where previous work has shown that *Co. sesamiae* was more common than *Co. flavipes*.

(2) An extensive sampling was conducted in areas extending from the coast to western Kenya along the main highway. Areas sampled are indicated (see Table 5.1b). Stemborer population densities, as well as the percentage parasitism, were recorded.

In the first survey, 9 sites were sampled in the southern coastal area (south of Mombasa). The percentage parasitism ranged from 0.7 to 2.7 and 2.5 to 19 % for *Co. sesamiae* and *Co. flavipes*, respectively. In the northern coastal area (between Mombasa and Malindi), 6 sites were sampled and parasitism ranged from 2.2 to 11.1% for *Co. sesamiae*, and *Co. flavipes* was not found (Table 5.1a). In the second survey, parasitism at the coast ranged from 0.2 to 12.5% and 0.6 to 12.5% of *Co. sesamiae* and *Co. flavipes*, respectively. *Cotesia sesamiae* was also recovered from Nakuru and Voi and Vihiga and Webuye in western Kenya. In Muranga, 4.5 % parasitism by *Co. flavipes* was observed, indicating that *Co. flavipes* has spread to Central Province and is becoming an important species (Table 5.1b).

5.2 SUITABILITY OF FOUR MAJOR STEMBORER SPECIES FOR THE DEVELOPMENT OF FOUR GEOGRAPHIC POPULATIONS OF *CO. SESAMIAE* FOUND IN KENYA

The performance of populations of *Co. sesamiae* from Kitale, Kuja, Machakos, North Coast and South Coast was evaluated in the laboratory on *S. calamistis*, *B. fusca*, *Ch. partellus* and *Ch. orichalcociliellus*. *Chilo orichalcociliellus* was, however, not available for the test with the parasitoid population from Kuja. Results showed that *Ch. partellus* and *S. calamistis* were suitable for the development of all the five parasitoid populations (Tables 5.2a and 5.2b). However, *B. fusca* was not a suitable host for the populations from Machakos or Mombasa. The data from Machakos were quite interesting, as they suggested that the separation line between populations that developed in *B. fusca* and those that did not, might be further west.

Table 5.2a . Mean progeny (Mean ± SE) for five different populations of *Cotesia sesamiae* for different stemborer species

	Location of *Co. sesamiae*				
Host	Kitale	Kuja	Machakos	North Coast	South Coast
B. fusca	36.1 ± 3.0	39.2 ± 3.6	0	0	0
S. calamistis	32.1 ± 2.4	29.6 ± 2.9	31.4 ± 2.0	33.3 ± 2.7	48.7 ± 3.2
Ch. partellus	13.7 ± 1.7	16.2 ± 1.6	21.2 ± 2.5	15.5 ± 1.9	15.6 ± 2.5
Ch. orichalcociliellus	11.9 ± 1.7	NA	13.9 ± 2.0	14.3 ± 2.5	11.8 ± 0.4

Table 5.2b. Percentage parasitism (Mean ± SE) of five different populations of *Cotesia sesamiae* for different stemborer species

	Location of *Co. sesamiae*				
Host	Kitale	Kuja	Machakos	North Coast	South Coast
B. fusca	66.2 ± 0.1	86.7 ± 0.1	0	0	0
S. calamistis	75.1 ± 0.1	80.0 ± 0.1	66.7 ± 0.1	82.6 ± 0.1	77.3 ± 0.1
Ch. partellus	67.1 ± 0.1	83.5 ± 0.1	80.0 ± 0.1	77.3 ± 0.1	50.6 ± 0.1
Ch. orichalcociliellus	61.9 ± 0.1	NA	84.4 ± 0.1	66.7 ± 0.1	44.0 ± 0.1

Table 5.3. Distribution of *Wolbachia* infection among *Cotesia sesamiae* populations in some eastern and southern African countries

Countries (# samples tested)	*Wolbachia* (present or absent)	Host species of collected wasps
Western Kenya		
Kitale (6)	—	*B. fusca*
Kuja (6)	—	*Ch. partellus, S. calamistis*
Eastern Kenya		
Machakos (5)	++	*Ch. partellus, S. calamistis*
Mombasa (7)	++	*Ch. partellus*
Uganda		
Mbale (1)	—	*Ch. partellus*
Masindi (1)	—	*B. fusca*
Mpigi (2)	—	*B. fusca*
Masaka (3)	—	*B. fusca*
Iganga (3)	—	*B. fusca*
Eastern Zambia		
Chipata (1)	++	*B. fusca*
Katete (1)	++	*B. fusca*
Zimbabwe		
Chisumbamje (7)	++	*Ch. partellus*
Henderson (8)	++	*B. fusca*
Mozambique		
Mafuiana (7)	++	*Ch. partellus*

Note: (—) indicates absence of *Wolbachia* infection; (++) indicates presence of the infection.

5.3 DISTRIBUTION OF *WOLBACHIA* INFECTION AMONG *CO. SESAMIAE* POPULATION IN EASTERN AND SOUTHERN AFRICA

The presence of *Wolbachia* infections in *Co. sesamiae* populations collected from Zambia, Zimbabwe, Mozambique, Uganda, and Kenya was tested using a PCR technique. DNA was extracted from 5 individuals of each population. In Kenya, the populations from Mombasa and Machakos were positive for infection with *Wolbachia* and served as a positive control for subsequent tests. All PCR reactions using the FTSZ Holden primers and the primer combinations A and B were positive. None of the *Wolbachia*-specific primers produced any product for the populations from Kuja and Kitale areas (Table 5.3). The parasitoids from Mombasa were doubly infected with both *Wolbachia* groups A and B.

Cotesia sesamiae samples obtained from field surveys conducted in Uganda showed no infection. Samples from Zambia, Zimbabwe and Mozambique were infected. More samples are being collected in these countries for confirmation of these observations. Samples from other East African countries, including Malawi, Ethiopia and Zanzibar will be tested in 2000. Surveys of different populations of *Co. sesamiae* will continue in the next rainy season and samples collected will also be screened for infection.

6. STUDY OF THE SUITABILITY OF A NON-TARGET HOST, *SPODOPTERA EXEMPTA*, FOR THE DEVELOPMENT OF *COTESIA FLAVIPES* IN KENYA

In tropical agriculture, due to the high cost and adverse effects of pesticides on human health and the environment, the use of alternative control measures has been advocated. Biological control is one of them. Biological control is a method for managing and restoring ecosystems affected by particular, undesired pest species. How the introduction of biological control agents affects ecosystems is critical to understanding and predicting their value and risk. At present, little is known about the ecological processes underlying the effects of introducing biological control. Very little is known about the potential impact of the introduced wasp, *Co. flavipes*, on other insects already present in the environment.

This study aims at generating information on the potential ecological impacts of the introduction of *Co. flavipes* in Kenya on non-target Lepidoptera. The first insect used in the study was *Spodoptera exempta* collected during an armyworm outbreak in Nairobi in May 1999. Collected larvae were fed on young maize leaves. A total number of 120 3rd to 4th instar larvae of *S. exempta* were offered to *Co. flavipes* in the laboratory assay. Wasps were allowed to sting once and the stung larvae were reared on maize leaves until pupation. No parasitoids emerged from the larvae, 27 died and the rest pupated normally. Dissection of larvae 48 hours after parasitisation showed that all parasitoid eggs were encapsulated in this host, suggesting that *S. exempta* is not a suitable host for *Co. flavipes* development.

The suitability of *Galleria mellonella* for the development of *Co. flavipes* is currently under study. It is important to note that suitability alone should not be interpreted as an indication that a natural enemy will attack non-target hosts in nature, as there are other processes, such as host searching and acceptance, which are equally important. However, examining host suitability is a first step towards understanding the potential risks for interactions between introduced agents and non-target species.

7. DISTRIBUTION AND MORTALITY OF *CHILO* SPP. EGGS IN MAIZE AND SORGHUM AT THE KENYA COAST

Abundance, distribution and mortality of stemborer eggs were studied in Mtwapa and Kilifi, on the Kenya coast, during four consecutive growing seasons. Infestation started in an early crop stage, and one to three oviposition peaks could be found in most fields. Infestation levels varied between 0 and 10% over the season, with peaks of 28% of plants infested. If plants were infested in, 85–100% of cases only one egg batch per plant was found. Infestation was higher on sorghum than maize during all seasons, except for the first 2–4 weeks after plant emergence. Average egg batch sizes varied between 16 and 26 eggs, depending on the season. The distribution of egg batches was found to be random, uniform or aggregated, depending on location and season. Egg mortality ranged between 18 and 78%, with parasitism being the most important mortality factor. Disappearance, predation and non-hatching were relatively unimportant, each accounting for less than 12% mortality.

8. DISTRIBUTION OF STEMBORERS AND ASSOCIATED PARASITOIDS THAT INFEST WILD GRASSES

This study was initiated in July 1997 and continued to the end of April 1998 in two farms in each of the six agroecological zones (AEZs) in semi-arid eastern Kenya. The objectives were to determine the stemborer species and parasitoids found in potential alternate wild hosts of stemborers in each of the six AEZs, and to examine the temporal dynamics of stemborers and their parasitoids in wild grasses. Preliminary analyses of the data indicate that the most common wild host grasses of stemborers were *Sorghum versicolor*, *Pennisetum purpureum*, *Pennisetum trachyphillum* and *Panicum maximum*. *Sorghum versicolor* was the most heavily infested grass in lower-midland zone 5 and *Ch. partellus* was the dominant stemborer. *Pennisetum trachyphillum* was the most heavily infested grass in the other AEZs, and again, *Ch. partellus* was the predominant stemborer. The parasitoids recovered from *Ch. partellus* larvae were *Co. flavipes* and *Cotesia* sp. The hyperparasitoid *Aphanogmus fijiensis* was recovered from *Cotesia* sp. cocoons.

9. FARMERS' PERCEPTIONS OF THE IMPORTANCE, CONTROL METHODS AND NATURAL ENEMIES OF MAIZE STEMBORERS AT THE KENYA COAST

This study was conducted in 1997 in 12 villages in Kwale and Kilifi Districts, Coast Province of Kenya. The data were analysed in early 1998, and did therefore not appear in earlier progress reports. Insects were generally considered to be the main constraint to maize production. Nearly all of the 240 respondents mentioned stemborers to be the most important group of insect pests. Stemborer larvae and pupae were known by more than 75% of farmers, while adults and eggs were less frequently recognised. Knowledge of the stemborers' life cycle was limited.

Alternative grass hosts for stemborers were common near maize fields, and were often not destroyed until after the first rains. These grasses may serve as a reservoir for stemborers during the dry season, but may also serve as a reservoir for natural enemies or act as a trap crop for stemborers. Another source of infestation may be the dry stems and stubble that were left in the field after harvest by nearly all farmers.

Farmers knew many methods to control stemborers, but only 32 and 56% of farmers in Kilifi and Kwale Districts, respectively, used any of these methods. Chemical control was the most popular control method, and was regularly applied by 19 and 38% of farmers in Kilifi and Kwale Districts, respectively. Traditional methods and cultural control methods were seldom used. Approximately 50% of farmers had heard of beneficial insects, and farmers collectively mentioned 17 predators of stemborers, including ants, spiders, termites, praying mantids and grasshoppers.

Cocoons of *Cotesia* spp. had been seen by 33% of respondents, but none of the respondents knew what they were. The results of the present study stresses the need for training extension workers and farmers in basic knowledge of stemborers and their natural enemies. Also, after effective control methods suitable for smallscale farmers have been identified, both groups should be trained in pest management methods, possibly through the Farmers' Field School approach.

10. IMPACT OF PREDATORS ON *CHILO PARTELLUS* EGGS

The impact of predators on *Ch. partellus* eggs was studied at Muhaka Field Station at the beginning of the long rains (May 1998), and again during the short rains. Maize plants (2–4 weeks old) with one or more egg batches were placed in single plant cages. In the closed cage treatment, insect glue was applied around the egg batch to prevent predators from reaching it, and the net of the cage was buried in the soil. In the open cages, the net was lifted 20 cm off the ground to allow predators access to the cage. Egg batches remained in the field for 4 days, after which the fate of each egg in the batch was determined.

Results indicated that 30% of the eggs disappeared in open cages, compared to 0% in closed cages. Egg batches were found to disappear completely rather than partly, and no traces of the chorion remained after disappearance. Non-hatching was not an important mortality factor (about 2–6% in both treatments) and parasitism was not observed. In the short rains experiments, however, 19% of eggs disappeared and 1% exhibited visible signs of predation. This was significantly higher than the 0.2% disappearance and 0% visible predation found in closed cages (*t*-test, $P<0.0001$). Non-hatching was a relatively important mortality factor (19–32%), possibly because some moths had not mated before they were released in oviposition cages. Parasitism by *Trichogramma* spp. averaged 3% in closed cages and 17% in open cages.

11. IMPACT OF PREDATORS ON *CHILO PARTELLUS* PUPAE

Seventy uninfested plants were selected in a maize field at ICIPE's Muhaka Field Station at the coast. In each plant, three small holes were made in the stem with a cork borer. One pupa was placed in each hole. Sticky insect glue was applied at the base of the stem of 30 plants to prevent crawling predators (e.g. ants) from entering the plant. Plants were collected after 4 days, and the number of pupae and development were recorded. In the unprotected plants, 28% of pupae had disappeared and 3% were visibly preyed upon. This was considerably more than in protected plants, where only 10% of pupae had disappeared and predation was not observed. Disappearance in protected plants may have been caused by large flying predators (e.g. some wasp species, crickets), or pupae may have fallen out of holes by pupal or plant movements.

12. INVESTIGATIONS ON *DIAPERASTICUS ERYTHROCEPHALA*, A PREDATOR OF MAIZE STEMBORERS

The earwig *D. erythrocephala* is one of the most common and widespread predators in maize fields at the Kenya coast. The earwig readily preys on *Ch. partellus* eggs and young larvae in Petri dishes, but also feeds on aphids and planthoppers. Previous studies have shown that all prey types occur concurrently in maize fields. To improve our understanding of predator-prey relationships, prey preference and the functional response of *D. erythrocephala* were studied on 4-week-old maize plants in the laboratory.

12.1 PREY PREFERENCE OF *DIAPERASTICUS ERYTHROCEPHALA*

Significantly more aphids and/or 1st instar *Ch. partellus* larvae disappeared from plants with earwigs than from plants without earwigs (control plants) (Table 12.1). This indicates a positive relationship between stemborer disappearance and the presence of earwigs. When both aphids and *Ch. partellus* larvae were offered concurrently, significantly more aphids than larvae disappeared from the plants (*t*-test, $P<0.01$). This suggests that earwigs may prefer aphids to young *Chilo* larvae. However, the higher disappearance of aphids on control plants also suggests that prey preference may not be the only mechanism involved. It is possible that the exposed location and higher mobility of aphids causes them to fall off the plant, thus increasing disappearance.

Comparing disappearance on choice plants to disappearance on single-prey plants showed that 59% of aphids disappeared on choice plants (plant with aphids and *Ch. partellus* larvae), compared to 43% on single-prey plants. However, disappearance of larvae was significantly higher on single-prey plants (27 %) than on choice plants (19%), when earwigs were present. There were no differences between choice plants and single-prey plants when predators were absent (Table 12.1).

Table 12.1. The mean proportion (SD) of aphids and 1st instar *Chilo partellus* larvae which disappeared from plants with *Diaperasticus erythrocephala* and on control plants at different infestation densities

	Infestation density		
	100 A: 0 L1	50 A: 50 L1	0 A: 100 L1
Plants with earwigs			
N	26	29	31
Aphids	0.43 (0.15) a+	0.59 (0.19) b ▲ ++	-
L1	-	0.19 (0.14) a X	0.27 (0.15)
b			
Control plants			
N	11	11	10
Aphids	0.27 (0.13) a	0.35 (0.21) a ▲	-
L1	-	0.10 (0.10) a X	0.15 (0.14)
a			

+Different letters indicate significant differences in a row (*t*-test, $P<0.05$).
++Different symbols in a column indicate significant differences in disappearance of aphids (A) and first instar larvae (L1), on plants with earwigs or on control plants (*t*-test, $P<0.005$).

12.2 FUNCTIONAL RESPONSE OF *DIAPERASTICUS ERYTHROCEPHALA* FEEDING ON *CHILO PARTELLUS* EGGS AND YOUNG LARVAE

Diaperasticus erythrocephala adults were released individually on plants with 1 to 16 *Ch. partellus* egg batches. Egg batches were seldom attacked; only 2 of

Table 14. Survival of *Diaperasticus erythrocephala* fed on *Chilo partellus* larvae which were reared on a diet containing neem seed powder

	Neem concentration in diet							
	Experiment 1				Experiment 2			
	0 ppm		25 ppm		0 ppm		75 ppm	
Time	N	mean (SD)	N	mean (SD)	N	mean (SD)	N	mean (SD)
Prey consumed								
Day 1	42	35.9 (7.2) a	39	35.7 (6.1) a	38	34.6 (7.8) a	40	34.1 (6.8) a
Day 2	42	32.9 (9.0) a	39	32.7 (7.4) a	38	33.1 (7.6) a	40	30.5 (8.4) a
Day 3	42	33.1 (9.4) a	39	32.8 (7.1) a	38	33.8 (6.3) a	40	32.8 (5.8) a
Survival								
Day 3	42	24.1 (13.0) a	38	28.1 (11.9) a	29	26.8 (14.8) a	37	23.3 (11.7) a

Values in rows within the same experiment followed by the same letter are not significantly different (*t*-test, $P<0.05$).

the 114 offered batches disappeared and none of the batches was visibly preyed upon. Functional response effects could not be observed because of the low predation rate.

First instar larvae of *Ch. partellus* were offered to individual earwigs at densities of 10, 25, 50 or 100 larvae per plant. At initial densities of 25, 50 and 100 larvae, significantly more larvae disappeared from plants with earwigs than from control plants (*t*-test, $P<0.05$). Depending on the initial density, 5 to 15% of larvae disappeared from control plants compared to 22 to 30% of larvae disappearing from plants with earwigs. There was no difference in numbers disappearing between initial densities (Student Newman Keuls-test, $P<0.05$), suggesting there was no increase in predation as density increased.

13. EFFECT OF WEEDING ON STEMBORERS AND NATURAL ENEMIES

During the long rains of 1998, two weeding regimes (clean weeding and strip weeding) were compared at ICIPE's Shimba Hills site, Coast Province. The number of stemborers did not vary between clean-weeded plots (Farmers' Practice, FP) and plots in which a strip of 30 cm between maize rows was left unweeded (SW) on any of the sampling dates (*t*-test, $P<0.05$). Ants were the most abundant predators, with earwigs, spiders, coccinellids, cockroaches, chrysopids, praying mantids, staphylinids and crickets occasionally found. Predator numbers did not differ significantly between treatments, except for ants on the fifth sampling date and crickets on the last sampling date. On these dates, ants were more abundant in the SW plots ($P<0.05$), while crickets were more abundant in FP plots ($P<0.01$). Weed coverage in the experiment was low. During the first 5 weeks after plant emergence, weed coverage was close to 0%, while in the following weeks it reached a maximum of 23%. Differences in weed coverage between treatments were not significant, except immediately after the second weeding.

14. IMPACT OF NEEM BIOPESTICIDES ON PREDATORS

Diaperasticus erythrocephala were fed on 4-day-old *Ch. partellus* larvae reared on a diet containing 0, 25 or 75 ppm neem seed powder. Predation rate and predator survival did not differ significantly between 0, 25 ppm and 75 ppm treatments (*t*-test, $P<0.05$) (Table 14). Thus, consumption of young larvae raised on neem seed powder does not appear to have negative effects on predation capacity and survival of the earwig, *D. erythrocephala*.

15. RELATIONSHIPS AMONG STEMBORER DAMAGE, PLANT GROWTH PARAMETERS AND THEIR INFLUENCE ON GRAIN YIELD IN MAIZE

This study was repeated for a second season in the long rains of 1998 at Katumani field station in the Eastern Province of Kenya. The objective was to determine the relationships between various stemborer damage and plant growth parameters and to assess their effect on grain yield in maize. Path analysis of results of the data showed that among the damage variables, tunnel length at the vegetative stage had the highest negative effect on grain weight. This means that earlier damage of maize by stemborers results in greater yield loss as compared to damage that occurs later in the plant growth.

Plant height at the maturity stage had the highest positive effect on grain weight related to the number of exit holes at the vegetative stage. This was followed by stem diameter at the reproductive stage, which had a direct and positive effect on grain weight and was associated negatively with tunnelling length at the vegetative stage.

16. COLLABORATIVE ACTIVITIES WITH NATIONAL PROGRAMMES IN EASTERN AND SOUTHERN AFRICA

The Project has continued to expand collaborative activities with national programmes in the region.

Agreements are already in place with Uganda, Mozambique, Malawi, Ethiopia, Zambia, Zimbabwe and Zanzibar. The most recent country to join the Project was Tanzania, with the signing of a collaborative agreement between ICIPE, the Tanzanian Government and GTZ Tanzania IPM Project in 1999. Country-wide surveys of cereal stemborers and their natural enemies will start during the long rainy season of the year 2000. Parasitoid releases in most countries continued in 1999, and post-release surveys were carried out in some countries.

16.1 MOZAMBIQUE

Stemborer surveys were carried out in Mozambique in the provinces of Maputo, Gaza, Inhambane, Manica, Nampula and Niassa. *Chilo partellus* was the predominant stemborer species in most districts, followed by *S. calamistis*. Surveys in the area where *Co. flavipes* was released in 1996 revealed that the parasitoid is established in Maputo Province, but densities were very low (Table 16.1). Additional parasitoid releases were made in Maputo and Gaza Provinces in 1999.

16.2 UGANDA

Surveys of cereal stemborers and their natural enemies were made in 1998 and 1999 in six districts, Iganga, Kumi, Masindi, Soroti, Mbale and Lira. In 1999, pre-release stemborer surveys and parasitoid releases were carried out mainly in Masindi District. Overall, *Ch. partellus* relative abundance was 96 and 69.4% in Buruli and Kibanda Counties of Masindi District, respectively. *Busseola fusca* accounted for 1.7 and 30.5% of stemborers in Buruli and Kibanda Counties, respectively (Table 16.2). Pre-release surveys also revealed that parasitism due to indigenous parasitoids ranged from 0 to 2.8% in the district.

The first releases of *Co. flavipes* were made in

Table 16.1. Parasitism of stemborer larvae by *Cotesia flavipes* and *Cotesia sesamiae* in farmers' fields in southern Mozambique near one of the 1996 release sites

Field	Longitude	Latitude	Distance (km) and direction to release site	No. Cp	No. Sc	Percent parasitism Cp/Cs	Cp/Cf	Sc/Cs
1	25°47.510′	32°36.545′	14.0 SE	131	0	21.4	0.8	-
2	25°47.280′	32°36.657′	13.5 SE	156	0	17.3	1.3	-
3	25°46.376′	32°36.501′	12.2 S	164	0	9.8	0.0	-
4	25°47.135′	32°37.089′	10.7 SW	139	4	28.0	3.0	25.0
5	25°46.050′	32°37.939′	11.3 S	154	0	13.6	0.0	-
6	25°42.670′	32°39.604′	3.6 S	65	0	13.8	0.0	-
7	25°42.000′	32°39.000′	3.2 SW	51	0	33.3	0.0	-
8	25°41.642′	32°39.636′	2.0 SW	56	0	41.0	0.0	-
9	25°40.817′	32°40.397′	0.0 C	77	2	22.0	0.0	0.0
10	25°41.107′	32°39.899′	1.0 W	163	0	25.8	0.6	-
11	25°40.800′	32°40.047′	0.2 W	92	2	26.0	1.1	0.0
12	25°39.490′	32°40.311′	2.5 NW	117	0	41.0	0.0	-
13	25°38.804′	32°40.427′	3.7 NW	79	3	27.8	0.0	33.3
14	25°38.655′	32°40.957′	4.2 N	152	4	15.1	0.0	50.0
15	25°38.708′	32°40.830′	4.0 NW	97	3	20.6	0.0	0.0
16	25°42.709′	32°40.599′	3.9 NW	46	2	32.6	0.0	50.0
17	25°37.470′	32°40.661′	6.2 NW	53	0	22.6	1.9	-
18	25°36.984′	32°40.388′	7.1 N	139	0	8.6	0.0	-
19	25°36.583′	32°41.388′	8.0 N	41	0	39.0	2.4	-
20	25°36.595′	32°41.903′	8.2 N	137	3	16.0	2.2	33.3
Total				2109	24	21.5	0.7	25.5

Cp = *Chilo partellus*, Cs = *Cotesia sesamiae*, Sc = *Sesamia calamistis*, Cf = *Cotesia flavipes*.

Table 16.2. Relative abundance of different stemborer species in Masindi District of Uganda

County	Species: *Ch. partellus*	*B. fusca*	*E. saccharina*	*S. calamistis*
Buruli	167 (96)*	3 (1.7)	3 (1.7)	1 (0.6)
Kibanda	755 (69.4)	332 (30.5)	0 (0)	1 (0.09)
Overall	922 (73.1)	335 (26.5)	3 (0.23)	2 (0.16)

*Percentage of stemborer species

December 1997 during the short rainy season and continued during the long rains in June and July 1998. The releases were carried out by collaborators in the National Agricultural Research Organisation (NARO) and Makerere University. *Cotesia flavipes* was released in four districts: Iganga, Kumi, Mbale and Soroti. During the long rains, releases of *Co. flavipes* were carried out in three sites in Iganga, Soroti and Kumi and in two sites in Mbale. Four releases were made in about 2-week intervals for each location and the number of wasps released in each site varied from 600 to 1500.

Levels of parasitism recorded in the four districts during June and July surveys were 15% in Iganga, 25% in Kumi, 11% in Soroti and 40% in Mbale. These parasitism levels were mainly recorded on *Ch. partellus* and were likely due to *Co. flavipes*. Confirmation of parasitoid identifications has not yet been done. The results strongly suggest that *Co. flavipes* released in December has colonised the release sites.

16.3 ZAMBIA

Following completion of pre-release surveys in eight provinces, the first release of *Co. flavipes* was made in the country in April 1999. *Cotesia flavipes* (30,000 individuals) were released in two fields of maize and sorghum at Buleya Malima Irrigation Scheme at Sinasese in Sinazongwe District, about 300 km south of Lusaka. This was followed by releases at Luangwa in Lusaka Province and Sesheke in Western Province. The parasitoid release programme will continue during the 1999–2000 long rains season and post-release surveys will commence to determine establishment from the 1999 releases.

16.4 MALAWI

Pre-release stemborer surveys were started in Malawi in the second half of 1998. Districts in the south have been well covered and the surveys were extended to the central and northern part of the country during the main growing season. *Chilo partellus* was the dominant stemborer of maize in most districts. *Busseola fusca* was dominant in Kasungu, Lilongwe, Dedza and Ntcheu. Initial parasitoid releases were carried out during the main growing season in the districts of Mulanje, Chikwawa and Balaka (Figure 16.4). Additional releases were made in these districts during winter. Release efforts will be targeted at those districts in central and northern Malawi where *Ch. partellus* is the dominant stemborer species. Monitoring activities for determining establishment and spread will start next season.

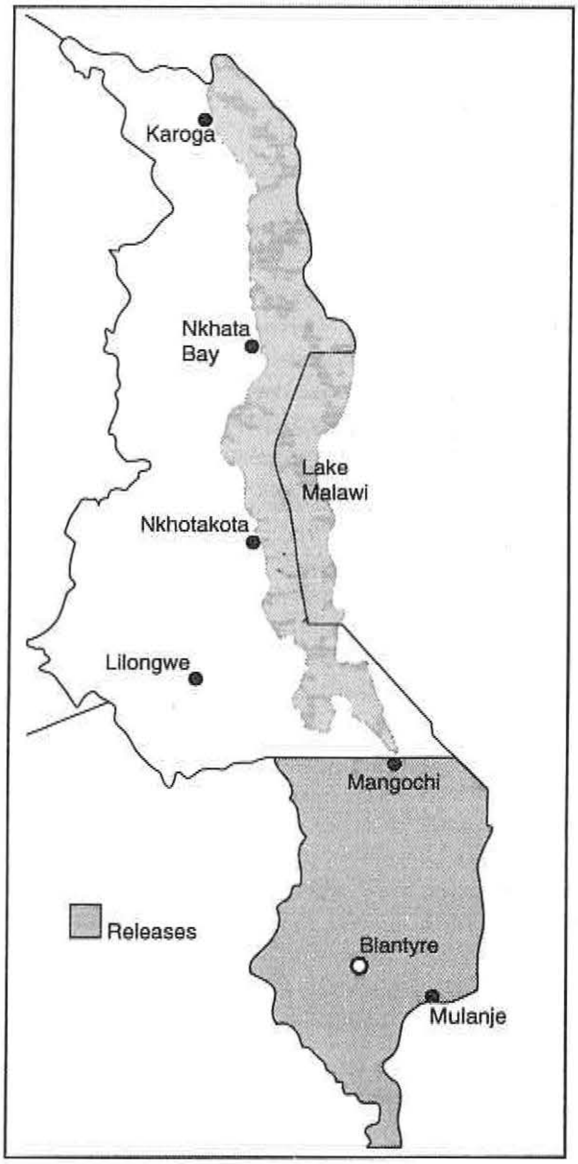

Figure 16.4. Map of Malawi showing region (shaded) where parasitoid releases were carried out in 1999

16.5 ETHIOPIA

A PhD scholar from Ethiopia started work with the Project in 1998. The focus of the PhD research is to predict locations in Ethiopia where *Co. flavipes* has a high potential for establishment. A country-wide survey conducted by the student in 1999 revealed that *Ch. partellus* was widespread, and found as high as 1900 m, which may be an elevation record for this stemborer in Africa. More surprisingly, *Co. flavipes* was found at several locations where it had never been intentionally released in Ethiopia. We speculate that the parasitoid may have entered the country from Somalia, where it was released in 1997.

16.6 ZIMBABWE

The project recruited a PhD student to carry out studies on patterns of field parasitism of cereal stemborers and carryover mechanisms of parasitoids in unimodal rainfall regime. Project activities started in December 1998 and only a limited stemborer survey has been carried in the country. The data from Save Valley in the lowveld indicated that *Ch. partellus* was the predominant species. A one-time release of 50,000 individuals of *Co. flavipes* was made in the irrigated winter maize in Musikavanhu Irrigation Scheme in Save Valley, eastern Zimbabwe. In 2000, country wide stemborer surveys will be carried out.

16.7 ZANZIBAR

A PhD student working under the supervision of ICIPE and Wageningen Agricultural University, and in close collaboration with the Zanzibar Plant Protection Department, made releases of *Co. flavipes* in July 1999 in Unguja and Pemba Islands. Three isolines of *Co. flavipes* collected from India were released, along with a high diversity mixed population, to assess the colonising ability of different parasitoid genotypes. During the season of release, only a few *Co. flavipes* were recovered. Additional sampling will be conducted during the short rains (November 1999–January 2000). If adequate numbers of the parasitoid are not recovered, additional releases will be made in 2000.

16.8 TANZANIA

A project agreement was signed between ICIPE, the Tanzania Government and the Tanzania GTZ-IPM Project, in December 1999. Country-wide stemborer surveys and possible parasitoid releases will commence during the long rains season of 2000.

Output

Publications

Kimani-Njogu S. W., Overholt W. A., Woolley J. B. and Omwega C. O. (1998) Electrophoretic and phylogenetic analysis of selected allopatric populations of the *Cotesia flavipes* complex. *Biochemical Systematics and Ecology* 26, 285–296.

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Takasu K. and Overholt W. A. (1998) Brood guarding behavior and life history characteristics of *Goniozus indicus* Ashmead (Hymenoptera: Bethylidae), a larval ectoparasitoid of lepidopteran stemborers. *Applied Entomology and Zoology* 33(1), 121–126.

Conferences attended

Bonhof M.J., Overholt W.A. and Lammers P.M. (1998) 6th European Congress of Entomology, Ceske Budejovice, Czech Republic, 23–29 August, 1998. Poster presented, 'Distribution and mortality of *Chilo* spp. (Lepidoptera: Pyraloidea) eggs in maize and sorghum in coastal Kenya'.

Bonhof M. J. (1998) Workshop on the Management of Cereal Stemborers in Africa, Nairobi, Kenya, 12–13 October, 1998. Paper presented, 'Associations between predators and stemborers'.

Ngi-Song A. J. (1998) 6th Regional Maize Conference for East and southern Africa, Addis Ababa, Ethiopia, 21–25 September, 1998. Poster presented, 'Diversity in *Cotesia sesamiae*, larval parasitoids of African stemborers'.

Ngi-Song A. J. (1998) Annual meeting of the Entomological Society of America, Las Vegas, Nevada, USA, 8–12 November, 1998. Poster presented, 'Diversity in *Cotesia sesamiae*, larval parasitoids of African stemborers'.

Ngi-Song A. J. (1998) Workshop on the Management of Cereal Stemborers in Africa, Nairobi, Kenya, 12–13 October 1998. Paper presented, 'Biodiversity of the indigenous stemborer parasitoid, *Cotesia sesamiae*'.

Ngi-Song A. J. (1999) Scientific Conference and Annual Meeting of the African Association of Insect Scientists. Ouagadougou, Burkina Faso, 19–23 July 1999. Paper presented, 'Effect of multiple parasitism by *Cotesia sesamiae* and *Cotesia flavipes* (Hymenoptera Braconidae) on *Busseola fusca* (Lepidoptera: Noctuidae)'.

Ngi-Song A. J. (1999) ARPPIS Scholars Association 2nd Symposium, Addis Ababa, Ethiopia, 6–9 Dec. 1999.

Ngi-Song A. J. (1999) African Women in Science and Engineering Conference; A vision for the 21st century, ICRAF, Nairobi, 29 November to 3 December 1999. Paper presented, 'Six years of classical biological control of a pest of graminaceous crops in Africa: Lesson learned'.

Omwega C. O. (1998) Workshop on the Management of Cereal Stemborers in Africa, Nairobi, Kenya, 12–13 October, 1998. Paper presented, 'Networking on biological control of stemborers'.

Overholt W. A. (1998) Crop Protection Society of Ethiopia Annual Conference, Addis Ababa, Ethiopia, 3–5 June, 1998. Paper presented, 'Progress on the biological control of cereal stemborers in East and southern Africa'.

Overholt W. A. (1998) 6th Regional Maize Conference for East and southern Africa, Addis Ababa, Ethiopia, 21–25 September, 1998. Paper presented, 'A review of the introduction and establishment of *Cotesia flavipes* (Hymenoptera: Braconidae) in East Africa for biological control of gramineous stemborers (Lepidoptera: Pyralidae, Noctuidae)'.

Overholt W. A. (1998) Workshop on Habitat Management Strategies for the Suppression of Stemborers and Striga in Maize-Based Cropping Systems, Addis Ababa, Ethiopia, 9 September, 1998. Paper presented, 'Overview of cereal stemborers in Africa'.

Overholt W. A. (1998) Workshop on the Management of Cereal Stemborers in Africa, Nairobi, Kenya, 12–13 October, 1998. Paper presented, 'Achievement and challenges in stemborer biological control'.

Sequeira G. (1998) Workshop on the Management of Cereal Stemborers in Africa, Nairobi, Kenya, 12–13 October, 1998. Paper presented 'African Stemborer Information System on the Internet'.

Songa J. (1998) Workshop on the Management of Cereal Stemborers in Africa, Nairobi, Kenya, 12–13 October 1998. Paper presented, 'Farmers' perceptions of constraints to maize production'.

Zhou G. (1998) Workshop on the Management of Cereal Stemborers in Africa, Nairobi, Kenya, 12–13 October, 1998. Paper presented, 'The role of GIS in biological control research'.

Proposals written

- 'Genetic variability in *Cotesia flavipes* (Cameron) and its signficance for population establishment in the biological control of lepidopteran stemborers'. Joint proposal by ICIPE and Wageningen Agricultural University, submitted to the Netherlands Foundation for Tropical Science (WOTRO). Funding (dfl 100,000) for a 4-year PhD programme was approved in 1998.
- 'Increasing the capacity of national programmes and non-governmental organisations in southern Africa to manage maize and sorghum stemborers using environmentally sustainable methods'. Joint proposal by ICIPE and the Agricultural Research Council of South Africa, submitted to USAID. Funding (US$ 200,000) for a 2-year project starting in 2000 was approved at the end of 1999.

Capacity building

Postgraduate training

The following students participated in the project in 1998/99:

Mohamed Sallam (Completed PhD at Kenyatta University, Kenya, in June 1998). Comparative evaluation of certain aspects of the biology of *Cotesia flavipes* and *Cotesia sesamiae* (Hymenoptera: Braconidae) for the management of *Chilo partellus* (Lepidoptera: Pyralidae) in Kenya.

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

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

Mochiah Brandford (PhD student, University of Cape Coast, Ghana. Research to be completed in 2001). Physiological and genetic diversity in the cereal stemborer parasitoid, *Cotesia sesamiae.*

Emana Getu Degaga (PhD student, Kenyatta University, Kenya. Research to be completed in 2001). Optimisation of parasitoid release strategy against cereal stemborers in Ethiopia.

Emmanuel Niyibigira (PhD student, Wageningen Agricultural University, the Netherlands. Research to be completed in 2002). Genetic variability in *Cotesia flavipes* (Cameron) and its significance for population establishment in the biological control of lepidopteran stemborers.

Domingos Cugala (MSc student, Edwardo Mondlane University, Mozambique. Research to be completed in 2000). Performance of *Cotesia flavipes* and *Cotesia sesamiae* as biological control of cereal stemborers in Mozambique.

Teddy Kauma (MSc student, Makerere University, Uganda. Research to be completed in 1999). Colonisation of *Cotesia flavipes* at selected sites in Uganda.

Esther Ngumbi (MSc student, Kenyatta University, Nairobi, Kenya. Research to be completed in 2000). An assessment of kairomones for use as monitoring tool for *Cotesia flavipes.*

Peter Chinwada (PhD student, Kenyatta Univrrsity, Nairobi, Kenya. Research to be completed in 2002) Variations in stemborer field parasitism patterns by

Sturmiopsis parasitica and *Cotesia sesamiae* and their mechanisms of seasonal carry-over in unimodal rainfall regions as typified by Zimbabwe.

Impact

The results of surveys in Kenya clearly indicate that the distribution of *Co. flavipes* is increasing and the population is growing. In the coastal area, average parasitism of > 9% over all sites is a dramatic increase over the levels of parasitism that were typically encountered prior to the introduction of the exotic parasitoid (< 3 %). From 1998, there is evidence of a decrease in population density of *Ch. partellus* in the coastal area of Kenya. Surveys also revealed high levels of parasitism in the Eastern Province, but not in western Kenya where two stemborers, *B. fusca* and *E. saccharina*, are not suitable for the development of *Co. flavipes*.

In Uganda, the high levels of parasitism of *Ch. partellus* by *Co. flavipes* are also very encouraging, particularly so soon after releases. The situation in Mozambique is unclear, and densities of the exotic parasitoid have remained low for 3 years after the release. The surprising finding that *Co. flavipes* had spread through much of Ethiopia was also encouraging. In other countries, it may be too soon to begin measuring the success of the project.

(See also reports on the Biosystematics Unit, on Neem and the previous Habitat Management Project report.)

Understanding Mechanisms of Maize Streak Virus Resistance of Maize Lines from Kenya, Eastern and Southern Africa: Vector Ecology Component

Background, approach and objectives

Annual maize yield losses to diseases are commonly in the range of 15 to 50%. In some years, epidemics of such Africa-specific diseases as Maize Streak Virus (MSV) can cause yield losses of 100%.

The genus *Cicadulina* has a worldwide distribution in tropical and subtropical grasses, but has the greatest impact in Africa. Yield loss is not caused by direct feeding, but by the ability of some *Cicadulina* spp. to transmit the Maize Streak Virus. The objective of the project is to gain some understanding of the mechanism of MSV resistance using maize germplasm from various sources. ICIPE is studying the biology of MSV and its leafhopper vectors, *Cicadulina* spp., 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*, W. A. Overholt, J. Baumgärtner, Z. R. Khan, M. O. Odindo*
*(*Project Coordinator)*

Donors: *Rockefeller Foundation and ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark)*

Collaborators: *• Kenya Agricultural Research Institute • John Innes Centre • University of Cape Town • International Service for the Acquisition of AgriBiotechnology Application (ISAAA)*

Work in progress

1. MAIZE STREAK VIRUS INCIDENCE AND ECONOMIC DAMAGE THRESHOLDS

The project requires yield loss/disease incidence information over several years in order to develop predictive models and build risk maps. Field surveys were undertaken in nine districts of Nyanza and Western Provinces in Kenya in the first cropping season of 1998. The methodology used combined field observations by the survey team and interviews of farmers. Data was collected on disease incidence and prevalence. Screenhouse and field experiments were undertaken to study the relationship of yield loss, crop phenology and the time of MSV infestation. Viliferous *Cicadulina* were allowed to feed on maize plants at different growth stages (viz., appearance of leaf 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 and control).

The survey indicated that MSV is prevalent (96%) in Kenya and appears to be increasing in intensity. A preliminary observation made on the effect of the maize cultivar on MSV incidence indicated that changes in cultivar could have exacerbated the problem. In a field survey, MSV incidence in the local variety was 43%, in H-511 77% and in Katumani 91%. The yield loss-crop phenology relationship at the time of MSV attack is sigmoidal. Maize plants attacked at the sixth leaf or earlier had significant reductions in leaf area, plant height and grain yield. On-farm crop losses due to MSV disease was very high and was estimated at 39–53 % in the 1998 first cropping season.

1.1 SOURCES OF MSV AND VECTOR MOVEMENT

It is doubtful that the progeny of *Cicadulina* breeding in maize are ever an important source of streak increase within the crop. However, it is believed that they are a most important source of spread of the disease to later-planted maize. This question is of paramount importance, as it impinges on control strategies and defines the role of long distance movement and local dispersal in disease epidemiology. A long-term experiment was established to determine the importance of the source of infestation and local movement in vector epidemiology. Maize H-511 was planted as either a monocrop or maize and cowpea intercrop in a single alternate row arrangement at ICIPE's Mbita Point Field Station (MPFS) at 3–4 week intervals. The first crop was planted in April 1997 and the 20th crop was completed in December 1998. MSV diseased plants were counted and the spatial distribution mapped out at 2-weekly intervals starting from the third week until tasselling. The study was complemented with aerial trapping of *Cicadulina* with yellow sticky traps deployed at MPFS.

Seasonal abundance and aerial densities of trapped *Cicadulina* indicated two annual peaks, July–August and November–December. Sticky trap catches of *Cicadulina* indicated that larger numbers of *Cicadulina* were caught at canopy levels 1–3 m. The catch was done at random and is not indicative of migrating leafhoppers. It was also concluded that MSV incidence in the field is a seasonal phenomenon. A highly significant positive relationship was found between field MSV incidence and *Cicadulina* in trap catches. In addition, a significant negative correlation was observed between field disease incidence and rainfall. The progeny of *Cicadulina* breeding in maize are therefore not an important source of spread of the disease to later planted maize.

These results and methodology help to explain MSV incidence in growing seasons. Maize streak virus outbreaks can be major, sporadic or occasional and vary every year. The relationship between trap catches, MSV incidence and rainfall could form the basis for a pest forecasting system. The objective of the pest forecasting system is to provide at the farm or regional level some forewarning of pest incidence to assist in making rational control decisions.

1.2 ROLE OF ALTERNATE HOSTS IN THE EPIDEMIOLOGY OF MSV

Field surveys were undertaken on wild hosts of *Cicadulina* in the Lake Victoria Basin. Assessments were made on host species and numbers of *Cicadulina* adults and nymphs. *Cicadulina* adults were found in 22 out of 26 alternate hosts that were examined. *Cenchrus ciliaris* L., *Setaria spacelata* var. *splendida*, *Echinochloa pyramidalis* (Lam.), *Setaria incrassata* (Hochst.) Hack. and *Phragmitis* sp., were classified as breeding hosts. The complete absence of both *Cicadulina* adults and nymphs on *Melinis minutiflora* and high attractiveness of *Setaria* spp. as breeding hosts, should be evaluated further for their possible use in a push-pull strategy for the management of MSV.

1.3 COMPARATIVE EFFICIENCY OF MSV TRANSMISSION BY *CICADULINA* SPP. FROM DIFFERENT AGROECOLOGIES

Efficiency of transmission of MSV by viruliferous *Cicadulina* spp. from different agroecologies was studied using standard acquisition testing procedures. Comparative transmission efficiency tests showed *C. chinai* had a transmission efficiency of 70% as the most efficient transmitter, followed by *C. mbila* (60%) and then *C. storeyi* (40%). The proportion of males (44.8%) to females (55.2%) with ability to transmit MSV disease was not significant (χ^2 20.34, $P>0.99$). Species from different ecological conditions differed in their transmission efficiency. *Cicadulina mbila* from Meru were the most efficient transmitters. Doubtless, most *Cicadulina* spp. are capable of transmitting Maize Streak diseases. The presence of large numbers of a particular species in a particular ecology increases the probability of transmission occurring and the importance of that species. The variation in transmission efficiency is being combined with varietal resistance, mature plant resistance and initial virus level to develop indices of vector efficiency to aid in resistance breeding.

1.4 MAINTENANCE OF *CICADULINA* CULTURES

In the ICIPE/KARI Project, rearing of leafhoppers was carried out at the MPFS. The objectives of the activity are to ensure the availability of different species for vector biology and maize streak virus infectivity studies. Sixteen colonies of *Cicadulina* are being maintained in the insectary (Table 1.4).

Table 1.4. *Cicadulina* spp. available at MPFS insectary

Leafhopper species	Locality collected	Host plant
Cicadulina chinai	Mbita Point	*Setaria* sp.
Cicadulina storeyi	Oyugis	Napier grass
	Mbita Point	*Phragmitis*
	Homa Bay	Sudan grass
	Mombasa	Maize
Cicadulina mbila	Mbita Point	Sudan grass
	Kitale	Maize
	Ndhiwa	
	Meru	

AGRICULTURAL RESEARCH

PLANT HEALTH MANAGEMENT

LOCUSTS AND MIGRATORY PESTS

Of over 1500 acridoids (grasshoppers and locusts) in Africa, about 200 are agricultural pests of varying importance. Of these, about 10 species are of prime concern to food security. They are characterised by a changing lifestyle, ranging between solitary (when population densities are low) and gregarious phases (when the insects occur in high densities). In the gregarious phase the insects are highly mobile, multiply rapidly and can pose a serious threat to agriculture. Between them, they affect virtually the whole of the continent and have threatened the region intermittently over the past centuries. Damaging populations occur each year somewhere in the continent, but major and lasting outbreaks (plagues) covering vast areas are episodic.

In addition to acridoids, one species of Lepidoptera, the African armyworm *(Spodoptera exempta* Walker) also shows a similar lifestyle. In its gregarious and migratory phase, this moth becomes a serious pest of gramineous crops in most eastern and central African countries.

The high material and environmental costs of controlling outbreaks of these pests in Africa have led to two kinds of responses during the last decade by the international and regional communities. The first is focused on the need to find alternative agents other than the environmentally harmful pesticides for controlling gregarious populations. Research by different groups has identified a number of effective biocontrol agents (biopesticides) and synthetic insect growth regulators which are environmentally more benign. However, they cost significantly more than the synthetic organophosphates in common use. In the case of biocontrol agents, the market is limited to the region of outbreak, and thus there is the problem of commercial viability and therefore of availability when needed. In any case, should these agents find widespread use, there will be concerns about their effects on non-target acridoids and other arthropods.

The second response involves attempts at analysing the cost-effectiveness of large-scale control operations during acridoid plagues or upsurges, and their actual impact on vegetation and on food production in affected areas. The outcome has been controversial. One view asserts that locusts and grasshoppers constitute only a very small proportion of the overall crop protection problem in Africa, even at their worst. Another view holds that acridoid outbreaks occur in some of the most famine-prone areas of the globe. The lack of reliable data, and the enormous scale of the affected area often hide the large local variations in damage and threat to food security among resource-poor farmers and herders — acridoids (and the armyworm) are capable of causing total crop or forage losses within hours at the local level— and intervention can prevent this.

An emerging consensus is that control of acridoids as it is currently practised is inefficient, expensive, and difficult to justify, both economically and environmentally. While intervention at times may help break the sequence of processes that eventually evolve into major outbreaks, the fundamental problem is that we simply do not know enough yet about the population and gregarisation-solitarisation dynamics of acridoids to allow us to make meaningful early assessments of probable outbreaks. Neither do we understand enough of the spatial and temporal factors which influence gregarisation in breeding habitats and the development of upsurges or plagues, nor the biotic and abiotic factors that underlie their demise.

What then should be our response to locusts and aggregating grasshoppers in Africa and the problems they periodically present us? First, it is clear that gregarisation-solitarisation dynamics is central to the biology, ecology and pest status of these insects. This we must understand fully for each target species. ICIPE's research has focused largely on the chemical ecology of the desert locust, *Schistocerca gregaria* (Forskål) with a twofold objective: (i) to identify the chemical signals (semiochemicals) that mediate and sustain the key behavioural and physiological attributes of gregarious locusts, and (ii) to elucidate the eco-physiological and behavioural bases of the genesis of aggregation in the solitarious locusts. Considerable progress has been made on both fronts. Perhaps the most exciting finding to date relates to cross-stage effects of aggregation signals (pheromones) of adults and nymphs. The adult signal inhibits the nymphs' perception of their own signal, and vice-versa. The potential of using such signals in very small amounts (pheromonal concentrations) in disrupting the gregarious phase of both stages and in effecting high levels of control has been demonstrated in the field during the last two years. These findings are laying down the groundwork for a radically new solution to the desert locust problem.

This work provides a model for other migratory insect pests. Projects are being planned to tackle the Madagascar migratory locust, *Locusta migratoria capito* (in collaboration with the Office National de L'Environment, Madagascar and LUBILOSA) and the red locust, *Nomadacris septemfasciata* (in collaboration with the International Red Locust Control Organisation for Central and Southern Africa (IRLCO-CSA), Zambia. We are also exploring the possiblity of ICIPE's working with institutions in central Asia, in particular Kazakhistan, to address the three important locust pests in that region.

Plant Health Division

LOCUSTS AND OTHER MIGRATORY PESTS

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

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 locusts and aggregating/ migratory insect pests. The goal of ICIPE's locust semiochemicals research has been twofold:

(i) to explore the use of the insect's own communication signals to manipulate the process of gregarisation for control purposes, and
(ii) to develop an understanding of gregarisation in order to assemble the components of a preventive intervention strategy.

The project initially started with behavioural and physiological studies relating to three important characteristics of gregarious locusts, i.e. cohesive behaviour, synchronous maturation and communal oviposition, and characterisation of their mediating pheromone systems (*see ICIPE Annual Reports: 1993, 1994*). One of the most interesting results of this phase of the study was the finding that different pheromone blends mediate the aggregation behaviour of nymphal and adult stages. Exposure of nymphs to the adult blend, or vice versa, resulted in a loss of aggregation behaviour. A specific component of the adult pheromone (phenylacetonitrile, PAN) inhibits the nymphs' perception of their own pheromone blend, and leads to the immediate arrestment of the marching behaviour of hopper bands (*1995–1997 ICIPE Annual Scientific Report*). Affected individuals become disoriented, hyperactive, feed less and gradually solitarise. The stressed insects become susceptible to enhanced predation and other mortality factors. In addition to the foregoing work, investigations on aspects of the behavioural ecology of solitarious insects and factors underlying their propensity to gregarise were initiated (*1995–1997 ICIPE Annual Scientific Report*).

During 1998–1999 period, the project undertook the following activities to:

- Document the combined effects of nymphs exposed to PAN and low doses of chemical insecticides and mycopesticides.
- Conduct field trials involving treatment of large hopper bands with PAN and *Metarhizium anisopliae* var. *acridum* (Green Muscle) developed by Lutte Biologique Contre les Locustes et les Sauteriaux (LUBILOSA).
- Organise a 3-day workshop to discuss ICIPE's results on the pheromone system of the desert locust and to set up a consortium of collaborators to plan multi-site field trials.
- Complete a 3-year survey of oviposition preferences of solitarious females and conduct cage-experiments in the field to compare oviposition preferences of solitaria and gregaria.
- Initiate studies to document the effects of nymphal pheromone blend (NPB) on gregarious adults.
- Undertake additional laboratory studies on factors involved in gregarisation including the primer and releaser effects of aggregation pheromones and their endocrine control.

Participating scientists: *M. O. Bashir, B. Torto, P. Njagi, A. Hassanali** *(*Project Coordinator)*

Postgraduate students: *A.G. Malual (PhD), T.A. El-Salam Fager (PhD), A. E. M. El-Sayed (MSc), I. M. El-Hanan (MSc), N. El-Tayeb Goreshi (MSc)*

Assistants: *H.H. Korina, I. H. Ismail, M.B. Gasmalla, M. M. S. Osman, A. R .W. Bashir, P. M. Njiru, H. C. Amiani*

Donors: *IFAD, ADB*

Collaborators: *• IITA/CABI (LUBILOSA) • Sudanese Department of Plant Protection*

Work in progress

1. USE OF ADULT PHEROMONE COMPONENT (PAN) WITH CHEMO- AND BIOPESTICIDES

1.1 PAN WITH ORGANOPHOSPHATES/ CARBAMATES

Nymphs pre-exposed to 0.01 and 0.05% dilutions of PAN suffered significantly higher mortality from a 15-fold dilution of propoxur than those pre-exposed

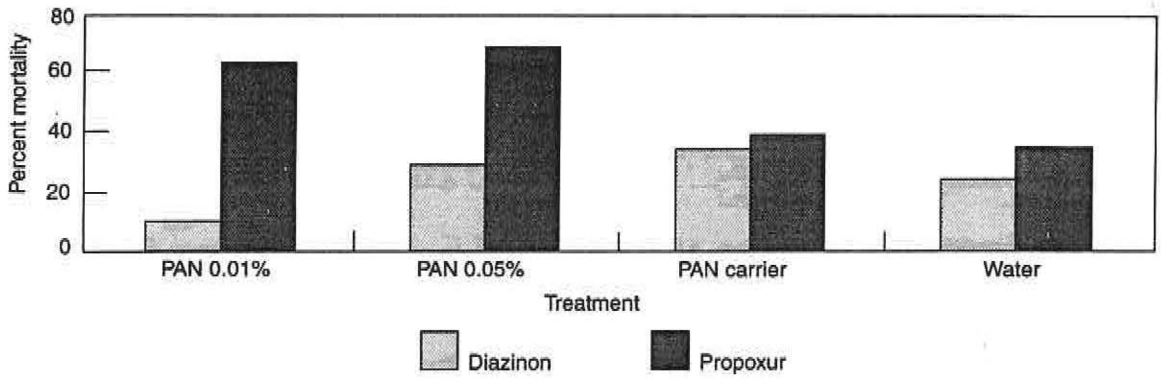

Figure 1.1a. Percent mortality of desert locust 5th instar nymphs exposed to PAN and then to 15-fold dilutions of diazinon or propoxur

to PAN carrier ingredients alone (Figure 1.1a). No significant differences between treatments were found when a 15-fold dilution of diazinon was used. Examination of the mortality rate when a 15-fold dilution of propoxur was used revealed that pre-exposure to the pheromone resulted in higher mortality (65–70%) and extended effect of the insecticide (up to 13 days). On the other hand, in the control treatments, mortality due to the insecticide reached a lower maximum (35–40%) by day 8 (Figure 1.1b). Comparable results were also obtained with

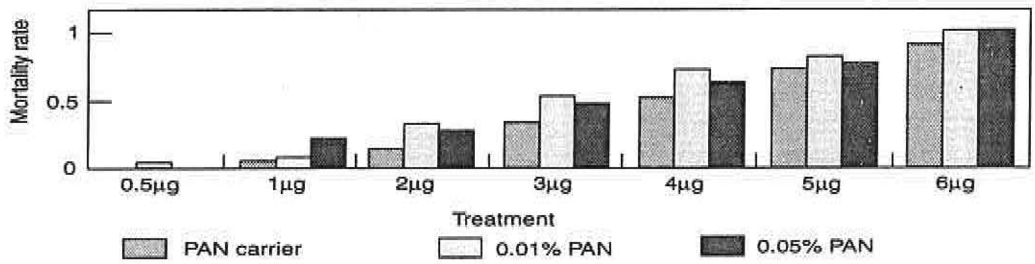

Figure 1.1b. Mortality rate of 5th instar nymphs of the desert locust pre-exposed to PAN, then to propoxur diluted 15 times

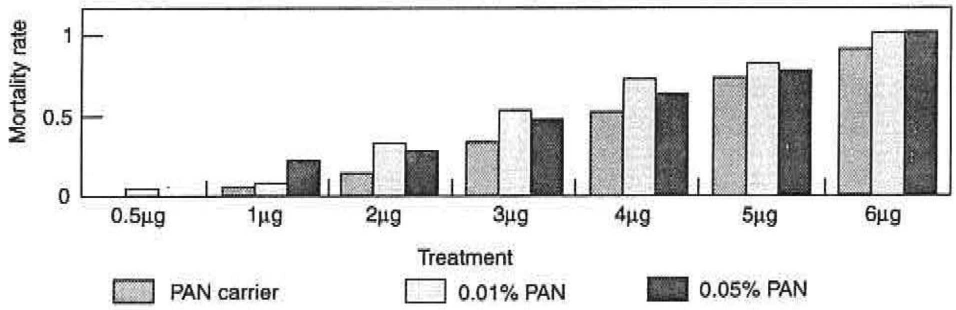

Figure 1.1c. Mortality rate after 96 hours of 4th instar nymphs of the desert locust exposed to PAN, then treated with different concentrations of malathion

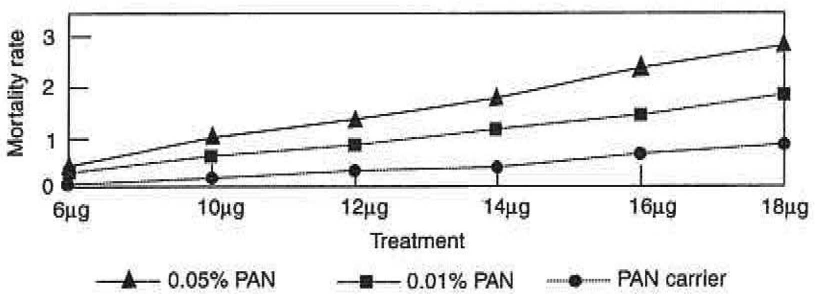

Figure 1.1d. Mortality rate after 96 hours of 4th instar nymphs of the desert locust exposed to PAN then treated with different concentrations of Seven

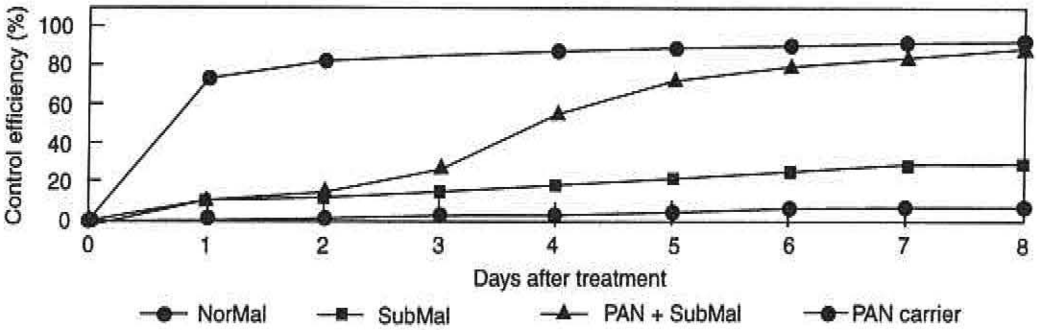

Figure 1.2. Control efficiency of treating desert locust bands with regular dose of malathion, sublethal dose (diluted 15 times) and sublethal dose combined with PAN (Henderson/Tilton)

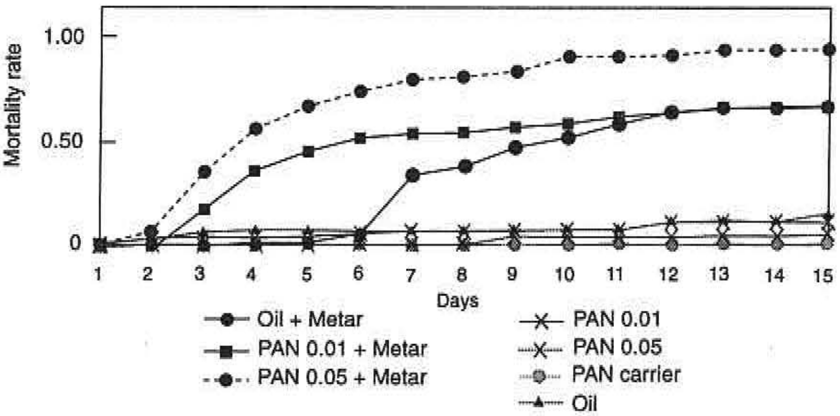

Figure 1.3a. Mortality rate of 4th instar nymphs of the desert locust treated with a low concentation of *Metarhizium anisopliae* ($2.7x10^3$) oil formulation and the adult pheromone component, PAN

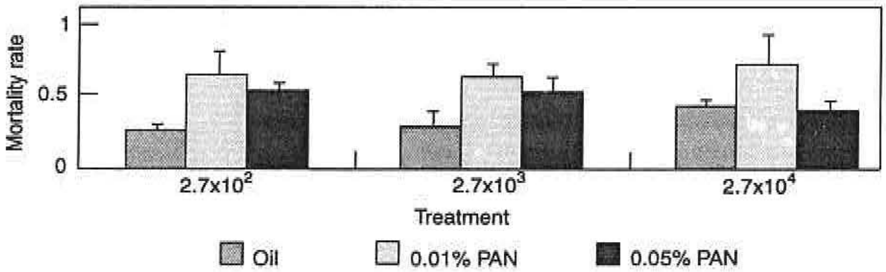

Figure 1.3b. Mortality rate after 15 days of 4th instar nymphs of the desert locust treated with different concentrations of *Metarhizium flavoride* oil formulation ($2.7x10^2$–$2.7x10^4$) and adult pheromone component, PAN

sub-lethal dosages of malathion and Seven (Figures 1.1c and 1.1d).

1.2 PAN WITH MALATHION ON HOPPER BANDS IN THE FIELD

The adult pheromone component (PAN) was tested under field conditions in collaboration with the Sudanese Ministry of Agriculture (Department of Plant Protection). The tests were conducted at five sites during the winter breeding season in 1998. Nymphal mortality from the usual dose of malathion was compared with those from a 15-fold dilution of malathion with and without PAN. Despite the low mortality, the final control efficiency of a 15-fold dilution of the insecticide was comparable to that obtained from the dose currently used to control hoppers (Figure 1.2.). The results indicate the high potential of PAN in enhancing the effect of sublethal dosages of a conventional pesticide in the control of desert locust hoppers.

1.3 PAN WITH MYCOPESTICIDES

Tests with the oil formulations of the mycopesticides *Metarhizium anisoplae* and *Metarhizium flavoviride* revealed enhanced efficacy at very low dosages when used in the presence of the adult pheromone component (Figures 1.3a and 1.3b). Experiments were performed with caged insects.

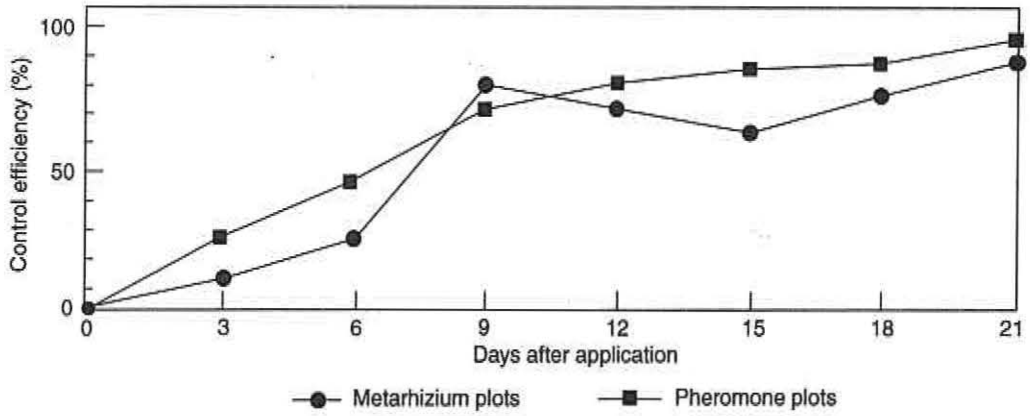

Figure 1.4. Control efficiency (Henderson/Tilton) of desert locust treated bands. Gobe site, Sudan

1.4 FIELD TESTS OF PAN WITH AND WITHOUT A MYCOPESTICIDE ON HOPPER BANDS

The trials were undertaken in collaboration with Lutte Biologique Contre les Locustes et les Sauteriaux (LUBILOSA) IITA/CABI, and the Sudanese Department of Plant Protection. They were conducted on large hopper bands (>100,000 insects) at two sites (Gobe and Hosheri/Ingaz) in the Sudan with 3 replicates (3 bands) for each treatment including untreated control. Data on density per bush and mortality counts were taken every 3 days; 40 samples were taken by 4 observers, each taking 10 samples. The normal dose of Green Muscle was used. In plots treated with the pheromone alone, the bands were arrested, gradually fragmented and dispersed over a wide area as individuals solitarised. A high rate of predation was evident. Sampling over the area gave levels of control (as measured by decline in numbers), comparable to plots treated with Green Muscle (e.g. Figure 1.4). In plots treated with both PAN and Green Muscle, the arrested nymphs milled in the plots, which appeared to enhance their exposure to sprayed spores. There was evidence of delivery of the inoculum by the dispersing individuals to untreated bands in the neighbourhood. However, this needs a more detailed quantitative assessment.

Unfortunately, no significant outbreak of gregarious desert locusts occurred in either winter or summer breeding seasons in any of the locust breeding areas in Africa and the Middle East throughout the rest of the 1998–1999 reporting period. Consequently, no additional trials were undertaken.

2. OVIPOSITION PREFERENCES OF SOLITARIA (AND GENESIS OF GREGARISATION)

Field surveys at five sites within desert locust breeding habitats around Port Sudan during three successive seasons indicated that, early in the rainy season, the incoming solitarious females oviposited predominantly in the vicinity of *Heliotropium* spp. (66%) and millet (32%) seedlings (Table 2a). Significantly, solitarious nymphs also preferred to feed on these plants (Table 2b). Follow-up cage experiments were conducted in the field in which solitarious and gregarious female locusts were presented with choices of selected desert plants and egg pods. When presented with bullrush millet, *Heliotropium* spp., *Zygophyllum simplex* and untreated moistened sand, solitarious females oviposited adjacent to the first two plants (40 and 60%, respectively) (Table 2c). However, when offered a choice of either or both of these plants together with

Table 2a. Percentage of desert locust egg pods (from predominantly solitarious population) observed in the vicinity of desert plants in 5 sites in Sudan (total for the 3 seasons 1995–1999)

Site	*Heliotropium*	Millet	*Z. simplex*	Others
1	68.2	22.7	0.0	9.1
2	55.6	44.4	0.0	0.0
3	72.2	27.8	0.0	0.0
4	69.0	31.0	0.0	0.0
5	66.7	33.3	0.0	0.0
Mean	66.3 a	31.9 b	0.0	1.8
SD	±6.4	±8.1	0.0	±4.1

Means followed by different letters are significantly different ($P<0.05$) N=50 plants/species or groups/site.

Table 2b. Percentage of *S. gregaria* solitarious nymphs found on different desert plants in 5 sites in Sudan (total for the 3 seasons 1995–1997)

Site	*Heliotropium*	Millet	*Z. simplex*	Others
1	53.1	28.1	6.3	12.5
2	68.2	22.7	0.0	9.1
3	58.8	23.5	2.9	14.7
4	58.8	27.1	5.9	8.2
5	60.3	29.3	4.4	6.9
Mean	59.9 a	26.2 b	3.7 d	10.3 c
SD	±5.4	±2.9	±2.5	±3.2

Means followed by different letters are significantly different ($P<0.05$) N=50 plants/species or groups/site.

Table 2c. Oviposition attempts and egg pods deposited by individual solitarious *S. gregaria* to 4-choice treatments involving different combinations of host plants, egg pods, eggs and egg froth in the field cage experiments

		Egg pods deposited			
		Attempts		Egg pods	
Exp.	Treatment	Mean ± SE	%	Mean ± SE	%
1	Control	0.07 ± 0.07 c	0.9	0.00 ± 0.00 c	0.00
	Heliotropium	5.93 ± 0.58 a	74.1	1.80 ± 0.17 a	75.00
	Millet	2.00 ± 0.31 b	25.0	0.60 ± 0.13 b	25.00
	Zygophyllum	0.00 ± 0.00 c	0.0	0.00 ± 0.00 c	0.00
2	Control	0.07 ± 0.07 c	0.9	0.00 ± 0.00 c	0.00
	Heliotropium	4.33 ± 0.30 b	25.0	0.80 ± 0.11 b	29.3
	Millet	1.80 ± 0.20 b	25.0	0.80 ± 0.11 b	29.3
	Sol pods	1.00 ± 024 c	13.9	0.20 ± 0.11 c	7.3
3	Control	0.33 ± 0.13 d	3.4	0.00 ± 0.00 c	0.00
	Heliotropium	2.60 ± 0.21 b	30.2	0.93 ± 0.15 b	30.4
	Millet	1.27 ± 0.21 c	14.7	0.33 ± 0.13 c	10.9
	Greg pods	4.40 ± 0.36 a	51.2	1.80 ± 0.14 a	58.7
4	*Heliotropium*	2.53 ± 0.29 b	32.5	0.80 ± 0.11 b	26.1
	Millet	0.87 ± 0.198c	11.1	0.40 ± 0.13 c	13.0
	Greg egg pods	3.80 ± 0.37 a	48.7	1.80 ± 0.17 a	58.7
	Sol pods	0.60 ± 0.24 c	7.7	0.07 ± 0.07 c	2.2
5	Control	0.67 ± 0.21 c	10.3	0.00 ± 0.00 c	0.0
	Heliotropium	1.73 ± 0.23 b	26.8	0.70 ± 0.15 b	30.6
	Greg egg pods	3.47 ± 0.34 a	53.6	1.53 ± 0.19 a	63.9
	Sol pods	0.60 ± 0.16 c	9.3	0.13 ± 0.09 c	5.6
6	Control	0.07 ± 0.07 c	1.4	0.00 ± 0.00 c	0.0
	Greg eggs	0.53 ± 0.13 c	10.7	0.07 ± 0.07 c	2.9
	Greg froth	1.87 ± 0.24 b	37.9	0.67 ± 0.16 b	29.4
	Greg pods	2.47 ± 0.22 a	50.0	1.53 ± 0.22 a	67.7

Means (N=15) followed by the same letter are not significantly different ($P>0.05$).

egg pods derived from gregarious and/or solitarious insects, solitarious females showed a significantly higher preference for ovipositing near *gregaria* egg pods than near the plants, with *solitaria* egg pods, eliciting the least response (Table 2c). In contrast with solitarious females, in the absence of *gregaria* egg pods, gregarious females preferred to oviposit in untreated moist sand (control) (74–77%), away from the plants (6–14%) or *solitaria* egg pods (4%) (Table 2d). However, when present, *gregaria* egg pods elicited significantly more oviposition. These and previous results indicate a hierarchy of phase-dependent oviposition preferences in the desert locust, that serve to facilitate the onset of gregarisation and its horizontal spread and transmission across generations. The study has shown that specific desert plants in the breeding areas help concentrate egg laying by solitarious females and promote the formation of nuclei of relatively high densities of young hoppers that emerge. This provides new insights into the mechanism underlying the genesis of gregariousness in the desert locust.

3. EFFECTS OF NYMPHAL PHEROMONE BLEND (NPB) ON GREGARIOUS ADULTS

The effects of exposing gregarious adults to NPB on their feeding rates, circadian rhythm (roosting, feeding, moving), maturation and female preoviposition period, oviposition behaviour and fecundity were studied as part of an MSc student's research work. Unlike in treatments of hoppers with the adult pheromone, no significant effect of NPB on adults was found with respect to feeding and circadian rhythm. However, NPB exposure led to a significant delay in maturation and the onset of oviposition. The most interesting finding was that females exposed to the nymphal pheromone showed a tendency to scatter their egg pods during oviposition (Figure 3), suggesting that substantial solitarisation had taken place. In view of the significance of this result, a detailed study has been mounted under both controlled conditions and in the field to optimise and document the effects of NPB.

4. STUDIES ON GREGARISATION

Three studies undertaken by ARPPIS scholars to provide some insights into phase dynamics were completed during the period:

- Time-course haemolymph JH titres in solitarious and gregarious adults of the desert locust and their relation to pheromone emission, CA volumetric changes and oocyte growth
- The effect of food distribution in cages on the degree of gregarisation of solitarious desert locusts as measured by adult pheromone titres and other phase characters

Table 2d. Oviposition attempts and egg pods deposited by individual gregarious *S. gregaria* (in groups of 25) to 4-choice treatments involving different combinations of host plants, egg pods, eggs and egg froth in the field cage experiments

		Egg pods deposited			
		Oviposition attempts		Egg pods	
Exp.	Treatment	Mean ± SE	%	Mean ± SE	%
1	Control	56.40 ± 3.25 a	70.8	49.80 ± 0.66 a	73.5
	Heliotropium	11.50 ± 1.16 b	14.4	11.20 ± 1.36 b	16.5
	Millet	7.30 ± 0.82 b	9.2	5.10 ± 0.98 c	7.5
	Zygophyllum	4.50 ± 0.52 c	5.7	1.70 ± 0.62 d	2.5
2	Control	48.50 ± 1.76 a	62.8	47.50 ± 1.19 a	68.0
	Heliotropium	12.70 ± 1.03 b	16.5	12.50 ± 0.95 b	17.9
	Millet	8.40 ± 0.79 c	10.9	3.70 ± 0.62 c	8.2
	Sol pods	7.60 ± 1.15 c	9.8	4.20 ± 0.83 c	6.0
3	Control	15.10 ± 2.66 b	19.5	14.90 ± 1.04 b	20.3
	Heliotropium	7.00 ± 0.71 c	9.1	4.80 ± 0.65 c	6.5
	Millet	6.60 ± 1.45 c	8.5	2.60 ± 0.67 c	3.5
	Greg pods	48.60 ± 2.13 a	62.9	51.10 ± 1.29 a	69.6
4	*Heliotropium*	10.60 ± 1.03 c	13.4	4.70 ± 0.68 b	7.4
	Millet	14.60 ± 0.19 b	18.5	4.00 ± 0.49 b	6.3
	Greg egg pods	46.30 ± 1.29 a	58.5	50.30 ± 1.02 a	79.6
	Sol pods	7.60 ± 0.58 d	9.6	4.20 ± 0.36 b	6.7
5	Control	30.10 ± 1.83 b	32.4	15.70 ± 0.98 b	27.3
	Heliotropium	10.20 ± 1.35 c	11.0	2.70 ± 0.50 c	4.7
	Greg egg pods	45.20 ± 1.65 a	48.6	37.60 ± 1.00 a	65.4
	Sol pods	7.50 ± 0.83 c	8.1	1.50 ± 0.31 c	2.6
6	Control	8.90 ± 1.11 c	9.9	4.10 ± 0.35 c	6.9
	Greg eggs	13.80 ± 2.03 c	15.30	4.30 ± 0.54 c	7.3
	Greg froth	30.30 ± 2.15 b	33.6	18.80 ± 0.89 b	31.8
	Greg pods	37.20 ± 1.87 a	41.2	31.90 ± 0.78 a	54.0

Means (N=10) with the same letters are not significantly different ($P>0.05$).

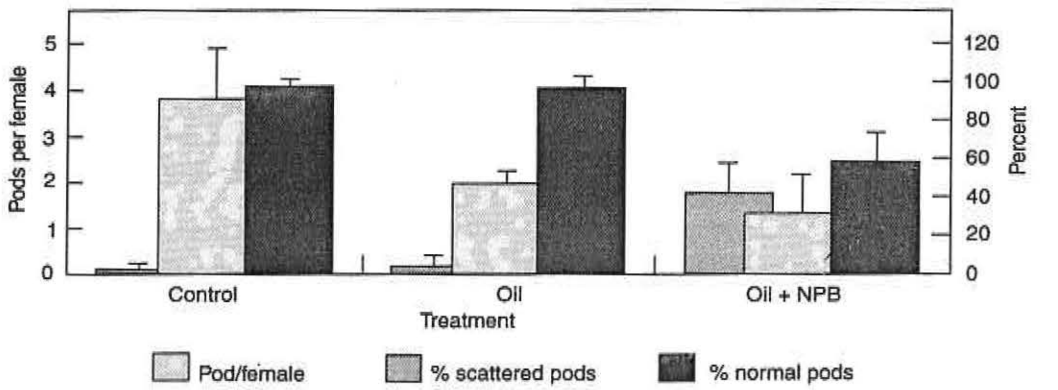

Figure 3. Effect of the nymphal pheromone blend (NPB) on the fecundity and oviposition behaviour of gregarious fledglings of the desert locust

- The rate of solitarisation of isolated gregarious nymphs and adults exposed/unexposed to cohesion pheromones to elucidate the primer physiological roles, if any, of these signals.

4.1 JH-TITRES, CA VOLUMES, OOCYTE DEVELOPMENT AND PHEROMONE EMISSION IN ADULTS

The haemolymph JH III titres in solitarious and gregarious adult desert locusts, *S. gregaria*, were examined in relation to corpus allatum (CA) volumes, aggregation-maturation pheromone production in males and oocyte growth in females. The JH titres of gregarious females were generally higher than those of solitarious females at all ages studied (Figure 4.1a). The titre patterns, however, were similar: relatively high on day 10, dropping to low levels between days 20–25, before rising again by day 25.

In the solitarious males, the JH titre was very low on day 10 after fledging, but increased gradually reaching a maximum on day 30. The JH titre in gregarious males was low on day 10, rising on day 15

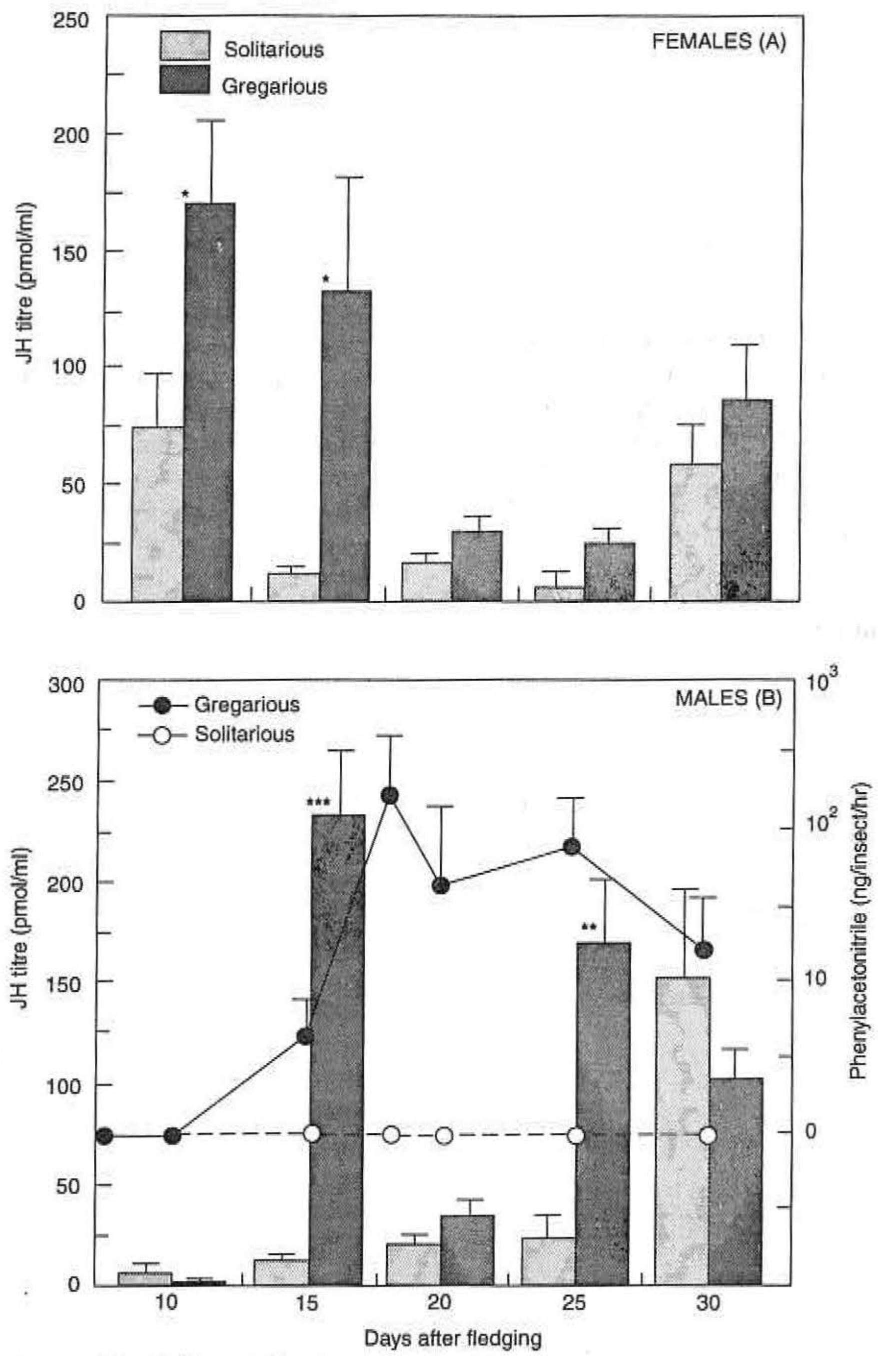

Figure 4.1. JH titres (±SD) in the haemolymph of solitarious and gregarious adult females (A) and males (B) respectively; and pheromone titres (±SD) measured by amounts of phenylacetonitrile in gregarious and solitarious males. *, $P<0.05$; ** $P<0.01$; *** $P<0.001$

to coincide with the production of the pheromone, and dropped to a relatively low level on day 20 around the peak pheromone production to rise again by day 25 (Figure 4.1b). These results suggest that the biosynthesis of the pheromone is associated with JH titre peak in the haemolymph. A clear relationship was found during the first gonadotropic cycle between JH titres and CA volume and oocyte growth; in both phases, no such correlation could be discerned in the second cycle.

4.2 EFFECT OF FOOD DISTRIBUTION ON GREGARISATION

The effect of food distribution on the phase characters of solitarious desert locust, *S. gregaria* (Forskal), was studied using the solitarious nymphal densities of 4, 6, 8, 10 and 12 nymphs per 100 x 100 x 50 cm cages. They were reared on the same mass of wheat and kale plants localised (centre of the cage) or delocalised (distributed into equidistant parts in the cage). Phase change was monitored in the adults through aggregation pheromone titres, measured as phenylacetonitrile emission, haemolymph pigment composition (measured as absorbency ratio at 460 and 680nm), integumental colour and morphometrics.

The results showed that at low densities (4 and 6 per cage) there was no evidence of gregarisation. At a moderate density (8 per cage), solitarious locusts reared in cages with localised food gregarised, whereas those in cages with delocalised food failed to show any sign of phase change. At higher densities (10 or 12/cage), insects in both situations showed evidence of gregarisation with those in cages with localised food showing a more pronounced shift toward the gregarious phase. These results are consistent with previous field observations that gregarisation is associated with patchy environments with favourable micro-environments attractive to solitaria. The results of this study and those on oviposition behaviour provide a clear basis for an area-wide study of gregarisation over a chain of seasons, in order to elucidate quantitatively the precise circumstances of locust outbreaks in the breeding areas.

4.3 PRIMER ROLE OF AGGREGATION PHEROMONES

In our previous studies, it was shown that solitarious locusts are very sensitive to crowding (*1995–1997 ICIPE Annual Scientific Report*). Placement of only a few (2–4) solitarous individuals led to rapid (a few days) production of the gregarious-phase aggregation pheromones. Conversely, uncrowding of gregarious locusts led to rapid loss of gregarious characters. Exposure of solitarious individuals to aggregation pheromones had no effect on phase, although there was a significant pigmentary change to darker shades. On the other hand, previous observations in the laboratory and in the field suggested that the rate of solitarisation of gregarious individuals that are separated from the crowd, but that are within the perceptible range of the volatile aggregation pheromones, might not solitarise as readily. The present study was undertaken to explore this possibility.

The rate of solitarisation of isolated gregarious nymphs and adults exposed or unexposed to pheromone emissions of conspecifics was investigated in the absence of visual and contact cues. The rate of solitarisation was monitored using pheromone titres (as measured by the levels of nonanal plus nonanoic acid in nymphs and phenylacetonitrile in adults volatile emissions), behaviour, pigmentary changes and body weights. The results showed that the presence of pheromone slowed down the process of solitarisation in isolated recipient insects (nymphs and adults), and that this was dependent on the quality and dose of the stimulus (Figure 4.3). Adults exposed to their own volatile emissions solitarised more slowly than those exposed to nymphal volatiles. In contrast, solitarisation of nymphs appeared to be independent of the quality of the volatile signal. In both stages, increasing pheromone emission dose provided by a higher locust source density, slowed the rate of solitarisation in recipient locusts, although the effect was stronger in adults than in nymphs.

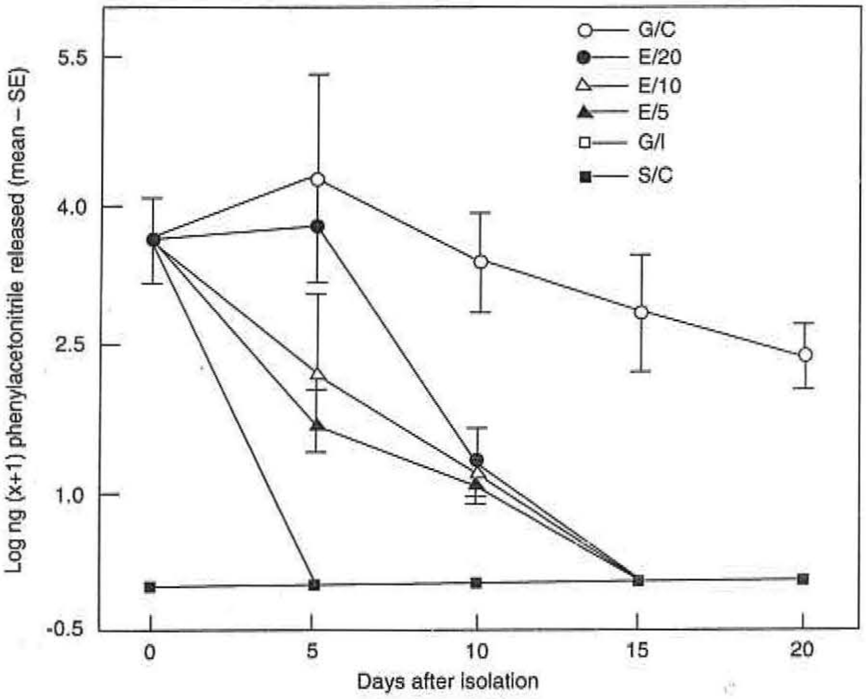

Figure 4.3. Phenylacetonitrile titres in the pheromone emission of gregarious mature adult males exposed to the volatile emissions of gregarious conspecifics.
G/C = gregarious control, E/20 = exposed to 20 conspecifics; E/10 = exposed to 10; E/5= exposed to 5; 1/G = isolated gregarious; S/C = solitarious control

Continued gregarious status (resulting from pheromone emissions) was reflected in the retention of gregarious behaviour, colour and higher body weights of recipients compared to non-recipients of pheromones. Thus, once the insects are gregarious, the volatile aggregation pheromones contribute significantly to maintaining the insects physiologically gregarious, and therefore behaviourally cohesive.

Output

Publications

Bashir M., Hassanali A., Njagi P., Obeng-Ofori D. and Torto B. (1998) Gregarisation-disrupting factors in a novel approach of controlling locusts and grasshoppers. Patent Application.

Hassanali A. and Torto B. (1999) Grasshoppers and locusts, pp. 305–328. In *Pheromones of Non-Lepidopteran Insects Associated with Agricultural Plants* (Edited by J. Hardie and A. K. Minks). CABI Publishing.

Niassy A., Torto B., Njagi P.G.N., Hassanali A., Obeng-Ofori D. and Ayertey J.N. (1999) Intra- and interspecific aggregation responses of *Locusta migratoria migratoriodes* and *Schistocerca gregaria* and a comparison of their pheromone emissions. *Journal of Chemical Ecology* 25, 1029–1041.

Tanaka S. and Shigemi Y. (1998) Evidence for the involvement of a neuropeptide in the control of body color in the desert locust, *Schistocerca gregaria. Japanese Journal of Entomology* 65(3), 447–457.

Torto B., Assad Y.O.H., Njagi P.G.N. and Hassanali A. (1999) Semiochemical modulation of oviposition behaviour in the gregarious desert locust *Schistocerca gregaria. Pesticide Science* 55, 570-571.

Torto B., Assad Y.O.H., Njagi P.G.N. and Hassanali A. (1999) Evidence for additional pheromonal components mediating oviposition aggregation in *Schistocerca gregaria. Journal of Chemical Ecology* 25, 835–845.

(See also reports on the Entomopathology Unit and the Behavioural and Chemical Ecology Department)

Capacity building

Conferences/Workshops attended

Lwande W. and Hassanali A. (1998) Workshop on Networking on Bioprospecting for Anti-Malarial, Mosquito Repellent, ICIPE.

Hassanali A. (1998) Fourth Annual Scientific Conference of Tanzania Entomological Association (TEA) at TPRI, Arusha, Tanzania. Keynote address on, 'Chemical ecology and insect management'.

Njagi P. (1999) First Asia-Pacific Conference on Chemical Ecology, Shanghai, China. Paper presented, 'Ovipositing female desert locust, *Schistocerca gregaria* (Forsk.) produce a chemical signal for short-term recruitment of gravid conspecific to the site'.

Hassanali A., Njagi P. , Torto B. and Bashir M. O. (1998) Workshop on Planning for Multi-site Trials of DL Pheromones and *Metarhizium* and Sublethal Doses of Pesticides. Paper presented, 'Effect of the adult DL gregarisation pheromone on the life system of gregarious nymphs and bands'.

Bashir M. O. (1998) Sudanese Environment Protection Society, Arkawet Resort, Red Sea.

Hassanali A. (1999) Workshop on Locust Biocontrol Project organised by VG Tech, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA.

Torto B. (1999) Joint Congress of the African Association of Insect Scientists (13th Congress) and the Entomological Society of Burkina Faso , Burkina Faso, Ouagadougou, 19–23 July 1999. Paper presented, 'Controlling locusts with pheromones: How feasible is it?'

MSc students supervised in 1998 at the Sudan Sub-Station

A. E. M. El-Sayed (Univ. of Gezira) : Mortality rate of nymphs of the desert locust *Schistocerca gregaria* (Forskål) (Acrididae: Orthoptera) subjected to low dosages of conventional pesticides and the adult pheromone. (Supervisor: M. O. Bashir)

N. El-Tayeb (Univ. of Khartoum): Studies on oil formulation of the mycopesticides *Metarhizium flavoviride* and pheromones on nymphs of the desert locust *Schistocerca gregaria* (Forskål) (Acrididae: Orthoptera). (Supervisor: M. O. Bashir)

H. El-Tigani Abd El-Rahman (Univ. of Khartoum): Studies on the effect of different food plant species on the life system of the desert locust *Schistocerca gregaria* (Forskål) (Acrididae: Orthoptera). (Supervisor: M. O. Bashir)

I. M. El-Hassan (Univ. of Khartoum): Studies on *Metarhizium anisopliae* in conjunction with pheromone on the desert locust *Schistocerca gregaria* (Forskål) (Acrididae: Orthoptera) in the Red Sea area. (Supervisor: M. O. Bashir)

PhD students supervised in 1999 at the Sudan Sub-Station

O. M. Abdalla (Univ. of Khartoum): Field evaluation of control efficiency of the DL nymphs with *Metarhizium anisopliae* used with the adult pheromone in the Red Sea area. (Supervisor: M. O. Bashir)

T. A. El-Salam Fager (Univ. of Khartoum): Examination of the effect of the nymph pheromone blend on the DL adults. (Supervisor: M. O. Bashir)

I. M. Abdalla (Univ. of Khartoum): Mass culturing and use of the DL in poultry food supplements. (Supervisor: M. O. Bashir)

A. A. Fadul Nuri (Univ. of the Red Sea): Studies on the suitability of the most prevalent 3 species of *Helioptropium* on the life of the solitary DL. (Supervisor: M. O. Bashir)

L. K. Edward (Univ. of Khartoum): Sexual behaviour and responses of the solitary DL to different cues. (Supervisor: M. O. Bashir)

PhD students supervised in 1998/99 at the ICIPE Headquarters, Nairobi

M. A. Garang (University of Khartoum): The effect of plant density on gregarisation of desert locust *Schistocerca gregaria* (Forskål). (Supervisors: A. Hassanali and B. Torto)

S. O. Ely (University of Khartoum): Relative position preferences of solitarious desert locusts on different *Heliotropium* spp. and their semiochemical basis. (Supervisors: M. O. Bashir, A. Hassanali, B.Torto and P. Njagi)

C. M. H. Kane (Kenyatta University): Optimisation of use of phenylacetonitrile in enhancing susceptibility of gregarious nymphal desert locust, *Schistocerca gregaria* (Forsk.) to insecticides and pathogens. (Supervisors: P. Njagi, B. Torto and A. Hassanali)

Development of Biopesticides for Management of Grasshoppers and Locusts in Sub-Saharan Africa

Background, approach and objectives

Integrated pest management (IPM) interventions do not yet exist for control of locusts and grasshoppers in sub-Saharan Africa. The lack of alternative locust control methods are a crucial limiting factor to IPM programmes. Both large-scale and local or village grasshopper or locust control programmes have relied almost exclusively on chemical insecticides. Effective, economical and safe alternative methods are needed to control acridids.

Entomopathogens can be applied using the same application technology as the chemicals that currently form the basis for control and are hence a suitable focus for generating alternative control measures. The specific objective of this Project is to increase the efficacy of entomopathogens used as biopesticides, by increasing their virulence and environmental persistence sufficiently to become marketable products.

Participating scientists: N. K. Maniania, B. Torto, E. Osir* (*Project Coordinator)

Assistants: E. Ouna, M. Mbeke

Donors: USAID/Africa Bureau

Collaborators: • *Virginia Polytechnic Institute and State University (USA)* • *USDA* • *Insect Biological Control Laboratory (France)* • *Locustox (FAO)* • *DLCO (East Africa)* • *INRA (France)* • *DPV (Senegal)*

Work in progress

1. FORMULATION OF PATHOGEN/ PHEROMONE COCKTAILS

1.1 COMPATIBILITY BETWEEN *METARHIZIUM ANISOPLIAE* AND PHENYLACETONITRILE

Compatibility of the pathogen, *Metarhizium anisopliae* var. *acridum* (IMI330189) and the principal active component (phenylacetonitrile) of the adult aggregation pheromone of the desert locust, *Schistocerca gregaria*, was assessed in the laboratory in terms of conidial germination, shelflife and pheromone recovery.

1.1.1 *Compatibility assays*

Compatibility assays between the fungus and the pheromone were carried out:

- without pheromone in oils (Tween 20, Tween 80, TX-100, PEG and paraffin) at 28°C. Three replicates of each treatment were performed.
- with pheromone in the carrier Tween 20. Four different concentrations (10^{-3}, 10^{-2}, 10^{-1} and 1% v/v) of the pheromone were prepared, and each assessed at 28 and 35°C.

Three replicates of each treatment were performed. An additional three replicates were prepared for the 1% v/v pheromone/fungus cocktail for pheromone recovery analysis. Controls comprised fungus and pheromone each alone at 1 % v/v in Tween 20. Exposure times of 0 and 7 days were assessed.

At a concentration of 0.1% v/v of all the carriers, [Tween 20 (85%), Tween 80 (90%), TX-100 (90%), PEG 200 (75%), paraffin (96%), and control (91%)], no significant difference in conidial germination after 24 hours was found at 28°C. However, Tween 20 was selected because of its low viscosity.

At day 0 exposure of fungus to the pheromone at the tested concentrations, no effect on germination of the fungus was observed at 28°C. There was, however, a delay of 24 hours in germination at 35°C and no germination occurred at 40°C. One week of exposure reduced the viability by 46% at 28°C, while at 35°C the reduction was higher.

1.1.2 *Pheromone recovery*

The fate of the pheromone after conidia germination was determined to assess its stability at the two different temperatures, 28°C and 35°C. After 72 hours of conidia germination, control and treatment, samples were extracted with HPLC-grade hexane (3 ml, Aldrich, UK) for 5 min, filtered through a Pasteur pipette plugged with cotton wool and the filtrate concentrated to 1 ml in a stream of nitrogen at 0°C. Aliquots (1 ml), were analysed by GC on a Hewlett-

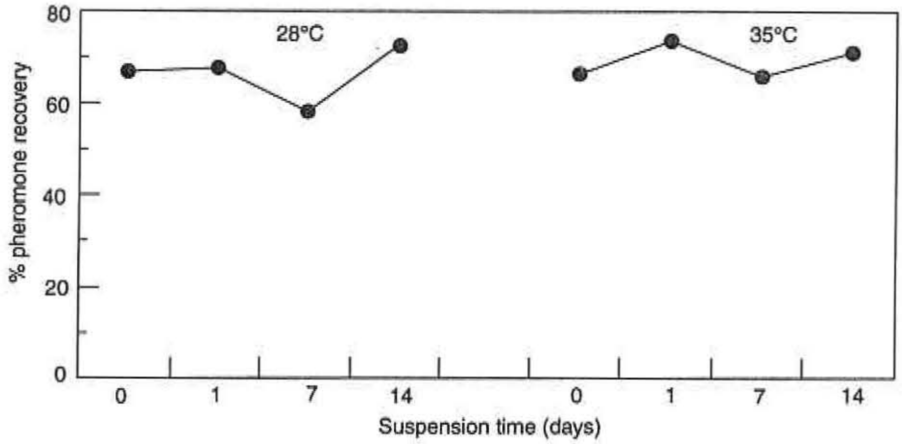

Figure 1.1.2. Percent pheromone recovery after 72 hours of conidia germination at 28°C and 35°C

Packard (HP) 5890 Series II gas chromatograph, equipped with a flame ionisation detector (FID). The GC oven was fitted with an HP capillary column (Carbowax 20M, 50 m x 0.2 mm ID x 0.2 mm), and temperature programmed at 140°C (5 min), 5°C/min to 220°C held for 10 min. Phenylacetonitrile was detected at a retention time of 17.7 min by comparison with that of an authentic sample and confirmed by co-injection with the sample.

Pheromone recovery for the exposure times 0, 1, 7 and 14 were assessed. The relative amount of phenylacetonitrile was quantified in GC runs on an HP3396 Series II integrator using peak areas.

The pattern of recovery of the pheromone at the two different temperatures was similar (Figure 1.1.2), and about 70 % of the pheromone was recovered after 72 hours of conidia germination. Comparison of the chromatographic profiles of the controls (fungus and pheromone each alone) and the pheromone/ fungus cocktail showed no detectable breakdown products. It is concluded that germination of the fungus has no degradation effect on the pheromone.

2. EVALUATION OF FORMULATION OF PHENYLACETONITRILE IN COMBINATION WITH *METARHIZIUM ANISOPLIAE* OR *NOSEMA LOCUSTAE*

The objective of the present study was to assess the performance of phenylacetonitrile alone or in combination with the entomopathogenic fungus *M. anisopliae* or the protozoan *N. locustae* on 4th instars of desert locust, *S. gregaria.*

The strain of *N. locustae* used in this study was obtained from China, but originated from the USA. The pathogen was used as a model until strains from Africa are found. Protozoa were harvested at cyst stage from dead insects. Prior to the experiment on protozoa–pheromone cocktails (*see section 1.1*), a bioassay was carried out to assess the pathogenicity of the strain of *N. locustae* on *S. gregaria.*

Metarhizium anisopliae var. *acridum* isolate 330189 (Green Muscle™) used in this study was obtained from CABI Bioscience. The fungus was cultured on Sabouraud dextrose agar medium (SDA) and incubated for 2 weeks at 24–26°C before use in bioassays. The spore concentration of *M. anisopliae* and *M. locustae* was determined using an improved Neubauer counting chamber. Different spore concentrations (1 x 10^6 and 1 x 10^7/ml) were obtained through serial dilution.

Bioassays were carried out on 4th instar *S. gregaria.* In bioassays on pathogenicity of *N. locustae,* insects exposed to grass treated with different concentrations of the pathogen succumbed to infection by protozoa (Table 2a). Mortality was dose-dependent.

The pheromone applied alone resulted in low mortality (Table 2b). No significant difference in cumulative mortality was found between pheromone–protozoa cocktails at different concentrations. Furthermore, no significant increase in mortality was observed between protozoan treatment and different concentrations of pheromone combined with the protozoan. However, the LT_{50} of the pheromone–protozoan treatments were approximately 2 to 4 times shorter than the protozoan alone.

The results of this study demonstrate the efficacy of the strain *N. locustae* received from China. At the concentration of 10^7 spores/ml, the mortality of the *Nosema*-only treatment in the protozoa bioassay was lower than *Nosema*-only mortality in the pheromone–protozoa cocktail bioassay (Table 2c). The difference could be explained by the fact that the pathogen used in the second test was obtained after passage through insect. The mortality observed in the pheromone treatments was not expected, since phenylacetonitrile

Table 2a. Pathogenicity of *Nosema locustae* towards 4th instar *Schistocerca gregaria*

Treatment (concentrations)	Per cent mortality
Control	16.7 ± 8.8
1 x 10^7/ml	50.0 ± 0
1 x 10^8/ml	86.7 ± 13.3
1 x 10^9/ml	100

Table 2b. Cumulative 20-day mortality of 4th instar *Schistocerca gregaria* following exposure to *Nosema locustae* and pheromone cocktails

Treatment	Percent mortality ± SE	LT_{50} in days (CL)
Tween 20	10.1 ± 7.4 b	-
Pheromone 10^{-4} [1]	30.8 ± 12.6 b	-
Pheromone 10^{-3}	8.2 ± 8.2 b	-
Pheromone 10^{-2}	20.8 ± 20.8 b	-
Pheromone 10^{-1}	0.0 b	
N. locustae 10^7/ml[2]	87.4 ± 12.6 a	13.5(13.2–13.8)
Pheromone 10^{-4} + *N. locustae* 10^7/ml	81.0 ± 0 a	6.2 (5.8–6.7)
Pheromone 10^{-3} + *N. locustae* 10^7/ml	93.7 ± 6.3 a	3.4 (2.9–4.0)
Pheromone 10^{-2} + *N. locustae* 10^7/ml	93.7 ± 6.3 a	6.0 (5.5–6.4)
Pheromone 10^{-1} + *N. locustae* 10^7/ml	100 a	7.1 (6.9–7.4)

No observed values. Within-column means followed by the same letters are not significantly different by Student-Newman-Keuls ($P<0.05$). Means were angularly transformed before analysis, but values represent untransformed means.
[1]Concentration as v/v.
[2]Concentration in cysts/ml.

Table 2c. Susceptibility of 4th instar *Schistocerca gregaria* following exposure to *Metarhizium anisopliae* and pheromone cocktails

Treatment	Percent mortality
Tween 20	10.1 ± 7.4
Pheromone 10^{-4}	30.8 ± 12.6
Pheromone 10^{-3}	8.2 ± 8.2
Pheromone 10^{-2}	20.8 ± 20.8
Pheromone 10^{-1}	0
M. anisopliae 10^6/ml	8.2 ± 8.2
Pheromone 10^{-4} + *M. anisopliae* 10^6/ml	18.3 ± 12.6
Pheromone 10^{-3} + *M. anisopliae* 10^6/ml	18.3 ± 12.6
Pheromone 10^{-2} + *M. anisopliae* 10^6/ml	8.2 ± 8.2
Pheromone 10^{-1} + *M. anisopliae* 10^6/ml	22.6 ± 12.6

is not a lethal compound, but serves for gregarisation in locusts. These results are not conclusive and will need to be repeated.

3. DISCOVERING NEW INDIGENOUS PATHOGENS

One of the objectives of the project is to carry out field surveys that may later lead to the discovery of new biological control agents. As a repository centre for pathogens, ICIPE received during the reporting period a number of fungal isolates from Département de Protection des Végétaux (DPV), Senegal and the ICIPE-Sudan sub-station. Samples received from DPV were contaminated by *Aspergillus* and *Penicillium*. Three isolates of *Metarhizium* spp. were isolated from dead *S. gregaria.*

(See also the previous report on locusts and the Entomopathology Unit report.)

JH Biosynthesis by *Schistocerca gregaria* and *Locusta migratoria* Fed on Artificial Diets

Background, approach and objectives

As rearing locusts in the laboratory involves considerable costs, particularly for labour, an attempt has been made to develop artificial diets which can provide uniform and easy rearing methods. The diets were constituted from orchard grass, protein concentrates and sucrose. The effects of these candidate diets on the ovarian development and *in vitro* biosynthesis of juvenile hormone (JH) which promotes egg maturation were studied in two species of locusts, *Schistocerca gregaria* and *Locusta migratoria migratorioides*. In addition, the effects of brain and corpora cardiaca (CC) extracts on JH production by corpora allata (CA) from insects fed on different diets were investigated to compare the responses in the two species of locusts.

Participating scientists: S. Nakamura*, T. Okuda
(*Visiting Scientist)

Assistant: D. O. Otieno

Donor: JIRCAS

Work in progress

1. EFFECT OF DIET ON JH BIOSYNTHESIS

When reared on artificial diet, ovarian maturation in both species of locusts, *S. gregaria*, and *L. m. migratorioides* was delayed by 5 to 7 days compared with those reared on fresh leaves (Figures 1.1 and 1.2). In *S. gregaria* the rate of JH biosynthesis by CA on artificial diet was consistently lower than those on fresh leaves (Figure 1.1), while in *L. m. migratorioides* the JH production by CA *in vitro* was enhanced by feeding on artificial diet (Figure 1.2).

A consistent allatotropic effect was found in brains and CC extracts in *S. gregaria* (Figure 1.3). In contrast, an allatostatic effect was significant in brains and CC extracts from *L. m. migratorioides* (Figure 1.4). JH synthesis by CA *in vitro* does not necessarily reflect JH production *in vivo* in *L. m. migratorioides*. Brains and CC extracts from *S. gregaria* had different (allatostatic) effects on JH production by CA from *L. m. migratorioides*.

These results show that different mechanisms are involved in the two species in brain regulation of JH synthesis by CA.

In addition, our results (data not presented) suggest that the rate of nymphal mortality was much lower on artificial diet than on fresh leaves, indicating an advantage of using the former at this stage of the insect. More data in this respect are being collected on all stages of the insects.

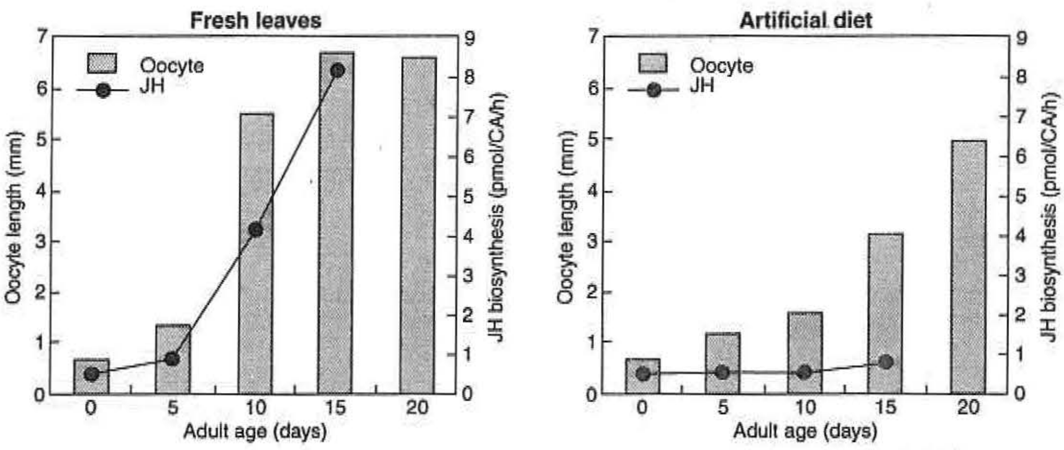

Figure 1.1. Ovarian development and JH biosynthesis by CA *in vitro* in *Schistocerca gregaria* fed on fresh leaves and artificial diet, respectively

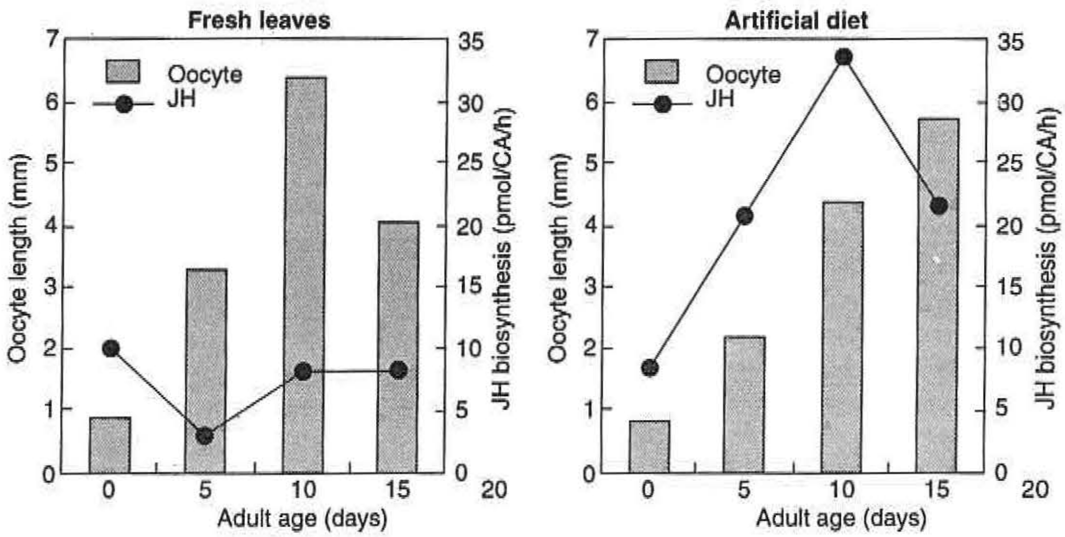

Figure 1.2. Ovarian development and JH biosynthesis by CA *in vitro* in *Locusta migratoria migratorioides* fed on fresh leaves and artificial diet, respectively

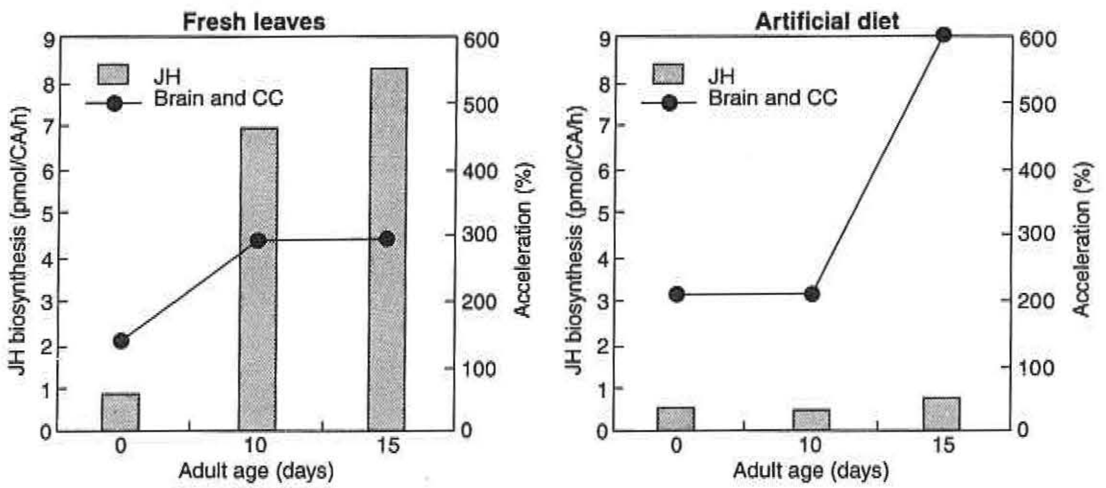

Figure 1.3. Allatostatic effect on brain and CC extracts on JH synthesis by CA *in vitro* in *Schistocerca gregaria* fed on fresh leaves and artificial diet, respectively

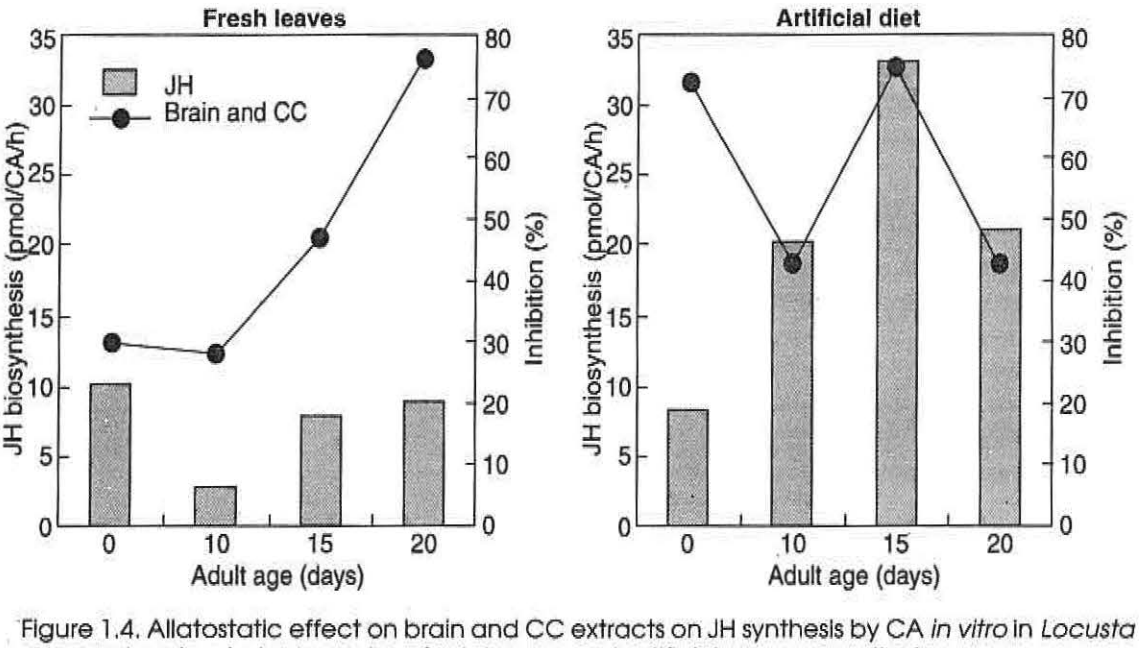

Figure 1.4. Allatostatic effect on brain and CC extracts on JH synthesis by CA *in vitro* in *Locusta migratoria migratorioides* fed on fresh leaves and artificial diet, respectively

ENVIRONMENTAL RESEARCH

ENVIRONMENTAL HEALTH MANAGEMENT

BIODIVERSITY AND CONSERVATION

The Biodiversity and Conservation (B&C) Programme is a new initiative that goes beyond the traditional ICIPE interest in 'environmentally friendly' pest control to deal with the roles insects play in ecosystem stability, including critical issues such as soil fertility, pollination and the impacts of invasive alien species. The Programme was started in response to the realisation that almost all entomological research being undertaken within tropical Africa focuses on the very few species that are directly linked to human activities, while most conservation research and management activities in tropical Africa ignore invertebrates. This leaves a major gap in understanding the organisms that are among the most important in mediating ecosystem processes that support the production base.

This Programme addresses the challenges of the 1992 United Nations Convention on Biological Diversity, and the more recent decisions of the Conference of the Parties related to agrobiodiversity, in identifying critical species, where they occur, understanding their natural history and establishing sustainable resource use patterns.

During 1999, this new initiative undertook three concurrent activities:

- working with stakeholders to show them what ICIPE can do, while building partnerships with collaborating agencies;
- starting projects to quickly generate products so as to provide credibility, and
- soliciting funding from both ICIPE's traditional donors and new donors.

Products underway include the inventory of African insects; guide to key publications; field surveys assessing the use of insects as indicators of environmental health; building regional capacity to manage invasive species and natural products chemistry projects; and training of students.

The workplan corresponds closely to the approach on conservation laid out by E.O.Wilson in his book, *The Diversity of Life*: (a) survey the world's flora and fauna; (b) create biological wealth; (c) promote sustainable development; (d) save what remains; and (e) restore the wildlands.

The early years of our workplan are focusing by necessity on basic foundational activities that will support the more management-oriented later steps. Bridges are already being created to areas where opportunities already exist, such as ICIPE's programmes in natural products chemistry, honey bees and native silkmoths, among others.

Environmental Health Division

BIODIVERSITY AND CONSERVATION

African Arthropod Biodiversity: Gaining Knowledge for Utilisation and Conservation

Participating scientists: *S.E. Miller*, L. Rogo, R. Copeland, W. Lwande (*Programme Leader)*

Assistants: *N. Onyimbo, B.A. Omolo, R. Mwikodi, L. Moreka, D. Mbuvi, E. Nyandat*

Visiting scientists: *T. Wagner, R.R. Snelling, N. Springate, L. Springate, N. Minakawa, R. Copeland, B. Gemmill, R. Pasquet, B. Frei, A. Brune, E.E. Lyons*

Donors: *Government of Norway, David and Lucile Packard Foundation, UNEP, UNDP, IDRC, World Laboratory, ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark) and others as noted later.*

Collaborators: Primary in-country collaborations are: • *National Museums of Kenya (MOU signed)* • *Kenya Wildlife Service (MOU in progress)* • *Mpala Research Centre (MOU in progress)* • *Taita Hills Biodiversity Project* • *Tropical Soil Biology and Fertility Programme* • *African Butterfly Research Institute.* Primary external collaborations are: • *Natural History Museum, London* • *Royal Museum of Central Africa, Tervuren (MOU signed)* • *Plant Protection Research Institute, Pretoria (MOU signed)* • *Entomological Information Services (MOU signed)* • *Smithsonian Institution* • *Bionet International.*

A. INFORMATION MANAGEMENT AND DISSEMINATION

Background, approach and objectives

As a result of the colonial history of Africa, there is probably much more known about Afrotropical insects than those in the New World and Asian tropics. This same history makes the information almost impossible to obtain in tropical Africa, as it is mostly incarcerated in European museums and libraries and in a variety of languages and intellectual traditions. A modern checklist of the insects exists for only one of the more than 50 African countries (Nigeria).

There are problems of synthesising the different language-based bodies of literature, and the logistics of handling both literature and specimens. Hence, it is far more cost-effective to undertake data compilation for the Afrotropical region than on a country-by-country basis.

Having access to even the most basic information is vital to any meaningful activities in insect conservation. Most of the key museums are eager to work with ICIPE in gathering, synthesising and repatriating this information. Some countries are in a position to use this information immediately, while others must wait until civil wars or other issues have been resolved. As the information will be largely in electronic form, it can be readily copied and will be available whenever the countries are ready for it.

Work in progress

1. CHECKLIST OF AFROTROPICAL INSECTS

This basic inventory of the insects known from tropical Africa is the backbone of the Biology and Conservation (B&C) Programme's information management activities. About 30% was completed by the end of 1999 and will be available on the Internet as reviews are completed at **http://www.icipe.org/icipedata/africachecklist/index.html.** Dependent on the availability of funding, we hope to complete the data input by 2001, and disseminate the product in online, CD-ROM and print formats in 2002. The insect orders that have been completed are Odonata, Ephemeroptera, Plecoptera, Trichoptera, Heteroptera (Hemiptera), Homoptera, and most of the Hymenoptera.

When the checklist project was started, there were only crude estimates available for the number of described insect species in Africa, based on comparisons to the recently completed North American checklist. We estimate that there are presently about 100,000 described species of insects considered valid for Africa south of the Sahara. Comparisons amongst numbers of species for various insect orders and families for Africa and North America show considerable variance, some with more species in Africa or vice versa, but the overall tendency is for the total number of species to be similar.

2. PATTERNS OF AFROTROPICAL INSECT DIVERSITY

Several agricultural projects at ICIPE are starting GIS-based mapping, modelling and analysis of distribution patterns of key insect groups in East and Central Africa. The B&C Programme will add data on insects of conservation interest, supplementing the geographic coverage and undertaking conservation-oriented analyses by looking at such key questions as, "Do existing conservation management areas adequately support conservation of hotspots of insect diversity?" Although funding has not yet been obtained for this activity, ICIPE has laid the basis for collaboration with the World Map Group at the Natural History Museum, London, the African Biodiversity Mapping group at the University of Copenhagen and many other museums. In cooperation with the African Fruit Fly Initiative, the B&C Programme began to work with museums to obtain specimen data of the fruit fly genus *Ceratitis* from Africa. We are also cooperating with the Natural History Museum, London in their effort to collect data on four species of the swallowtail butterfly genus *Graphium* from Africa from museums around the world.

3. KEY WORKS ON AFROTROPICAL INSECTS

A major obstacle to Africa-based scientists working on any aspect of African insects is finding what information is already published on a particular group of insects. This is especially important when species identification is required, because taxonomic works are often published in low circulation journals or books; many key papers pre-date abstracting services' and electronic databases and therefore cannot easily be found. To overcome this obstacle, ICIPE and its partners are compiling a database of the key published works on African insects. This will be a multi-access, annotated list of publications, including information on biology, ecology, distribution, economic importance, identification and taxonomy. Wherever possible, texts on ethnobiology and indigenous names for insects are incorporated.

By giving Africa-based scientists rapid access to information on major publications, the resistance to beginning studies for fear of not knowing the literature will be overcome; the starting point for studies will be enhanced, and time wasted on rediscovering what is already known will be saved. In 1999, over 2000 citations were added to the working bibliography, bringing it to 7000 citations **(www.icipe.org/icipedata/biodiversity/Africasearch.cfm).** Further work is still necessary to make it a truly useful 'pre-digested' guide to the most important literature which can be distributed in paper and CD-ROM formats, in addition to the Internet.

4. DEVELOPMENT OF AN ICIPE WORLD-WIDE WEBSITE

Participating scientists: *S.E. Miller*, E. Lyons, R. Copeland, T. Robinson (*Project Leader)*

Assistants: *G. Sequeira, S. Nyakwara, J. Lago*

Donors: *ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway, Denmark), Netherlands government*

Collaborators: *R. Poole, V. Novotny, Y. Basset, N. Evenhuis*

Beyond major additions to the web pages established in 1998, a major addition was the online report of the workshop 'Invasive species in Eastern Africa' at **http://www.icipe.org/invasive**. The Biodiversity and Conservation Programme has developed over 50 html pages on the ICIPE World Wide Web (WWW) server, including searchable indexes to over 20,000 taxonomic and bibliographic records. We also collaborated in continued development of WWW pages on New Guinea insects on the Bishop Museum WWW site that include over 1300 insect images and 10,000 bibliographic citations. The WWW is viewed as a very important tool, because it allows immediate and inexpensive dissemination of products that can also be readily updated and improved. At the same time it is appreciated that many potential users of this information, especially in the tropics, do not have Internet access; we will therefore release a CD-ROM version in the future.

In addition to the following specific products, we also catalysed development of the WWW interfaces for the searchable index to the ICIPE library **[http://www.icipe.org/icipeLibrary/icipeLibrarySearch.html]** and the searchable databases of the Library of Congress Nairobi Office [hosted by ICIPE at **http://www.icipe.org/locnairobi]**. Indexes for the two libraries include over 22,500 citations.

5. TROPICAL INSECT ECOLOGY FIELD COURSE

Instructors: *C. Bjorkman and M. W. Pettersson (Swedish Agricultural University), R. Copeland (ICIPE)*

Donors: *Swedish University of Agricultural Sciences*

Collaborators: *• Swedish Agricultural University • Kenyatta University • National Museums of Kenya •*

ICIPE hosted a field course in tropical insect ecology from 22 January to 11 February 1999. This was a collaborative venture of the Swedish Agricultural University, Kenyatta University and ICIPE, and was held primarily at ICIPE's Nguruman Field Station. A total of 18 PhD students participated: 9 from Kenyatta University and 9 under the auspices of the Swedish Agricultural University. Countries of origin were Sweden (7), Finland (1), Peru (1), Kenya (7), Senegal

(1), and Ethiopia (1). Many of the Kenyatta University students are also enrolled in ICIPE's ARPPIS programme.

Orientation activities around Nairobi at the beginning of the course included trips to Gatamayu Forest, Nairobi National Park, Ololua Forest, National Museums of Kenya, and Kenyatta University. Most of the course (26 January to 6 February) was held at Nguruman, where the students all participated in two field projects, and were exposed to a series of guest lectures covering a broad range of ecological topics by staff from National Museums of Kenya, Kenyatta University, University of Nairobi, Leicester University, University of Lodz, and ICIPE. A trip to Mount Kenya was a welcome change from the Nguruman heat. The students spent the last three days in Nairobi, writing up their reports and preparing a presentation of their results at a mini-symposium, which included student reports on the following topics:

- Small mammals and their ectoparasites
- Dung beetle ecology and behaviour
- Territorial behaviour of stalked-eyed flies
- Leaf plasticity in *Solanum incanum* associated with herbivory by flea beetles
- Distribution of pollination services between wild and cultivated plants
- A survey of the benthic fauna at natural and man-made sites on Oloibortoto River
- Use of pitfall traps to assess species richness of terrestrial arthropods among islands in a recently disturbed river habitat

The course was a great success as assessed by the participants. This was the first time that ICIPE had been involved in an undertaking of this type, and it shows the potential for developing the Nguruman and Mbita Point Field Stations as centres for study and research.

6. INVASIVE SPECIES IN EASTERN AFRICA WORKSHOP

Scientists: *E.E. Lyons*, S.E. Miller, L. Rogo* (**Visiting Scientist*)

Assistants: *S. Nyakwara, N. Onyimbo, P. Machera*

Primary funding: *UNEP, IDRC*

In-kind support: *CAB International, National Museums of Kenya, Kenya Airways, Air Mauritius, South Africa Airways, ICIPE Core Fund donors (Development agencies of Swizerland, Sweden, Norway and Denmark)*

Co-sponsors: *•National Museums of Kenya • World Conservation Union (IUCN) • CAB International • Kenya Wildlife Service • EAFRINET Bionet International • Makerere University (Uganda) • Global Invasive Species Programme (GISP)*

A regional workshop on 'Invasive Species in Eastern Africa' was held at ICIPE on 5–6 July 1999 to bring together professionals from conservation, agriculture, forestry, research, land management, academia, information technology and the legal and policy fields, to explore the current status of invasive species in the region. The Workshop, which focused on four countries (Ethiopia, Kenya, Tanzania and Uganda), served as part of ICIPE's community outreach programme, and also part of the Biodiversity and Conservation Programme's contribution to conserving biodiversity within the region.

The Workshop was attended by more than 70 people from 41 different institutions, including participants from Ethiopia, Kenya, Tanzania and Uganda and with speakers from Kenya, Tanzania, Uganda, South Africa, Mauritius, Malawi and the UK. An Information Fair provided workshop participants with information and/or materials related to invasive species from more than a dozen groups. A Public Lecture/Panel Discussion held at the National Museums of Kenya, attended by 100–120 people, provided a forum for increasing public awareness of invasive species issues. Anecdotal information was collected from participants to produce a Preliminary Survey of Invasive Species in Eastern Africa.

The Workshop succeeded in:

- bringing together a diverse set of regional professionals who deal with invasive species and linking them in a loose network and providing them with contact information for all workshop participants;
- raising participants' awareness of the complexity of invasive species problems by presenting a stimulating set of presentations;
- improving regional and national linkages by giving participants the chance to work in working groups on issues of common concern;
- collecting information for the Preliminary Survey of Invasive Species in Eastern Africa;
- linking the EAFRINET community of systematists with people working on invasive species problems. There were discussions of projects that EAFRINET could do to assist the efforts of this community (e.g. a handbook on Invasive Animals of Eastern Africa);
- EAFRINET, with its nascent network structure, also volunteered to serve in a coordinating role as the group moves forward with new initiatives. (A separate statement from EAFRINET will describe in more detail the outcomes of their workshop participation. EAFRINET is the eastern African unit of Bionet International;
- focusing attention on the status of invasive species in protected areas in the region;
- identifying specific ecosystems in each country that are likely to be vulnerable to invasive species;
- providing participants with a wide range of material on invasive species from many sources during the Information Fair;
- increasing the ability of the workshop to continue to raise awareness by assembling and

distributing workshop information kits to 3–5 institutions in each country;

- setting up a web page to publish the workshop proceedings, making the proceedings and related material available to a broad range of stakeholders in the region;
- generating, during the final discussion session of the workshop, several avenues for future steps in organising national and regional efforts against invasive species.

Although the purpose was awareness raising and not the creation of specific recommendations, several clear conclusions from the Workshop could be drawn:

- There are many invasive species in eastern Africa, and there exists in eastern Africa considerable knowledge about invasive species. However, that knowledge is often quite limited. To effectively control invasive species in the region, more information is needed about which invasive species are now in the region, where they are, their rate of spread, and the nature and fate of control efforts.
- There must be better systems of communication about invasive species both within and among countries. These linkages should bring together land managers and researchers so that the research serves the stakeholders' needs.
- There now exists in eastern Africa the capacity to identify and, in some cases, control invasive species. In order to strengthen that capacity, there must be additional attention directed to conducting research on invasive species, developing systems to monitor invasive species and training personnel to control invasive species. All of these require political will and funding. Better estimates of the ecological, social and economic costs of invasive species and the benefits of programmes to control them, may help marshall that political will and subsequent financial support.
- There is sufficient knowledge, enthusiasm and ideas to carry forward an invasive species initiative within Eastern Africa and the group present at the workshop forms a loose network for supporting such an effort. At the workshop, EAFRINET volunteered to serve as a coordinating focal point for any group or groups that want to pursue national and or regional projects on invasive species.

The Proceedings of the Workshop have been published on the ICIPE web site **(http://www.icipe.org/invasive)**. A printed version is in press produced and a video tape of key parts of the workshop is being produced.

B. BIODIVERSITY STUDIES

7. ASSESSING THE IMPACT OF FOREST FRAGMENTATION, VARIOUS LAND USES AND MANAGEMENT REGIMES ON INSECT BIODIVERSITY IN THE TAITA HILLS

Background, approach and objectives

The Taita Hills, located in southeastern Kenya, are the only representative of the Eastern Arc mountains

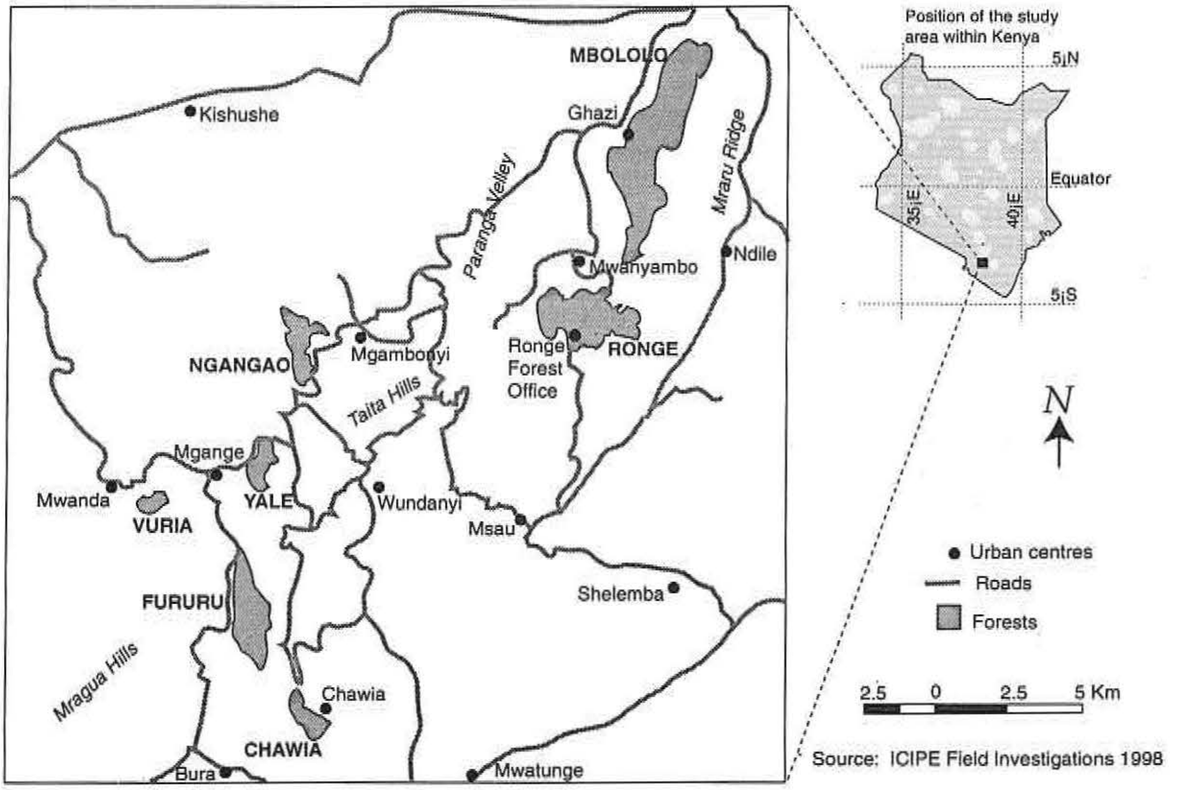

Figure 7. The Taita Hills study site

Similar to many Eastern Arc mountains, these hills harbour many rare and endemic fauna and flora. They have been recognised as one of the world's top 25 biodiversity hotspots, satisfying the world heritage criteria. Due to recent and past population pressure, the sylvatic cover of the area has reduced, with the remaining forest remnants becoming more fragmented and degraded. Some of the fragments face total clearance and with it, the disappearance of an important heritage. These facts render the forest remnants and the biodiversity found therein vulnerable to extinction.

The Taita Hills study area (Figure 7) represents forest remnants with highly diversified characteristics represented by differences in size (between 1–220 ha), altitude (1200–2200 m) and management regimes. Previous forest management included the planting of different types of exotic tree species by the Government around the forest remnants and along logged forest gaps. Variations between the forest remnants is also displayed in the forest type, level of disturbance and the surrounding matrix. Each forest remnant, therefore, represents a unique sampling site.

Simplistically, it is known that many invertebrate species are effected either directly or indirectly by forest fragmentation. An important step toward ascertaining the proportion of species affected by forest fragmentation, and hence the magnitude of biodiversity loss, must be an analysis of species responses to fragmentation in a diverse tropical forest assemblage.

This study aims to assess the impacts of fragmentation, different environmental gradients, land use patterns and management regimes on insect biodiversity. The impact these parameters have on insect biodiversity is being assessed using two groups of insects, the Lepidoptera and Coleoptera, that display different trophic requirements. Selection of insect indictors from within the original species assemblage for assessing environmental influences on insect populations over time will also be undertaken.

Trying to assess the effects of habitat modification and disturbance on tropical biodiversity by using only one group of taxa as indicators of change in the diversity of other taxa can give a misleading picture. A better alternative is to assess a wide range of taxa by embracing groups with very different ecologies and life histories. To achieve this, ICIPE entered into partnership with the Belgian- sponsored Taita Hills Biodiversity Project, being implemented by the National Museums of Kenya and Kenyatta University College, to assess the impact of fragmentation on birds, small mammals, plants and other groups of insects. Comparing data on such a wide variety of taxa will provide solid biotic data for the Taita Hills and allow for precise recommendations to policymakers and conservationists.

Participating scientist: *L. M. Rogo (Project Leader)*

Assistants: *N. Onyimbo, R. Mwakodi*

Donors: *ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark), Co-funding from the Belgian Administration for Development Co-operation (ABOS) through the Taita Hills Biodiversity Project (THBP)*

Collaborators: *• National Museums of Kenya • Kenyatta University College, Kenya • Royal Museum for Central Africa, Tervuren, Belgium • Carnegie Museum of Natural History, Pennsylvania, USA • Institute for Systematic Zoology at the Museum of Natural History of Humboldt, University of Berlin*

Work in progress

Previous studies at the Kenya coast showed the importance of forest remnants in maintaining viable butterfly populations, albeit in a reduced state, as compared to larger forest reserves. The study recommended the restoration of the logged patches in the forest remnants so as to increase and sustain biodiversity in these forests. The present study is a follow-up to investigate the best restoration/ management systems ideal for the maintenance of biological diversity and to study the effect of different environmental gradients on insect biodiversity.

7.1 EFFECT OF FRAGMENTATION AND ENVIRONMENTAL INFLUENCES ON INSECT POPULATIONS

The invertebrate groups selected for this study were the Coleoptera (leaf litter Carabidae and Staphylinidae) and the Lepidoptera (butterflies). Characterisation of these groups in 10 different forest remnants and investigation of their responses to various environmental gradients have been the main foci of the study. Butterflies were collected using butterfly nets and fruit-baited traps; beetles were collected by using pitfall traps and sieving of litter samples. A preliminary species list of these groups in

Table 7.1. Records of the butterfly species identified in the different forest remnants+

Forest remnant	Number of species
Chewia	20
Diwenyi	10
Fururu	17
Yale	11
Kasigau	14
Macha	10
Machora	14
Mbololo	16
Ngangao	15
Ronge	9

+Hesperiidae and Lycaenidae excluded in the Taita Hills, Kenya.

the main Taita Hills forest remnants is being compiled with assistance from specialists of these groups.

Table 7.1 shows the number of butterfly species identified so far in the different Taita Hills forest remnants. Characterisation of the beetles is in progress in collaboration with experts in these groups. Some of the carabid beetles have been sorted out to tribe and genus level. Preliminary sorting shows that the bulk of carabids from the Taita Hills fall into a large genus, *Metagonum* (Carabidae: Platynini). Other tribes of the Carabidae include Pterostichini, Peleciini, Masoreini, Panagaeini, Harpalini, Oodini and Lebiini. Many of the carabid specimens were found to belong to undescribed species. The Staphylinidae are still being sorted out with the help of experts. The relationship between these species to fragment size and altitude will be analysed in addition to other environmental influences of temperature, relative humidity, canopy cover, etc.

7.2 ASSESSING THE IMPACTS OF DIFFERENTLY MANAGED/UNMANAGED ENVIRONMENTS ON INSECT BIODIVERSITY

The processes of logging and conversion of forests to plantations and agricultural systems directly affect the original habitats. The exotic trees (cypress, pine and eucalyptus) planted by the Government in logged patches in the Taita Hills are believed to have exerted an indirect effect on biodiversity, by drying out the soil and suppressing the ground flora by shading. Accumulation of dead leaves is also heavy in these sites. This has resulted in loss of the original soil habitat, thus influencing biodiversity.

The important question to conservationists is how the different types of managed environments support biodiversity and how the different insect groups respond to disturbance gradients and managed regimes. Additionally, it is of particular interest to know what species of these target groups are supported outside of the remnants in mixed agricultural and unmanaged surroundings. Finding out the importance of the forest remnant in maintaining the insect populations not found in the matrix surrounding them would provide very relevant information to conservationists.

Five forest remnants representing a spectrum of land management options were selected for this study. In each of these remnants, traps were set along a 60-m transect at each trapping site, so that a total of 360 m representing 6 sites was sampled:

(a) Natural site of the remnant consisting only of indigenous trees (unmanaged)
(b) Partially disturbed site interspersed with planted exotic trees (partially managed)
(c) Logged site (forest gap and unmanaged)
(d) Afforested site (completely disturbed and managed)
(e) Forest surrounding matrix (unmanaged)
(f) Mixed subsistence agricultural site surrounding the forest remnant (disturbed and managed).

The data is currently being analysed.

7.3 LANDSCAPE ANALYSIS

Landscape analysis is in progress by the Taita Hills Biodiversity Project. This will provide data on the current sizes of the forest remnants, relative distances between the remnants, altitudinal differences, intermediate vegetation structure and any historical changes.

8. STUDIES OF INSECT COMMUNITIES IN NATURAL AND MANAGED ECOSYSTEMS

8.1 RAPID BIODIVERSITY ASSESSMENT USING TARGET GROUP HYMENOPTERA IN VARIOUS ECOSYSTEMS

Participating scientists: *N. Springate*, S.E. Miller*
*(*Visiting Scientist)*

Assistants: *R. O'Meara, V. Mahiva, B.A. Omolo*

Donors: *Royal Society (Hymenoptera study); British Ecological Society (tri-trophic study); collaborative funding from ICIPE's African Fruit Fly Initiative and Tsetse Project*

Collaborators: *• National Museums of Kenya • Natural History Museum (London) • Royal Botanic Garden (Edinburgh)*

Research continued on the suitability of Hymenoptera (wasps, bees and ants) as a target group in rapid biodiversity assessment (RBA) of Kenyan ecosystems, employing both long-term and spot-sampling in the field-layer. Pristine ecosystems investigated included upland and lowland forests and woodland/bushland/grassland mosaics in Kakamega, Mount Kenya, Machakos, Nairobi and Shimba Hills areas. The Rift Valley systems studied included acacia-dominated types at Mpala and Nguruman and a transect running from an inner craterine base to its rim at Crater Lake (Naivasha).

Overall, the studies (except for 'wet' season samples from Kakamega and Mount Kenya) showed a predominance of idiobiont (those which arrest the development of their hosts) endoparasitoids. This is in contrast with studies outside Kenya, which by concentrating on specific taxa of Hymenoptera rather than the group as a whole, have demonstrated a dominance of koinobionts (those which permit further development of their hosts).

Surveys of perturbed ecosystems continued with studies of tea- and cut-flower plantations in the Limuru and Lake Naivasha regions. With the exception of post-harvest samples from gramineous crops in the Timau District, there was a marked decrease in diversity as one progressed from the field margin into the centre of the agroecosystem, demonstrating the importance of the former in maintaining overall diversity in agroecosystems. Both this and the surveys of pristine systems indicate that longer-term studies give a better picture of hymenopteran diversity at both specific and higher taxon levels. *(See also Section C below on Agrobiodiversity)*

We expanded the Hymenoptera study into a unique 'tri-trophic' study of RBA, funded by The British Ecological Society and led by Lawrie S. Springate of the Royal Botanic Garden Edinburgh. Concentrating on forest fragments in the Nairobi and Machakos regions, simultaneous surveys were made of producers (Angiospermae) and primary (moths - Lepidoptera) and secondary (Hymenoptera) consumers on a spot-sampling basis. Opportunity was taken to train two Kenyan students in the basics of RBA during this programme.

8.1.1 *Environmental impact assessment of ICIPE's tsetse and fruit fly control*

In collaboration with ICIPE's Lethal Insect Technique (LIT) project for tsetse and the African Fruit Fly Initiative (AFFI) Programme, Hymenoptera were used to study the non-target effects of the application of control agents in the Nguruman region. Two 10-week studies of Hymenoptera diversity were made before the application of *Metarhizium anisopliae* and baited traps to control Glossinidae (tsetse fly) and Tephritidae (fruit fly) and catches analysed. Follow-up studies have been made (LIT) or are in progress (AFFI).

Identification and analysis of material from all three studies is in progress.

8.2 INSECT COMMUNITIES IN EAST AFRICAN FORESTS STUDIED BY CANOPY FOGGING

Participating scientists: *T. Wagner* (Museum Koenig and University of Bonn) (*Visiting scientist)*

Students: *Nadine Spitz (Bachelors student); Carsten Kneip (Masters student); and Eva-Maria Levermann (PhD student), all University of Bonn, Germany*

Donor: *German Science Foundation*

Collaborators: *•National Museums of Kenya • Kenya Wildlife Service • Museum Koenig • University of Bonn*

Forest canopy arthropods were sampled in January and February 1999 at various sites in Kenya, as an extension of earlier studies elsewhere in eastern Africa. Study sites included the Aberdare National Park, Mount Kenya National Park, Kikuyu Escarpment (Gatamayu), Kakamega Forest, and forest fragments near Nairobi.

Analysis of the material is in progress, but some preliminary observations are possible: The Gatamayu and Aberdare sites belong to a (more or less) closed block of forests, but the faunal overlap of beetles between these two sites is much lower than between the two disjunct sites, Aberdare and Mount Kenya. The weevils (Curculionidae) show a very high overlap between the 'true' montane forest sites, because they may be much better adapted to low temperatures. Many of these Curculionidae have closely related species in Europe. At Gatamayu, where another forest type occurs (about 300 m lower altitude), the diversity is higher and shows more overlap to the typical tropical sites, such as Kakamega Forest.

Dependant on funding, it is hoped to continue with these studies in Kenya, including comparison of (more or less) primary forest stands, adjacent secondary forests and forest fragments, in order to get data on biodiversity reduction under habitat fragmentation. These data should be of interest in understanding sustainable use of forest resources.

9. BIODIVERSITY STUDIES AT MPALA RESEARCH CENTRE

Background, approach and objectives

Mpala Research Centre is a field station situated in the Laikipia District of central Kenya near Mount Kenya, a region characterised by semi-arid savanna habitat. The Centre is a collaborative project of the Kenya Wildlife Service, National Museums of Kenya, Princeton University, and the Smithsonian Institution. The Centre is well situated in one of the most biologically interesting regions within Kenya, but almost no entomological study has been undertaken there. In addition to the specific project outputs, these projects are also solidifying collaboration between ICIPE and Mpala. ICIPE maintains a network of field stations in Kenya, and there are considerable potential benefits in the collaboration for both institutions, such as maximising use of facilities by both staff and visiting scientists.

9.1 INVENTORY OF MOTHS (LEPIDOPTERA)

Participating scientist: *S.E. Miller*

Assistants: *N. Onyimbo and others*

Donor: *Smithsonian Institution*

Collaborators: *• Mpala Research Centre • National Museums of Kenya • Natural History Museum (London) • Smithsonian Institution*

The inventory of the species of larger moths (Sphingoidea, Bombycoidea, Noctuoidea, Geometroidea, Zygaenoidea, and Pyraloidea) present at Mpala together with data on seasonality, will provide a baseline for further faunistic and ecological work at Mpala. It will also provide data for larger ICIPE projects and collaborators, mapping the distribution of selected species in Africa. The initial plan was to undertake a 1-year survey of moths at Mpala Research Centre. The sampling continued over 20 months because of the on-going drought, and was completed in December 1999. Specimen preparation is largely completed, but because of this extension, sampling, identification and analysis have only begun.

Blacklight sampling was undertaken on 24 nights in 11 sets from May 1998 to December 1999. Approximately 300 morphospecies of larger moths (Macrolepidoptera and Pyraloidea) have been segregated and tentative species identifications have been assigned to over half, using the National Museums of Kenya collection. Further identifications will be made at the Smithsonian and the Natural History Museum, London and an annotated checklist will be prepared; voucher collections will also be distributed. This survey of moths will have the direct impact of documenting a significant portion of the insect fauna at Mpala. The study has also had indirect impacts by promoting other research at Mpala and providing material for studies.

9.2 INVENTORY OF ANTS (HYMENOPTERA: FORMICIDAE)

Participating scientist: *R.R. Snelling (Visiting Scientist)*

Donor: *Smithsonian Institution*

Collaborators: • *Mpala Research Centre* • *National Museums of Kenya* • *Natural History Museum of Los Angeles County (USA)*

During September and October 1999, in the first of three visits that will allow seasonal coverage, 70 species of ants in the immediate vicinity of Mpala Research Centre, despite the dry conditions. Detailed identification of the species and preparation of taxonomic keys for their identification are in progress. The taxonomic information will be of immediate use to several projects already underway dealing with ant ecology at Mpala. This is one of the few detailed inventories of ants at a given site in East Africa (in contrast to West Africa, where there have been many more site-based studies). A reconnaissance visit was also made to Kakamega Forest, to assess the potential for further studies there.

9.3 IMPACT OF ANTS ON GROWTH AND REPRODUCTION OF *ACACIA DREPANOLOBIUM*

Participating scientist: *E.E. Lyons (Visiting scientist)*

Collaborators: • *Mpala Research Centre* • *National Museums of Kenya*

This project explores the impact of resident ant species on the growth and reproduction of *Acacia drepanolobium*, a small tree that covers millions of hectares in East Africa, particularly on black cotton soils. On any given tree, one of four ant species can live in the large swollen thorns (*Crematogaster mimosae*, *C. nigriceps*, and *Tetraponera penzigi*) or in the hollowed out, dead or dying parts of the stems (*C. sjostedti*). Trees with different resident ant species display different branch architecture and rates of flowering and fruiting. Trees with *C. nigriceps* residents tend to be more branched and to have few if any flowers. To determine whether the ants cause such changes, or whether they colonise trees with different attributes, an experimental plot was established at Mpala Research Centre in which ants of each species were permanently removed from some trees and not others. Bimonthly measures were initiated to document the number of leaves, flower buds, flowers and fruits on paired trees with and without ants.

Heavy browsing by an elephant herd several months into the project provided the first evidence that the presence of ants can influence elephant herbivory on *A. drepanolobium*. Trees from which ants had been removed suffered both a significantly greater likelihood of being browsed and branch lengths removed by the elephants.

Field observations and analysis are still underway.

10. IMPACT OF FRAGMENTATION IN THE COASTAL FOREST: CASE STUDY ON TERMITES (INSECTA: ISOPTERA)

Background, approach and objectives

The forest on the East African coast has existed for millions of years and has provided a refuge both for faunal and floral species that have evolved within it and for those that evolved outside. The resultant effect is a high level of endemism.

In the past, the forest covered an extensive area along the coast, but in the course of time, it has been destroyed to supply wood for fuel, building and carving. A large portion of the forest has been cleared to give way for farming and tourist development. As a result, the coastal forest remaining today exists as a series of small fragments, isolated from each other by expanding agricultural land, degraded scrubland and in some areas, savanna woodland. The remaining forest is of great conservation interest, since it is surrounded by an ever increasing human population that seeks to convert it to farmland.

Five forest fragments of different sizes were selected for the termite study. These are Arabuko Sokoke (size 41,716 ha), Marenje (size 1641 ha), Gongoni (900 ha), Muhaka (<200 ha) and Longo Mwagandi in Shimba Hills (<100 ha).

Termites are important indicators of human-induced changes since their species composition changes with alteration in landuse. When forests are cleared for agriculture or other forms of human development, termite species dependent on wood or woody litter decrease, while those with deep subterranean nests and ability to live on crops and crop residues increase. The key objective of this study is to establish and monitor the taxa of termites that habituate the fragmented forest. The taxa selected will be used for monitoring biotic response to anthropogenic environmental change associated with habitat fragmentation and modification.

Another output of the project will be evolution of identification keys for the coastal termites of Kenya. However, to be able to construct these taxonomic keys, it will be necessary to train staff in termite taxonomy.

The third output will be depiction of the relationship between termite species assemblage, microclimatic and edaphic factors and canopial and litter conditions. This project will seek to determine the extent of the edge effect and the resultant effect on termite species assemblage. This is important for the coastal forest, which has forest fragments of different sizes (the small 'kayas' for instance in comparison to larger forests such as Arabuko Sokoke). In addition, some of the larger forests may have only a few sites that possess the microclimate and structure of a 'normal' forest, with many of the sites having been subjected to heavy disturbance (for instance logging); this has not been investigated.

Leaf litter is an important habitat for arthropods in general, which are involved in its decomposition. This project seeks to document the termite species that inhabit the leaf litter, an area that has been poorly studied.

The canopy of a forest is in constant change with factors such as tree felling and old age, causing tree fall and creating canopy gaps. The relationship between canopial conditions and termite assemblage will be elucidated in this project. Likewise, the soil is among the most complex habitat systems. Sampling termites will generate substantial information regarding soil biodiversity.

Participating scientist: *L. Wekesa (ARPPIS scholar), L. Rogo*

Donor: *DSO*

Work in progress

The project began in January, 1999 and sampling is scheduled to end in October, 2000. Sampling is being conducted along 52 standardised transects established in five forest fragments. In each forest, a transect is located at the centre and at the edge. Wherever possible, an additional transect is laid in surrounding agricultural land or plantation. To date, 37 transects have been laid and sampled. The primary data being collected along each transect consists of the termite species sampled from the soil, leaf litter, tree trunks, epigeal mounds and wood. Data on atmospheric temperature and humidity, soil temperature and specific aspects of vegetation (percent canopy cover, density of dead, fallen trees, canopy and mid-canopy height and litter depth) is also being collected. A soil sample for analysis of standard soil groups, organic carbon, total nitrogen and particle size is being collected from each transect.

Identification of the collected termite specimens collected thus far is in progress.

11. MISSION OF THE CANOPY RAFT IN GABON: ENTOMOLOGICAL ASPECTS

Background, approach and objectives

Arthropods of the uppermost layer of leaves in the forest canopy, have rarely been selectively surveyed and studied in tropical rain forests. Fogging and light-trapping are unsuitable to selectively collect the arthropods of the upper canopy. The mission of the 'canopy raft', led by Prof. Francis Hallé (University of Montpellier, France), at La Makandé, Gabon (0° 40' 39" S, 11° 54' 35" E, 200–700 m asl), provided the opportunity to sample arthropods from the upper canopy of a lowland and undisturbed forest from January to March 1999. Canopy access was provided by the 'Radeau des Cimes' (canopy raft), the 'luge' (sledge), and the 'bulle des cimes' (treetop bubble). The canopy raft is a 580 m^2 platform of hexagonal shape, consisting of air-inflated beams and aramide netting. An air-inflated dirigible of 7500 m^3 lifts the raft and places it on the canopy. The raft is positioned at particular sites on the canopy and moved every fortnight by the dirigible. Access to the raft is provided by single rope techniques. The sledge is a triangular platform of about 16 m^2 which is suspended below the dirigible and 'glides' over the canopy at low speed. The bubble is an individual 180 m^3 helium balloon of 6 m in diameter, which runs along a fixed line set up in the upper canopy by the dirigible (treetop bubble). More information is online at www.radeau-des-cimes.com.

ICIPE sent Kenyan student Robert O'Meara, who helped with all aspects of sampling and pre-sorting of the material at La Makandé. He also helped in collecting leaves from the upper canopy and measuring insect damage there, as part of a survey organised by Margaret Lowman (Selby Botanical Gardens, Sarasota, Florida, USA). The group included the following professional entomologists: Yves Basset (Smithsonian Tropical Research Institute, Panama), Henri-Pierre Aberlenc (CIRAD, France), Hector Barrios (University of Panama), Gianfranco Curletti (Museo Civico di Storia Naturale, Carmagnola, Italy); and a group of volunteers and students.

11.1 ENTOMOLOGICAL SURVEYS

Participating student: *R. O'Meara, S. Miller*

The abundance, activity and species richness of arthropods, particularly of insect herbivores, were estimated in the upper canopy and understorey at La Makandé.

In total 14,161 arthropods were collected with beating, interception-flight and sticky traps, from 6 different canopy sites during day and night, from mid-January to mid-March 1999. Strata effects were most important, representing between 40 and 70% of the explained variance in arthropod distribution. Site effects represented between 20 and 40 % of the variance and emphasised the need for replication among canopy sites. Time effects (diel activity) explained a much lower fraction of variance (6–9%). The density and abundance of many arthropod taxa and species were significantly higher in the upper canopy than in the understorey. Arthropod activity was also higher during the day than night. In particular, insect herbivores were 2.5 times more abundant and twice as speciose in the upper canopy than in the understorey, probably responding to the higher and more diverse food resources in the former stratum.

Faunal overlap between the upper canopy and understorey was low. The most dissimilar herbivore communities foraged in the understorey at night and the upper canopy during day. A taxonomic study of a species-rich genus of herbivore collected at La Makandé (Coleoptera: Bupresetidae: *Agrilus*) confirmed that the fauna of the upper canopy was different, diverse and very poorly known. Herbivore turnover between day and night was rather high in the upper canopy and no strong influx of insect herbivores from the lower foliage to the upper canopy was detected during the night. This suggests that insect herbivores of the upper canopy may be resident and well adapted to environmental conditions there. Several manuscripts are in preparation.

C. AGROBIODIVERSITY STUDIES

12. IDENTIFICATION OF THE KEY POLLINATORS OF THE EGGPLANT (*SOLANUM MELONGENA* L.) IN NGURUMAN AND THEIR CONSERVATION

Background, approach and objectives

A direct consequence of sedentary cultivation in many regions of sub-Saharan Africa is the clearing of forests to create space for cultivation. The agricultural crops subsequently cultivated are generally not native to the area, but the pollinators which service them are. The pollinators in small areas of forest which are cleared for agriculture forage on wild plants and cultivated crops. Wild plants which are native to the area serve as an alternative source of of both pollen and nectar to the pollinators, especially when the cultivated crops are not flowering, or provide only one resource and not the other. The wild host plants and pollinator nesting sites are lost when forests are cleared, creating an imbalance in the pollination ecology of the area. Should forest clearing continue to intensify, the yields of crops may decrease since there will be fewer pollinators available. This pollination 'subsidy' which the natural environment provides to agriculture is an important one, and is all too often appreciated only after it is lost.

It is important to establish the most prominent pollinator species and the most effective pollinators of crops in farming areas currently undergoing development as the result of clearing of indigenous plant habitats. This will help farmers appreciate the measures needed to stem environmental degradation and increase their agricultural productivity.

Participating scientist: *B. Gemmill* (Visiting Scientist)

Student: *A. Ochieng*

Collaborators: • *Xerces Society* • *University of Nairobi*

Work in progress

In this study, carried out in the vicinity of ICIPE's Nguruman Field Station in southwestern Kenya, 10 bee species were identified as eggplant pollinators. The foraging behaviour of these pollinators was shown to be affected by temperature, time of day and the number of flowers per square meter in eggplant fields. Only two bee species, *Xylocopa senior* Vachal 1897 (Anthophoridae) and *Nomia* sp. Latrielle, 1804 (Halictidae), visited the eggplant blossoms frequently. Their effectiveness as pollinators was determined in two varieties of eggplant. *Xylocopa senior* proved to be the most efficient pollinator of eggplant.

Floral manipulations undertaken to study the most effective mode of pollination revealed that eggplant is self-compatible, but does not set fruit in the absence of insect visitors. Flowers that were hand-pollinated with pollen from their own anthers resulted in fruits of high fresh weight and seed set. Eggplants therefore need an effective mode of pollination to transfer the pollen from the anthers to the stigmas. The fresh fruit weight and seed set in fruits that were open-pollinated were higher than in self-pollinated flowers, but not as high as in the hand-pollinated flowers.

12.1 THE SPATIAL AND TEMPORAL DISTRIBUTION OF THE EGGPLANT POLLINATORS AND THEIR ALTERNATIVE FORAGE RESOURCES IN THE HABITATS AROUND THE FARMS

The alternative resources that the pollinators foraged were determined. A total of 12 alternative plant species were identified over a 5- month period along a transect traversing the surrounding wild habitat. None of the 12 plant species that served as an alternative forage to the eggplant pollinators was found in all the four habitats that surrounded the farmlands: farmland path edges, moist riparian forest, grassland, and dry Acacia woodland.

Justicia flava (Acanthaceae), *Commicarpus helenae* (Nyctaginaceae) and *Duosperma kilimandscharica* (Acanthaceae), which were visited most by the pollinators, occurred mainly in the farmlands. *Justicia flava* and *C. helenae* flowered during the entire study period, while *D. kilimandscharica* was in blossom for only 3 months (Table 12.1). These three species served as the most important alternatives for the eggplant pollinators. The bees foraged the farmland more frequently compared to the other habitats. The ratio

Table 12.1. Spatial and temporal distribution of eggplant pollinators and their alternative forage resources in Nguruman, Kenya

Habitat	% pollinator : % habitat cover	Plants species (Family)	Period of flowering*	Pollinator species
Farmlands	2.65	*Justicia flava* (Acanthaceae) *Commicarpus helenae* (Nyctaginaceae) *Duosperma kilimandscharicum* (Acanthaceae)	Jan, Feb, March, May, June Jan, Feb, March, May, June Jan, Feb, March,	*Xylocopa senior, Apis mellifera* Linn., *Pseudapis* sp., *Amegilla calens* Lepeletier, 1841 and *X. albiceps* Fabricius, 1804
Riparian forest	0.78	*Solanum incanum* (Solanaceae) *Lippia javanica* (Verbenaceae) *Tephrosia villosa* (Fabaceae) *Corida sinensis* (Boraginaceae) *Grewia bicolor* (Tiliaceae)	Jan, Feb, March, May, June Feb, March, Jan, Feb, June Jan, Feb, March, Jan, Feb,	*X. senior, A. mellifera, X. albiceps*
Grassland	0.08	*Solanum incanum* (Solanaceae)	Jan, Feb, March, May, June	*X. senior*
Dry acacia woodland	0.16	*Acacia mellifera* (Fabaceae) *Cadaba farinosa* (Capparaceae)	June June	*X. senior*

*Average over 5 months.

of the percentage numbers of bees to cover of the habitat in the farmland averaged 2.65, showing that the bees preferentially foraged this habitat. All the pollinator species were present in this habitat.

In the riparian forest, there were five plant species visited by the pollinators, namely *Solanum incanum* (Solanaceae), *Lippia javanica*(Verbenaceae), *Tephrosia villosa*(Fabaceae), *Cordia sinensis* (Boraginaceae) and *Grewia bicolor* (Tiliaceae). These plants only flowered for short periods of time as compared to the plants in the farmland. The riparian forest had the next highest number of pollinators. The average ratio of the % number of pollinators to the % cover of the habitat averaged 0.78. This habitat was preferentially foraged in February when all five alternative forage species in the habitat were flowering. During this month, the ratio of the % number of pollinators to cover of the habitat was 1.61.

In the grassland, only *S. incanum* served as an alternative resource and was visited only by *X. senior*. This habitat was the least preferred by the pollinators, and the ratio of the % number of bees to cover of the habitat averaged 0.08, which was very low compared to the farmland and the riparian forest. .

There were only two alternative forage resources in the dry woodland, *Acacia mellifera*(Fabaceae) and *Cadabe farinosa* (Capparaceae), and these flowered only in June. The ratio of the % number of bees to habitat cover averaged 0.16. Only *X. senior* foraged here, and they swarmed in large numbers over the trees. This explains why, although the trees flowered only in June, the woodland appeared more foraged by the pollinators than the grassland where *S. incanum* was flowering throughout the study, but was not foraged much.

An assessment of the relative abundance of the bees based on their frequencies (and the time spent in the habitat) showed that *X. senior* was the most abundant pollinator species. It was present in all the habitats and visited all the flowering plants that were found therein.

The most important habitat for the pollinators in terms of alternative forage resources is the farmland that comprises the farm edges, fallow land and the footpaths. The farmland is rich in alternative forage plant species and is not a habitat under threat. It was interesting to note, however, that the weeds in this area are almost all adventitious indigenous species, not cosmopolitan introduced noxious plants.

The riparian forest, which is the habitat that is under immediate threat by the farmers, was also heavily foraged in one critical time period. Had the study not collected information on spatial foraging patterns over time, this critical use may have been missed, and one might conclude that the forest did not supply alternate pollinator resources; the loss of the forest might remove a resource that serves to carry the pollinators through the dry season. Moreover, the dead dry wood found in this habitat is important as nesting sites for *X. senior*. Clearing of riparian forest, which is mainly done for charcoal production and increased cultivation, should therefore be checked so that nesting sites for this most important pollinator, are not lost.

13. EFFECTS OF IMPROVED FALLOWS ON NEMATODE BIODIVERSITY IN MAIZE-BASED AGROFORESTRY SYSTEMS OF WESTERN KENYA

Background, approach and objectives

In the densely populated highlands of western Kenya, the continuous cultivation of farmlands without adequate use of inputs has led to a widespread and steady decline of soil fertility. This situation is aggravated by two major factors. On the one hand, farmers lack the financial resources to purchase the inorganic fertilisers necessary to enhance maize production; on the other hand, the long duration of natural fallows, which have been traditionally used to restore soil fertility, are no longer sustainable due to population pressure. As a result, farm productivity in the area is low and local populations experience food shortages for 3 to 9 months of the year.

Planting of fast-growing legume trees or shrubs in exhausted soils has been tested in the area and has shown great potential in improving soil fertility and increasing crop production. There is a considerable body of results reporting on the benefits of this 'improved fallow' technology, and the mechanisms through which it improves the soil's physical and chemical properties are fairly well documented. However, there is a knowledge gap on the effect of these legume trees or shrubs on soil organisms.

The woody species used for improved fallows in western Kenya are known to be the hosts of some types of nematodes which can become detrimental to crop production if they reach a certain population level in the soil. The overwhelming majority of the Phylum Nematoda are harmless to crops and play a crucial role in the ecological processes of the soil. A few nematode species constitute a real threat to croplands and are responsible for heavy yield losses worldwide. Therefore, the role of trees on the build-up of such pathogenic nematodes on farms must be better understood if tree-planting is to remain productive and sustainable. This study was undertaken to find answers to this problem.

Participating scientists: *S. T. Kandji, S. Miller*

Donor: *German Academic Exchange Service (DAAD)*

Collaborators: • *International Centre for Research in Agroforestry (ICRAF), Nairobi* • *Institut de Recherches pour le Developpement (IRD), Dakar, Senegal* • *Kenyatta University, Nairobi*

Work in progress

A nematode survey was conducted in the highlands of western Kenya (latitude 0.00, longitude 35'50 east). Plots (70), distributed in seven different kinds of land uses (natural fallows, maize/beans farms, *Sesbania sesban* planted fallows, *Crotalaria grahamiana* planted fallows, *Tephrosia vogelii* planted fallows, *Sesbania-Crotalaria* mixed planted fallows and *Crotalaria-Tephrosia* mixed planted fallows) were systematically sampled. In each plot, samples were collected in the top 15 cm of soil in five different spots. The five samples from each plot were then mixed to make a homogeneous composite sample. Nematode extraction was done with the composite samples using the elutriation method.

Table 13a compares the nematode populations in the land use systems studied. In general, the planting of trees/shrubs in the croplands increased the populations of both plant-parasitic and free-living (microtrophic, predatory and detritivorous) nematodes in the soil. This increase in nematode populations is an indication of the improvement in the soil's physical and chemical properties. The lowest

Table 13a. Densities (log transformed) of the two trophic groups and total nematode populations under different land uses

	Nematode taxa		
Land use system	Parasitic nematodes	Free-living nematodes	Total nematodes
Maize–beans farms	3.20 bc	2.77 b	3.34 c
Natural fallows	2.96 c	3.32 a	3.51 bc
Crotalaria fallows	3.66 ab	3.42 a	3.87 ab
Sesbania fallows	3.50 abc	3.35 a	3.75 abc
Tephrosia fallows	3.54 ab	3.56 a	3.87 ab
Crotalaria/Sesbania fallows	3.51 abc	3.47 a	3.83 ab
Crotalaria/Tephrosia fallows	3.84 a	3.67 a	4.14 a
$F_{0.05}$	< .001	< .001	< .001

Means in the same column followed by different letters are significantly different by Tukey's test.

populations of free-living nematodes were recorded in the maize/beans farms, a phenomenon associated with the degradation of the soil's properties and the loss of fertility through cultivation. On the other hand, the pathogenic nematodes had their lowest densities in the natural fallows. This is consistent with the results of previous studies, and supports the use of natural fallows as an effective means of sanitising fields from nematodes.

The major plant-parasitic nematode species identified in the area are listed in Table 13b. A typology of the different land uses according to the species composition and structure of their nematode communities can now be made: The cultivated farms and the natural fallows, which are the two land uses traditionally practised in the area, yielded the most species. Significantly fewer nematode species were found in the improved fallows.

The cultivated farms were characterised by a dominance of root-lesion nematodes, *Pratylenchus zeae* and *P. brachyurus*, which made up 58% of the community. Rare species (*Xiphinema* spp., *Paratrichodorus* spp., *Ditylenchus* spp. and *Tylenchorenchus* spp., were also present but were virtually absent in the other land uses (Table 13c). In the *Crotalaria* fallows, there was an overwhelming dominance of the root-lesion nematodes (60%) and the spiral nematodes (*Scutellonema* spp. and *Helicotylenchus* spp.), which represented 38% of the nematode community. In the fallows planted to *S. sesban*, the predominant species were the root-knot nematodes *Meloidogyne javanica* and *M. incognita* (40%), and root-lesion nematodes (26%) and *Rotylenchulus borealis* (20%).

The *Tephrosia* plantations were characterised by a predominance of the spiral nematodes (49%) and

Table 13b. Major plant-parasitic nematode species and their distribution in seven different land use systems in western Kenya

Nematode species	Maize/ beans farms	Natural fallows	*Crotalaria* fallows	*Sesbania* fallows	*Tephrosia* fallows	*Crotalaria*/ *Sesbania*	*Crotalaria*/ *Tephrosia*
Pratylenchus brachyurus	++	++	++	0	0	++	++
Pratylenchus zeae	+++	++	+++	++	++	+++	+++
Meloidogyne incognita	++	++	0	++	++	++	++
Meloidogyne javanica	++	++	++	+++	+++	+++	+++
Helicotylenchus dihystera	++	++	+	++	+	++	++
Helicotylenchus pseudorobustus	++	++	+	+	+	+	+
Scutellonema clathricaudatum	++	+++	+++	+++	+++	+++	+++
Scutellonema magniphasmum	++	+++	+++	++	+++	+++	+++
Scutellonema brachyurum	++	++	+++	++	++	++	++
Scutellonema unum	+	0	0	0	0	0	0
Hemicriconemoides snoecki	+	+	0	0	+	0	+
Rotylenchulus borealis	++	+	+	+	+	+	+
Xiphinema elongatum	+	+	+	+	0	+	+
Xiphinema pinoides	+	+	+	0	+	+	+
Xiphinema setariae	+	0	+	0	+	0	0
Paratrichodorus minor	+	+	0	0	0	+	0
Ditylenchus spp.	+	+	+	0	0	+	0
Tylenchorenchus spp.	+	+	0	0	0	0	0

+++ observed in all plots; ++ observed in most plots; + observed in a few plots; 0 not observed.

Table 13c. Density (log transformed) of the major plant-parasitic nematode genera in the different land uses

	Nematode/Abundance (%)											
Land uses	*Pratylenchus*		*Helicotylenchus*		*Scutellonema*		*Rotylenchulus*		*Meloidogyne*		Dorylaimids	
Maize/beans	2.93 ab	(58)	1.11a	(14)	2.41 b	(19	1.20 a	(2)	0.92 b	(4)	1.88	(4)
Natural fallow	2.08 ab	(22)	1.52 a	(12)	2.19 b	(26)	0.99 a	(6)	1.74 ab	(33)	1.35	(2)
Crotalaria	3.38 a	(60)	0.66 a	(2)	3.08 ab	(36)	0.00 a	-	0.33 b	(1)	0.00	-
Sesbania	2.26 ab	(26)	1.81 a	(5	2.29 b	(9)	1.86 a	(20)	3.05 a	(40)	1.23	-
Tephrosia	1.71 b	(6)	0.84 a	(3)	2.88 ab	(46)	0.42 a	(1)	3.22 a	(43)	0.00	-
Crotalaria/ *Sesbania*	2.56 ab	(29)	1.78 a	(6)	2.94 ab	(40)	0.69 a	(8)	1.50 ab	(17)	0.00	-
Crotalaria/ *Tephrosia*	3.10 ab	(15)	1.49 a	(7)	3.43 a	(68)	1.31 a	(2)	1.88 ab	(8)	0.00	-

Means in the same column with different letters are significantly different by Tukey's test; the relative abundance of each genus in every land use is given in percentage.

root-knot nematodes (43%). The mixed-planted fallows showed a predominance of the genus *Scutellonema*, but also a strong presence of *Pratylenchus* and *Meloidogyne*.

Diversity indices have been calculated from the relative abundance of the different nematode genera in the different land uses (Table 13d). The most diverse nematode communities were found in the natural fallows and the planted fallows involving *S. sesban*. This situation is related to the more balanced distribution of the different nematodes in these land uses. Conversely, improved fallows and the maize/beans farms favoured the dominance of a few genera, reducing the diversity of the nematode communities.

The replacement of natural fallows by plantations of legume trees is a rapid and effective means to restoring fertility in degraded soils. This improvement of the soil properties is often reflected in the development of soil organisms, as exemplified by the increase in numbers of nematodes in the soil. This study has shown, however, that while the total number of nematodes increased substantially in the improved fallow plots, the number of species declined dramatically, generally resulting in a loss of diversity in the nematode communities. Improved fallows, therefore, favour a selection of nematodes.

The genus *Meloidogyne*, although polyphagous, recorded its highest populations in the plots planted to *T. vogelii* and *S. sesban*, which confirms the host status of both these plants to this nematode. *Pratylenchus* spp., which are common parasites of maize, built up high populations in the *Crotalaria* fallows.

This loss of biodiversity and the concentration of these parasitic nematodes raise concern, as the nematode species that thrive in the presence of the trees are among the most damaging species and attack the main crops grown in the area, i.e. maize and beans. Therefore, an appropriate understanding of the effect of the different combinations of nematodes (resulting from different combinations of trees) on the production of both these crops must be considered among the top research priorities. A judicious selection

Table 13d. Number of species, diversity index and evenness of plant-parasitic nematode communities in different land use systems

Land use	Number of species	Shanon diversity index (H)	Evenness (J)
Natural fallows	16	2.22	0.79
Sesbania fallows	10	2.06	0.80
Crotalaria/ *Sesbania* fallows	14	2.01	0.87
Maize/beans farm	18	1.78	0.63
Tephrosia fallows	12	1.51	0.65
Crotalaria/ *Tephrosia* fallows	13	1.47	0.63
Crotalaria fallows	13	1.16	0.58

of fallow trees and crops to be rotated, based on the knowledge of the host range and pathogenicity of the different nematode species, is needed if improved fallow is to remain a successful and sustainable practice in western Kenya.

D. CONSERVATION OF BIODIVERSITY THROUGH BIOPROSPECTING AND NATURAL PRODUCTS CHEMISTRY

Background, approach and objectives

Biodiversity continues to be destroyed worldwide due to economic and population pressures, and lack of awareness about the importance of its conservation. With this destruction is a corresponding loss of a vast wealth of useful plant arthropods and other animal species which could provide useful products for humankind. Bioprospecting, the systematic search, development and commercialisation of useful chemical products from natural sources, is now recognised as a possible means to biodiversity conservation. It may also be the last chance to rescue irreplaceable biological and associated chemical content evolved by species over millions of years, before it is lost forever. Bioprospecting will promote conservation only if the benefits that arise are shared with the custodians of biodiversity: the communities themselves.

The overall objective of the Bioprospecting Project at ICIPE is to contribute to the conservation of biodiversity through bioprospecting. The specific objectives are to:

- build awareness at ICIPE and among potential collaborating institutions in the complex area of bioprospecting, including value-adding opportunities in bioprospecting, sharing of benefits and intellectual property rights related to bioprospecting;
- initiate, promote and coordinate networks of collaborating scientists and institutions in Africa that are capable of working together on various bioprospecting projects;
- initiate and model collaborative projects that involve discovery, development, commercialisation, sharing of benefits and linking of bioprospecting to conservation of biodiversity.

In 1998 and 1999, ICIPE made major contributions in these areas, as follows:

14. AWARENESS BUILDING IN BIOPROSPECTING

14.1 ICIPE-IOCD WORKSHOP ON BIOPROSPECTING

Participating scientists: *W. Lwande*, S. Miller, L. Rogo, B. Frei, H. Herren , B. Gemmill+* (*Project Leader), (+Visiting Scientist)

Donors: *Novartis Foundation; Monsanto Life Sciences Company; Beckman Instruments; Swama*

Collaborator: *• The International Organisation of Chemical Sciences in Development (IOCD)*

ICIPE requested the International Organisation of Chemical Sciences in Development (IOCD) for assistance in developing projects on bioprospecting designed to encourage conservation of biodiversity. In July and August, 1998 IOCD sent a team of three volunteers with experience in bioprospecting, business and technology to Kenya and Uganda, to advise ICIPE and its potential partners on possible bioprospecting projects. This was done through a series of workshops, meetings, seminars and field trips. The team consisted of the following:

- Prof. Charles Weiss, Head of the IOCD mission, Distinguished Professor at Georgetown University School of Foreign Service in the USA, and former Science and Technology Advisor to the World Bank, and an Executive Officer of the IOCD Biotic Exploration Fund.
- Dr John Kilama, Chairman of the Global Biodiversity Institute and Senior Researcher at Dupont Agricultural Enterprises.
- Dr Tesfaye Biftu, Senior Investigator at Merck Pharmaceuticals.

The IOCD mission helped ICIPE and its potential collaborators to explore means of bioprospecting that promote sustainable development and conservation, while respecting intellectual property rights and supporting development of local research and production capacity. The mission served adual purpose as part of ICIPE's community outreach and capacity building programme and as an element of ICIPE's internal planning on how to apply bioprospecting opportunities to meet its development mandate.

Activities undertaken during the 16-day mission included a 3-day workshop in Nairobi with a wide cross-section of stakeholders (72 participants from 39 government and non-government agencies, organisations and businesses); a 1- day workshop in Kampala with a partial cross-section of stakeholders (29 participants from 8 government agencies and university departments); visits to government agencies, research and conservation organisations, businesses, traditional healers, and conservation areas; and a widely advertised public lecture in Nairobi (attended by over 70 people).

The two workshops in Kenya and Uganda were an eye opener for most of the participants. They led to the realisation that collaboration among African scientists and institutions is important for success. They also led to initiation of plans for various projects.

18.2 TRAINING COURSE ON BIOPROSPECTING, BIOTECHNOLOGY AND LAW

Participating scientists: *W. Lwande, H. Herren*

Donors: *USAID, MacArthur Foundation, Novartis Foundation*

Collaborator: *The Global Biodiversity Institute (GBDI)*

A 3-week training course on bioprospecting, biotechnology and law was organised by the Global Biodiversity Institute (GBDI), USA and ICIPE. The aim of the course was to produce a core of African experts involved in bioprospecting, who possess the requisite skills and knowledge to negotiate equitable agreements related to bioprospecting access to genetic resources and biotechnology research, principally between transnational corporations and the full range of local stakeholders. Scientists (21), intellectual property professionals and lawyers from 16 institutions in Tanzania, Uganda and Kenya attended the course.

The course took place at the ICIPE headquarters from 26 July to 14 August 1999. It focused on four principal modules: (i) the business of bioprospecting, (ii) constructing a contractual agreement, (iii) managing intellectual property, and (iv) benefit sharing. There were also cross-cutting issues such as the international context and the role of public sector institutions. An additional benefit was the development of a network for both intellectual support and the creation of contacts for bioprospecting among the East African institutions.

The course was conducted by an international faculty drawn from four continents, and provided the highest standard of technical training. The faculty included the following:

- Mr Preston T. Scott, Executive Director, World Foundation for Environment and Development (WFED), USA
- Dr Nicholas Mateo, Coordinator, Bioprospecting Program, National Biodiversity Institute (INBio), Costa Rica.
- Dr Philip Grubb, Senior Intellectual Property Specialist, Novartis International AG, Switzerland.
- Ms Rosemary Wolson, Office of Industry Liaison, University of Cape Town, South Africa
- Mr Mike Gollin, Partner, Venable, Baetjer, Howard, Civiletti, LLP, USA
- Dr John Kilama, President. Global Biodiversity Institute Inc., USA
- Ms Tomoko Miyamoto, World Intellectual Property Organisation (WIPO), Switzerland

The training course was successful in producing a knowledgeable team of 21 African scientists, intellectual property professionals and lawyers from 16 institutions in three African countries: Tanzania, Uganda and Kenya. The team is capable of effectively conducting their bioprospecting activities in a manner that is more profitable for their institutions, countries and for the conservation of biodiversity.

14.3 NETWORKS OF COLLABORATING SCIENTISTS AND INSTITUTIONS IN AFRICA

14.3.1 *Network for bioprospecting for mosquito repellent and insecticidal plants in East Africa*

Participating scientists: *A. Hassanali, W. Lwande, B. Knols, B. Frei*

Donors: *World Bank/UNDP/WHO*

Collaborators: *• Kenyatta University, Kenya • University of Dar-es-Salaam, Tanzania • Makerere University, Uganda • Addis Ababa University, Ethiopia • Jomo Kenyatta University of Agriculture and Technology, Kenya • Jestan Herbal Health Clinic Inc., Kenya*

During the period in review, ICIPE was awarded a research grant from WHO/World Bank/UNDP for networking among seven institutions in East Africa in a bioprospecting project coordinated at ICIPE. The Project, which commenced operations in June 1999, is on bioprospecting for mosquito repellents, insecticidal plants and associated natural products, through partnership between complementary institutions. The institutions involved include ICIPE (with a strong background and capability in analytical chemistry, vector ecology, behaviour and chemical ecology), the University of Dar-es-Salaam, Kenyatta University, Makerere University, Addis Ababa University, and Jomo Kenyatta University of Agriculture and Technology. The mandate in capacity building at all levels includes working a private traditional herbal clinic (Jestan Herbal Health Clinic Inc.).

The partners are screening for anti-mosquito plants, and developing plant products and working towards their integrated use in rural areas. They are also promoting the use of plants, partially processed plant materials and appropriate technologies in the commercial exploitation of safe phytochemicals. The Project is integrating all R&D work with postgraduate training, with an emphasis on interdisciplinary work, thereby making a significant contribution to capability and capacity building in bioprospecting.

14.3.2 *Bioprospecting network for Africa*

Participating scientists: *H. Herren, W. Lwande, A. Hassanali*

Assistants: *E. Nyandat, D. Mbuvi, L. Moreka*

Donor: *International Centre for Scientific Culture (ICSC)-World Laboratory*

In the period under review, the ICSC-World Laboratory funded a project on bioprospecting networking for Africa. The Project was aimed at building capacity in bioprospecting through networking among African institutions. The Project supported three activities: hosting of selected African scientists, provision of mass spectral services to African scientists and institutions, and improvement of analytical facilities at ICIPE.

Hosting of selected African scientists

In 1998 and 1999, ICIPE hosted seven African scientists from seven institutions in four African countries. The scientists worked at ICIPE on various bioprospecting projects, including discovery, development and commercialisation of anti-insect and medicinal natural products. The scientists included the following:

- Prof. Julius Mwangi from Kenya, Department of Pharmacology and Pharmacognosy, University of Nairobi;
- Dr Francis S.K. Tayman from Ghana, Department of Chemistry, University of Cape Coast;
- Dr Ogwal-Okeng from Uganda, Department of Pharmacology and Therapeutics, Makerere University;
- Dr Timothy Epidi from Nigeria;
- Dr Geoffrey Rukunga from Kenya, Traditional Medicines and Drugs Research Centre, Kenya Medical Research Institute;
- Mr Andrew Chapya from Kenya, Jestan Herbal Health Clinic, Inc.

The scientists made substantial achievements in their research work. Some products were also developed that are currently in the commercialisation phase.

Mass spectral analytical services for African scientists

Lack of chemical analytical facilities in good working condition is a major handicap to African scientists working in the area of bioprospecting. These are essential for characterisation of chemicals after extraction, fractionation and isolation of potentially useful chemicals from natural sources. Through funding from the ICSC-World Laboratory, ICIPE offered mass spectral services to African scientists in more than 10 countries working in the area of bioprospecting, and who do not have access to mass spectrometers.

Improvement of analytical facilities

In 1998, the ICSC-World Laboratory improved ICIPE's laboratory facilities through purchase of a new high-pressure liquid chromatograph (HPLC). The new HPLC, a Beckman Gold Nouveau System equipped with a UV detector, has been linked to the existing VG Platform II gas chromatograph-mass spectrometer (GC-MS) and has enabled the Centre to perform the following operations more effectively:

- Atmospheric pressure ionisation liquid chromatography-mass spectrometry (API LC-MS)
- Atmospheric pressure chemical ionisation liquid chromatography-mass spectrometry (APCI LC-MS)
- Electrospray liquid chromatography-mass spectrometry (ESI LC-MS)

15. A MODEL PROJECT TO LINK PRODUCTS FROM BIOPROSPECTING TO CONSERVATION OF BIODIVERSTITY

Participating scientists: *W. Lwande, A. Hassanali, L. Rogo, H. Herren*

Assistants: *D. Mbuvi, L. Moreka*

Donors: *ICSC-World laboratory, GEF/UNDP*

Collaborator: *University of Nairobi*

In 1998 and 1999, collaborative R&D work between the University of Nairobi and ICIPE, led to the development of several natural products of commercial potential. One of the products went through the process of market evaluation, agronomic studies of the source plants and economic feasibility evaluation, to assess the cost of production and level of profitability of the product. Called *'Naturub'*, the product can be used for alleviating insect bites, cold, flu, muscular aches and pains. It is formulated from essential oils derived from an indigenous plant. Agronomic studies of the plant conducted at ICIPE showed that the plant is easy to grow both by vegetative means (cuttings) and seed propagation.

In a market evaluation conducted in Kenya in 1999, the product received a very good reception. More than 90% of the respondents found it to be effective and recommended that it should be sold on the market. More than 90% preferred it to similar products on the market that are based on synthetic principal ingredients. Interestingly, all of the respondents preferred natural products to synthetic substances. In their opinion, 25 g of the product should be sold at between US $ 0.5 to 1.00.

In 2000, ICIPE and the University of Nairobi will make this product available in a project that will act as a model to further emphasise how bioprospecting can contribute to biodiversity conservation. The community-based project will utilise the indigenous plant and *Naturub*, the product developed from it, in efforts to conserve the highly endangered Kakamega Forest in western Kenya. The farmers will grow the plants as an alternative income-generating activity, thereby reducing their dependence on forest products.

The community of farmers at Kakamega have formed and registered a group, the Muliru Farmers Conservation Group, that will undertake the cultivation of the plant. Steam distillation equipment will also be installed for the farmers to distill and sell the essential oil for manufacture of the product. It is anticipated that the project will initiate commercial production of other essential oils, most of which are currently imported into Kenya.

Impact

Biodiversity and Conservation is a new Programme and many of the initial products are still under development, so measures of impact are hard to evaluate. The Programme grew out of an extensive consultative process with stakeholders and collaborators. Many international agencies and organisations, such as the Convention on Biological Diversity (CBD), FAO, DIVERSITAS, and Bionet International, continue to publish reports emphasising the need for the kinds of products that the programme plans to produce.

There has also been enthusiastic feedback on our workshops and World Wide Web products, especially from users in East Africa. Finally, the invitation of ICIPE to a series of functions hosted by CBD, DIVERSITAS, FAO and other international bodies, shows recognition of what ICIPE can contribute.

Output

Publications

Basset Y., Aberlenc H. P., Barrios H., Curletti G., Béranger J.M., Vesco J.P., Causse P., Haug A., Hennion A.S., Lesobre L., Marques F. and O'Meara R. Stratification and diel activity of arthropods foraging within the upper canopy and understorey of a rain forest at La Makandé, Gabon. In: F. Hallé (ed) *Biologie d'une canopé de forêt équatoriale -IV. Rapport de Mission: Radeau des cimes janver mars 1999, La Makandeé, Gabon.* (In press).

Curletti G., Aberlenc H.P., Barrios H., Basset Y., Béranger J.M., Vesco J.P., Causse P., Haug A., Hennion A.S., Lesobre L., Marques F. and O'Meara R. Considérations sur les Agrilus (Cleoptera, Buprestidae) recueillis en Forêt des Abeilles au Gabon au cours de l'expedition du Radeau des Cimes en 1999. In: F. Halleé (ed) *Biologie d'une canopée de forêt equatoriale - IV. Rapport de Mission: Radeau des cimes janvier mars 1999, La Makandé, Gabon.* (In press).

Kappler A. and Brune A. (1999) Influence of gut alkalinity and oxygen status on mobilization and size-class distribution of humic acids in the hindgut of soil-feeding termites. *Applied Soil Ecology* 395, 1–11.

Lyons, E.E. and Miller S.E. (eds.) *Invasive Species in Eastern Africa: Proceedings of a Workshop* held at ICIPE, July 5–6, 1999. International Centre of Insect Physiology and Ecology, Nairobi. (v) + 108 pp. ICIPE Science Press. (In press)

Miller S.E. Taxonomy for understanding biodiversity: The strengths of the BIONET-International model. *Proceedings of the Second BIONET-International Global Workshop* (In press).

Miller S.E., Gemmill B., Herren H.R., Rogo L.M. and Allen M. (1999) Biodiversity of terrestrial invertebrates in tropical Africa: Assessing the needs and plan of action, pp. 204–212. In *Nature and Human Society: The Quest for a Sustainable World* (ed. P.H. Raven). Proceedings of the 1997 Forum on Biodiversity. National Academy Press, Washington DC.

Rogo L., Lwande W., Miller S.E., Herren H. and Chapya A. (1999) Kakamega Forest: An integrated conservation project. *Bulletin of the East African Natural History Society* 29(3), 9–13.

Workshops attended

Miller S. (1999) Fourth Meeting of Subsidiary Body on Technical, Technological and Scientific Advice (SBSTTA) of Convention on Biological Diversity, Montreal, 21–25 June 1999.

Miller S. (1999) Tana River Primate National Reserve GEF Project Peer Review Workshop, Kenya Wildlife Service, Nairobi 8–9 July 1999.

Miller S., Kimani S. and Kioko E. (1999) BIONET-International Second Global Workshop, Cardiff. Papers presented, 'Taxonomy for understanding biodiversity: The strengths of the BIONET-International model' (keynote address by Scott Miller) and 'Computerised identification tools in the ICIPE African Fruit Fly Initiative' (Ian White and Scott Miller) 22–29 August 1999.

Miller S. and Lyons E. (1999) Third Eastern Africa Regional Biodiversity Forum, Nairobi 17–19 March 1999.

Rogo L. (1999) Liaison Group Meeting on Indicators of Biodiversity for Convention on Biological Diversity. Montreal, Canada, 25–26 October 1999.

Rogo L. and Lwande W. (1999) International Workshop on Intellectual Property Rights, Panafric Hotel, December 1999.

Internet products

- The Biodiversity Programme developed about 50 html pages on the ICIPE World Wide Web server, including searchable indexes to over 16,000 taxonomic and bibliographic records. We also collaborated in continued development of WWW pages on New Guinea insects on the Bishop Museum WWW site that include over 1000 insect images and 10,000 bibliographic citations. A CD-ROM version will be released in future.
- In addition to the following specific products, we also catalysed development of the WWW interfaces for the searchable index to the ICIPE library [http://www.icipe.org/icipeLibrary Search.html] and the searchable databases of the Library of Congress Nairobi Office [hosted by ICIPE at http://www.icipe.org/locnairobi]. Indexes for the two libraries include over 22,500 citations.
- Invasive Species in Eastern Africa. Online report of workshop held 5–6 July 1999, including workshop programme, text of papers presented and working group reports, status reports on invasive species, bibliographies and links [http://www.icipe.org/invasive] (developed by E. Lyons, S. Miller and G. Sequeira).
- Checklist of Insects of Africa South of the Sahara, including Odonata, Ephemeroptera, Plecoptera, and Homoptera, with Hemiptera-Heteroptera and Hymenoptera in the process of being posted (http://www.icipe.org/icipedata/africachecklist/index.html) (developed by R.W. Poole and collaborators).
- Bibliography on African Entomology: Partial bibliography of systematics and ecology of Afrotropical insects, some 7000 citations to papers on the systematics, distribution and ecology of insects of Africa south of the Sahara. (http://www.icipe.org/icipedata/biodiversity/Africasearch.cfm)developed by S.E. Miller and collaborators)
- Methods of entomological survey and analysis: Over 1000 citations on use of insects and other arthropods in biodiversity studies. (http://www.icipe.org/icipedata/biodiversity/Methodsearch.cfm) (developed by S.E. Miller and collaborators)
- Background information on ICIPE's field stations in Kenya and their surrounding habitats (http://www.icipe.org/environment/field_stations.html) (developed by S.E. Miller, K.V. Seshu Reddy and R. Copeland).

Capacity building

ARPPIS PhD students

Mr S.T. Kandji (Kenyatta University): 'Effects of improved fallows on nematode biodiversity in the maize-based agroforestry systems of western Kenya'. (Supervisors: C.P.K. Ogol, A.Albrecht and S. Miller)

Mr Levi Wekesa Mukhwana (Moi University): 'Assessment of the impact of forest fragmentation in coastal forests of Kenya: Case study on termites'. (Supervisors: L. M. Rogo, F.M.E. Wanjala, R. Odanga, R. Bagine and P. Eggleton)

Mr Washington Ayiemba (Kenyatta University): 'Ecological monitoring and sustainable utilization of butterflies at Arabuko-Sokoke forest'. (Supervisors: R. Okello, I. Gordon and L. Rogo).

DRIP scholars

Ms Janet Theresa Midega (Kenyatta University): 'A study of the genetic diversity in an endemic butterfly species, *Papilio desmondi teita* Van Someren in four forest fragments of the Taita Hills'. (Supervisors: L. M. Rogo, N. Oguge and E. Osir)

Mr Alfred Ochieng (University of Nairobi): 'Identification of the key pollinators of the eggplant

(*Solanum melongena* L.) in Nguruman'. (Supervisors: B. Gemmill and T. Mukiama).

Ms Esther W. Kamunya (Kenyatta University): 'Community dynamics and diversity of soil fauna assemblages in a maize-based agroforestry system in coastal Kenya'. (Supervisors: L. Rogo, S. Miller and C.P.K. Ogol).

Workshops organised

Regional Workshop on Invasive Species in East Africa, ICIPE, Nairobi (organised by E. Lyons and S. Miller), 5–6 July 1999.

Training Course on Biotechnology and Law (organised by W. Lwande), 26 July–13 August 1999.

Planning Workshop on Reducing Pressure on Kakamega Forest Resources, Golf Hotel, Kakamega. Funded by the Packard Foundation (organised by L. Rogo), 29 September 1999.

Training of Trainers (TOT), Kakamega Golf Hotel. Funded by the Packard Foundation (organised by L. Rogo), 11–13 December 1999.

E. RELATED ECOLOGICAL STUDIES

(Collaborative research activities not based at ICIPE)

16. DEVELOPMENT OF AN ECOLOGICAL DATA ARCHIVE WITH SAN DIEGO SUPERCOMPUTER CENTER

Participating scientist: *S.E. Miller*

Collaborators: *• San Diego Supercomputer Center • Ecological Society of America • US National Center for Ecological Synthesis and Analysis • Bishop Museum*

Donor: *US National Science Foundation (DBA 9631091)*

Work continued in the third and final year of a project to experiment with approaches to the controlled publication of scientific data on the Internet, in a collaboration led by the San Diego Supercomputer Center. The controlled publication of scientific data facilitates the integration and synthesis of data that propels the advancement of science, while providing a mechanism for the protection of intellectual investment and long-term maintenance of the data as errors are detected and modifications applied.

We have undertaken a series of experiments in the controlled publication of digital scientific data using the World-Wide Web for both peer-reviewed and non-peer-reviewed data. The seemingly simple task of determining the existence of a particular type of data, locating the owner and obtaining and comprehending the data, can consume tremendous amounts of time and effort. This investment often goes up faster than the number of datasets involved and, once found, their effective use is very sensitive to the sufficiency of the documentation (i.e., metadata). Additionally, the issues of intellectual property must be resolved and methods for the publication of data to ensure proper attribution and authorization for secondary use (i.e., intellectual property rights), must be developed and institutionalised.

In our approach, the basic objects to be published are computer-system files; either singly or as collections. Each data file(s) is combined with its corresponding metadata in a public-domain archive file format known as *tar*. Other archive formats could be used. However, the reason for using an archive file format is to enable multiple files and directory structure to be stored together in a single file. The archive file is also compressed using a public-domain method (e.g. zip) to save space and transfer time. The resulting file is referred to as an arbitrary digital object (ADO), to emphasise the fact that an ADO can contain anything that can be stored in a computer file system. These may contain measurements, images, sounds or any other digitally recorded data. Since ADOs are packaged as collections of data and metadata, they cannot be directly searched, based on their content.

Searching is performed using a catalogue of metadata based on information provided by the data contributor during the data publication process (i.e., data upload). The metadata which are entered from the keyboard via a 'metadata editor' are used to populate a database to enable the efficient search and retrieval of the ADOs from a distributed data archive. A variety of quality control and quality assessment tools have been developed to facilitate the process.

During 1999, we improved the design and implementation of the model web-site for the publication of non-peer-reviewed data, which we call 'CEED' for Caveat Emptor Ecological Data **[http://ceed.sdsc.edu]**, and the parallel web-site which provides controlled publication of peer-reviewed data as appendixes and supplements to the journal *Ecology*, **[http://esa.sdsc.edu/Archive]**. Many additional sample data sets were added to the archive, especially in collaboration with the Bishop Museum, Honolulu. Several manuscripts describing the experiment were submitted for publication.

17. INSECT COMMUNITY ECOLOGY STUDIES IN PAPUA NEW GUINEA

Participating scientist: *S. Miller (Project Leader)*

Donors: *US National Science Foundation (DEB 97-07928), Czech Academy of Sciences (A6007705/1997)*

Collaborators: *•Bishop Museum • Smithsonian Institution • University of Papua New Guinea • Czech Academy of Sciences*

Work continued on an insect ecology project in Papua New Guinea (PNG), coordinated by Scott Miller since 1994. The overall goal of the project is understanding how tropical herbivorous insects assemble into communities on plants. This has many implications for understanding the evolution, ecology and management of these communities. The fieldwork is carried out largely by local parataxonomists who were trained as part of the project. The project is also providing material for systematics studies of both the insects and the plants.

Once all data are collected, archived and analysed, a comparison will be made of the species richness and host specificity of communities of leaf-chewing insects feeding on 62 tree and shrub species of the lowland rain forest in a local area of 200 km^2 near Madang, PNG. The host plants were chosen to give allowance for host specificity by progressively widening the sampling universe from common, species-rich plant genera to species-rich plant families, and to representative species of both closely- and distantly-related plant families. These hosts included:

- 16 species of Moraceae, including 2 different genera and 15 species of *Ficus*
- 15 species of Euphorbiaceae, including 10 different genera and 6 species of *Macaranga*
- 16 species of Rubiaceae, including 13 different genera and 4 species of *Psychotria*
- 15 species from the following 15 families: Agavaceae, Apocynaceae, Araliaceae, Arecaceae, Eupomatiaceae, Fabaceae, Flacourtiaceae, Gnetaceae, Loganiaceae, Malvaceae, Monimiaceae, Sapindaceae, Ulmaceae, Urticaceae and Verbenaceae.

At the end of 1999, insect collections on Moraceae, Euphorbiaceae and Rubiaceae were complete, whilst surveys of other families were on-going. Representative insect collections for each plant species were obtained within a year of field work, at the rate of 15 plant species studied per year. With the help of a resident scientist and through a database developed specifically for this project, parataxonomists assign insect specimens to morphospecies (i.e. species, defined by morphological characteristics, but not necessarily named). Eventually, the insect material is studied and described by various taxonomists. A large sample size is a prerequisite to investigating the host specificity of species-rich insect taxa in diverse habitats such as lowland tropical rain forests. Our sampling protocols generate a considerable amount of data on a scale which has rarely been achieved in the tropics.

Excluding transient non-feeding insects, which represent about 40% of the material collected, 46,000 individuals of leaf-chewing insects on Moraceae, Euphorbiaceae and Rubiaceae, representing 854 species have been processed. In addition, over 61,000 individuals and 491 species of sap-sucking insects were also collected from *Ficus* spp. On average, the laboratory processes about 1400 insect specimens monthly, including 400 caterpillars reared to adults. To date, our insect databases document the host records of over 100,000 individuals from over 1300 species. In addition, the databases contain over 3200 insect pictures, including those of 200 species of caterpillars matched with adults, and drawings of genitalia of 500 species. Gradually, this information is being made available to the scientific community on the World Wide Web.

Species from Chrysomelidae, Cerambycidae, Curculionidae, Tettigoniidae, Tortricidae, Crambidae, Geometridae, Noctuidae and Phasmatidae dominated the leaf-chewing communities. In particular, the communities on *Ficus* were characterised by the prominence of Choreutidae and Nymphalidae and by the near absence of Geometridae; those on Euphorbiaceae by Thyrididae and Uraniidae and the scarcity of Crambidae; those on Rubiaceae by Sphingidae, Phasmatidae, Uraniidae and the scarcity of Chrysomelidae. The number of leaf-chewing species sustained by the hostplants studied varied by a factor of four, from 34 to 129.

Since many of the species collected were identified (63% of adult Lepidoptera, 36% of Coleoptera and 17% of Orthoptera and Phasmatodea), a list of leaf-chewing species feeding on *Ficus* spp. was compiled. A database of *Ficus*-feeding insects worldwide (2629 species to date) was assembled and showed that the composition of the Madang samples at a higher taxonomic level appeared to be similar to the fauna feeding on *Ficus* elsewhere in the world. However, samples from Madang were relatively diverse, probably as a result of the considerable diversity of *Ficus* in New Guinea. Further, *Ficus* spp. supporting many species of herbivorous insects were not always attractive to frugivorous vertebrates. Thus, the keystone-species concept was difficult to substantiate for *Ficus*-feeding insects, as it could not be applied across different guilds of consumers.

Plant family and genus were important determinants of herbivore community composition, since they explained 56% of the variability in the herbivore communities while the ecological distribution of plants explained only 4%. However, phylogenetic relationships among congeneric plants were unrelated to community composition of both leaf-chewing and sap-sucking insects. Trees in coastal habitats or forests sustained very different insect communities. The forest hosts had significant predictors of insect species richness, including leaf palatability and production for leaf-chewing insects and tree density and leaf expansion for sap-sucking insects. In Chrysomelidae, polyphagous species were concentrated on palatable hosts. Trees with high-density chrysomelid communities were dominated by specialists, whilst trees with low-density communities were fed upon mostly by generalists. The patterns of host use by Eumolpinae and Galerucinae was shifted towards oligophagy, in comparison with most of other chrysomelid subfamilies feeding on temperate herbs.

Singletons represented on average 45% of all species in the leaf-chewing communities. It is likely that species collected as singletons were also feeding on hosts not sampled, since our sampling effort implies that monophagous singletons should subsist at an extremely low population density, less than 1 individual per 10 ha of forest.

Most leaf-chewing species had wide host-plant ranges with regard to congeneric hosts. The modal host range was 12 *Ficus*, 6 *Macaranga* and 4 *Psychotria* species, i.e. at least 80 % of the congeneric species studied. Among the herbivore species feeding on *Ficus*, *Macaranga* or *Psychotria*, only 7% were restricted to a single host. Species (350) of leaf-chewing herbivores were collected on 15 species of *Ficus*, and it was estimated that the 48 *Ficus* species present locally could support a total of 508 leaf-chewing species.

A significant proportion of tropical flora consists of speciose genera. The three largest plant genera account for 40% of all Euphorbiaceae and 30% of all Rubiaceae in New Guinea, whilst a single genus, *Ficus*, represents 84% of all New Guinean Moraceae. This pattern has obvious consequences for regional and global estimates of herbivore species richness. Large differences in species richness between tropical and temperate flora are usually smaller, when the number of genera and families are considered. These differences, in combination with low host specificity of herbivores with respect to congeneric plants, suggest that the average overlap among herbivore communities on tropical trees may be higher than that on plants from the temperate zone. Any extrapolation of host specificity patterns from temperate to tropical forests may therefore be suspect.

A large overlap among insect communities on congeneric species also suggests that highly specialised interactions between insect herbivores and closely related hosts in New Guinea may not have been conserved in evolutionary time. This is at variance with the dogma of old, extremely specialised and conservative interactions between insect herbivores and their hosts, providing numerous ecological niches in the floristically-rich tropics.

Output

Publications

Allison A. and Miller S. E. Hawaii Biological Survey: Museum resources in support of conservation, pages 281–290. In *Nature and Human Society: The Quest for a Sustainable World. Proceedings of a Conference, 27–30 October 1997* (Edited by P.H. Raven and T. Williams). National Academy Press, Washington, D.C. (In press).

Basset Y., Novotny V., Miller S. E. and Pyle R. Quantifying biodiversity: Experience with parataxonomists and digital photography in New Guinea and Guyana. *BioScience* (In press).

Brown J. W. and Miller S. E. (1999) A new species of *Coelostathma* Clemens (Lepidoptera: Tortricidae) from Cocos Island, Costa Rica, with comments on the phylogenetic significance of abdominal dorsal pits in Sparganothini. *Proceedings of the Entomological Society of Washington* 101,701–707.

Novotny V., Basset Y., Samuelson G.A. and Miller S.E. (1999) Host use by chrysomelid beetles feeding on Moraceae and Euphorbiaceae in New Guinea, pp. 343–360. In *Advances in Chrysomelidae Biology 1*. (Edited by M.L. Cox). Backhuys Publishers b.v., Leiden.

Wetterer J.K., Miller S.E., Wheeler D.E., Olson C.A., Polhemus D.A., Pitts M., Ashton I.W., Himler A.G., Yospin M.M., Helms K.R., Harken E.L., Gallaher J., Dunning C.E., Nelson M., Litsinger J., Southern A., and Burgess T.L. (1999) Ecological dominance by *Paratrechina longicornis* (Hymenoptera: Formicidae), and invasive tramp ant, in Biosphere 2. *Florida Entomologist* 82: 381–388.

Wetterer J.K., Ward P.S., Wetterer A.L., Longino J.T., Trager J.C. and Miller S.E. Ants (Hymenoptera: Formicidae) of Santa Cruz Island, California. *Bulletin of the Southern California Academy of Sciences* (In press).

Internet products

- New Guinea insect ecology WWW site, including project background, data, images and results. (http://www.bishop.hawaii.org/bishop/natsci/ng/ngecol.html) (developed by Y. Basset, V. Novotny, S.E. Miller and N. Evenhuis, includes information on herbivore communities and over 1300 images of more than 900 species of insect herbivores)
- Entomological bibliographies of New Guinea including the Solomon Islands. Over 10,000 citations with partial abstracts. (http://entomology.si.edu:591/entomology/NewGuineaBib/search.html) (developed by S.E. Miller, based in part on earlier work by J.L. Gressitt and J.H.H. Szent-Ivany)
- Description of parataxonomist training programme in Papua New Guinea (http://www.entu.cas.cz/png/index.html) (developed by V. Novotny, Y. Basset and S.E. Miller)

(See also the reports on the Biosystematics Unit, Habitat Management for Control of Stemborers and Striga, African Fruit Fly Initiative, Tsetse projects, Behavioural and Chemical Ecology Department, Population Ecology and Ecosystems Science Department, Horticultural Crop Pests Programme, Commercial Insects Programme and Information Technology and Services Units.)

ENVIRONMENTAL RESEARCH

ENVIRONMENTAL HEALTH MANAGEMENT

COMMERCIAL INSECTS

The Commercial Insects Programme has three main components: (i) beekeeping, (ii) wild and domesticated silkworm rearing, and (iii) the conservation and utilisation of these commercial insects and their habitats. The Programme uses strategic research to resolve technical implementation problems. The developed technologies are demonstrated to end-users in the laboratory and in the field with the active participation of a great number of farmers. A summary of the Programme's achievements in Phase I (1996–1998) follows.

Apiculture

Three *Apis mellifera* honey bee races exist at various altitudes in East Africa. In the past, clear distinction between the races and hybrids has been exceedingly difficult. A morphometric means to resolve the identity of the different honey bee races and hybrids was developed, and the bees' swarming and migration/absconding patterns were explored in a few areas in East Africa. Mitochondrial DNA and microsatellite variability studies were initiated to determine markers which can be used to characterise and discriminate East African *A.mellifera* and their hybrids. As they differ with respect to their honey-gathering ability and pollination capacity, the information is being used to develop sound honey bee management plans for the region.

The population dynamics of the different honey bee races was studied in order to select the period of the year that is optimal for the harvest of beehive products such as honey, wax, royal jelly, pollen, propolis and bee venom. Floral calendars, which catalogue flower type, abundance and month and duration of bloom, were developed for a variety of localities in East Africa. The seasonal patterns of the honey flow and honey dearth periods in selected areas were determined. American 10-frame Langstroth hives were introduced in many areas in East Africa and the yield of honey produced with these hives was compared with the yield of honey raised from traditional and top-bar hives.

A major breakthrough in beekeeping was achieved by developing and improving queen rearing techniques. The queen rearing methods for African honeybee races were standardised and the package-queen has been developed for local beekeepers through natural mating. A line breeding programme is designed for phase II, for developing queens through artificial insemination with specific drones in order 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.

Royal jelly production systems and a bee venom extraction device have been developed as additional income-generating opportunities for beekeepers. Pollen collection devices and propolis production units are being introduced. Honey- and wax-processing and packaging plants have been developed and are operational.

The African bee industry is in an infant stage of modernisation and very little is known about bee diseases. The wax moth, *Galleria mellonella* is a major problem to beekeepers in Africa. In the laboratory, the use of the microbial pesticide *Bacillus thuringiensis* (B.t.) *aiziwai* proved successful, and preparations are being made to test this method of moth control in infected apiaries.

Sericulture

A number of advances were made in sericulture techniques and in their grassroots application. In the wild, the biodiversity of indigenous silkmoths and their habitats are deteriorating as a result of the lack of local knowledge on the value of silkworms for income generation. In some communities, silkmoth larvae and pupae are harvested in bulk as a protein food source, but there are no mechanisms in place for the replenishment of the silkworms consumed. In Kenya and Uganda, a survey on existing wild silkmoth species was undertaken and two potential species, *Argema mimosae* and *Gonometa* sp. from two lepidopteran families (Saturniidae and Lasiocampidae, respectively) were found to produce silk fibre of high quality. The population dynamics of *Argema* sp. and *Gonometa* sp. have been studied in farmers' fields at two locations in Kenya. A technique has been designed to reduce the larval mortality to 24% and farmers are learning the sericulture rearing techniques that will decrease silkworm losses due to natural enemies in the wild, and increase their productivity. Methods have been developed to de-synchronise the parasite cycles with those of the silkworm in order to decrease silkworm mortality and silk fibre spoilage. A bioassay is being designed to determine the optimal time for breaking pupal diapause and for mass egg production in the laboratory, in order to establish a continuous production system on the basis of host-plant availability. A saturniid moth, *Bunea alcinoe*, whose caterpillars are consumed in many parts of Africa, has been successfully reared in the laboratory using leaves of the host plant *Balanites aegyptiaca*. Species-specific qualities, such as the chorionic pattern of the eggs and the genitalia of the silkmoths have been verified through scanning electron microscopy.

New domestic silkmoth hybrids that flourish in the African environment and produce high quality silk were developed. The hybrids were selected by crossing a number of domestic silkmoths (*Bombyx mori*) strains and testing their vigour when grown on a variety of mulberry cultivars. The problems in rearing the domesticated silkworm, *B. mori* were identified and resolved. This is a prerequisite to establishing large-scale cocoon production facilities for East African farmers. The major disease attacking the silkworms in their larval stage was identified as the nuclear polyhedrosis virus. The therapy to manage this disease was developed and disseminated to sericulture farmers. The mulberry cultivars are also attacked by red rust disease, and methods of control were devised.

The unwinding process of the bivoltine and wild silk cocoons was facilitated by installing reeling and re-reeling units to examine the length of the raw silk and reeling characteristics produced by different silkmoth races. Degumming, bleaching and dyeing units have been established to process silk fibre and fabric. The twisting of the raw silk on a twisting unit has revealed the optimum strength of the silk yarn which can withstand the power of the looms. The warping unit and power- and handlooms to facilitate the weaving of the silkcloth were installed.

The complete package from egg production to finished cloth at ICIPE will assist sericulture farmers, reelers, weavers and traders to generate income from the sale of their respective raw materials. This will open up a market for sericulture products in East Africa.

Marketing

Marketing strategies for honey and other beehive products, silk cocoons, raw silk and silk cloth have been designed in collaboration with the local and international traders. A production line has been set up with the local beekeepers, sericulturists, NGOs and governments in East Africa to develop an outlet for their products. Linkages with the local and international markets have been initiated. As a result of implementation of these microenterprises, farmers' and beekeepers' income sources have increased. A revolving fund is being created at ICIPE for farmers to purchase the hives or rearing appliances for apiculture and sericulture. An initiative has been taken to mobilise the credit financing facilities for farmers through local governments. The Trickle-Up Programme of UNDP and TCP grants from FAO at the national and regional levels are being developed to help farmers obtain the initial financing for setting up apiculture/sericulture technologies. The economics of setting up these technologies for a single farm family and for a group of farmers in African conditions have been worked out. However, the investment required may vary by 20% from country-to-country. 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.

Training and technology transfer

On-farm trials and testing of apiculture and sericulture technologies are currently being conducted in Uganda, Tanzania, Kenya and Ethiopia. The Project has developed training and working modules for apiculture and sericulture with plans to set them up in other African countries. Approximately 5000 farmers, NGOs and government extension workers from East Africa were trained in short- and long-term training programmes on sericulture and apiculture at ICIPE. On-site farmer-participatory technology testing and development was initiated in East Africa and successful results have been achieved in many areas. However, disappointing results were also received from a few areas and the reasons for their failures are being investigated.

The Project is also helping in the capacity building of Africa: two Masters students and two PhD students have completed their degree courses through the Commercial Insects Programme.

Environmental Health Division

COMMERCIAL INSECTS PROGRAMME

Development and Transfer of Improved Apiculture and Sericulture Technologies

Participating scientists: *S. K. Raina* V. V. Adolkar (Sericulture), E. N. Kioko (Wild Sericulture)* (*Programme Leader)

Assistants: *D. M. Kimbu (Apiculture), H. G. Muiru (Sericulture)*

Donors: *IFAD – Phase II- Commercial Insects Project, IFAD-North Africa Project, FAO-TCP (Technical Cooperation Project) for African Countries*

Collaborators: Apiculture: • *Kenyatta University • Kenya Agricultural Research Institute (KARI) • International Bee Research Association (IBRA), UK • New South Wales (NWS), Australia • Chinese Academy of Agricultural Sciences (CAAS) • Local and international traders • Honeybee processors, Zimbabwe • Kakuzi Farm, Thika, Kenya • Coffee growers, Kenya • Beekeepers and farmers in E. Africa • NGOs.* Sericulture: *NGO Council of Kenya • Universities and schools • Sericulture farming community • Kenya Agricultural Research Institute (KARI) • International Centre for Research in Agroforestry (ICRAF) Nairobi • Wild Silk Research Stations of Japan, China and India • Shanshi Seritech • Central Silk Board (CBS), India • Sericulture Research Institute (SRI), China • Centre of Sericulture and Biological Pest Management Research (CSBR), India • Silk industries and regional textile traders and local NGOs • Sericulture Research Institute of Chinese Academy of Agricultural Sciences (SRICAAS) • ISC & ISA, France • NARES in operating countries • University of Nairobi, Kenya • Kenyatta University, Kenya • University of Zimbabwe • Rothamsted Experimental Station, UK • Ministries of Agriculture and Livestock in Nigeria, Ghana, Côte d'Ivoire, Uganda, Tanzania, Ethiopia, Eritrea, Senegal, Zimbabwe, Malawi, Sudan, Burkina Faso, Zambia, Madagascar, Algeria, Morocco, Libya and Tunisia • Food and Agriculture Organisation of the UN (FAO) • Claro, Switzerland • African and overseas traders, sales agents*

A. APICULTURE

The honey bees, *Apis mellifera* are native to Africa, Europe and Western Asia and were later introduced in North and South America and Australia.

Phase I of the project (1996–1998) dealt with East African bee races. Research was conducted to resolve the existing constraints for establishing a modern beekeeping industry for income generation in Africa.

Work in progress

1. UNDERSTANDING THE MAJOR CONSTRAINTS TO BEEKEEPING IN EAST AFRICA

1.1 INVESTIGATION OF FLORAL CALENDARS IN EAST AFRICA

A floral calendar which catalogues the flowers, their value to bees and abundance and time and duration of bloom, is essential for sound management in beekeeping and needs to be produced for ecological regions in which beekeeping is practised. Hence, in this project we have attempted to draw a floral calendar for various regions in East Africa. The seasonal cycles of *Acacia* spp. and races in East Africa differ radically at different altitudes and is being studied, in order to establish a calendar for a seasonal management plan. This plan will be based on the dates when the major honey flows occur and the extent to which these dates may vary from one year to the next, due to climatic irregularities which are common in Africa. Many plants from which bees store surplus honey in East Africa are being identified. The genera *Acacia* and *Eucalyptus* are very large and some species are extremely valuable to bees. In most areas, e.g. Kitui, Mwingi and Baringo in Kenya and Arusha in Tanzania, *Acacia* spp. is dominant, whereas in a few other areas like western Kenya, the exotic *Eucalyptus* spp. predominates. In very high altitudes like Kinangop, *Dombeya burgessiae* is the common plant. In Kampala, Uganda, banana is the major source of honey. Tree crops like passion, coffee, citrus, mango and avocado are widespread in East Africa and produce large honey yields. The various flower species of importance as producers of nectar and pollen are being identified with the help of national museums and University of Nairobi.

The 'nectar flow' period is at its peak when large forest trees, shrubs, climbers, weeds and crops are

Table 1.2.1. Mean values X and standard error (not bold); F ratio (bottom) of body length and abdominal width of honey bee, *Apis mellifera* races in seven regions of Kenya

		Body length				Abdominal width			
Localities	Altitude (m)	S1		S2		S1		S2	
Mombasa	75	**77.091^{AB}**	0.547	**62.500^{B}**	1.280	**23.364^{BC}**	0.270	**21.333^{A}**	0.514
Mwingi	650	**75.636^{B}**	0.472	**64.944^{AB}**	1.022	**23.136^{C}**	0.097	**19.556^{A}**	0.358
Kitui	850	**74.250^{C}**	0.901	**63.300^{AB}**	1.564	**23.375^{BC}**	0.157	**21.500^{A}**	0.465
Kimana	1250	**78.833^{A}**	0.477	**69.000^{A}**	0.951	**24.500^{A}**	0.224	**22.000^{A}**	0.154
Kakamega	1680	**79.286^{A}**	0.286	**68.333^{AB}**	0.882	**24.357^{AB}**	0.261	**22.167^{A}**	0.333
Central	1950	**78.667^{A}**	0.752	**69.667^{A}**	0.333	**24.333^{AB}**	0.178	**22.500^{A}**	0.000
Kinangop	3200	**77.333^{AB}**	0.667	**69.250^{A}**	0.250	**24.083^{ABC}**	0.651	**22.500^{A}**	0.000
F Value		9.71		4.84		4.94		0.7	

N.B. Means with the same letters (the superscripts on the mean values) are not significantly different.

Actual value $\overline{X}\frac{X*2}{2}$ mm

flowering and visited by bees. Among the trees which are rich in nectar are *Acacia* spp. and *Terminalia prunioides* which provide a distinct taste to honey. *Acacia nilotica, Entada leptostachya,* millet and maize are rich in pollen. Climbers and weeds are also good nectar and pollen sources. The honey flow period is long, because plants do not flower at the same time and some plants such as *Senna didymobotrya* flower almost throughout the year.

The swarming of bees begins from mid-September to mid-October and from mid-February to mid-March, depending on the rains.

Floral calendar studies have been also initiated in Embu District, Donyo Sabuk (Thika), Kinangop, Kimana, Eldoret, Baringo and Homa Bay in Kenya, Hoima District and Masindi in Uganda and Tigrai in Eritrea and Ethiopia.

1.2 RACE VARIATIONS OF THE EAST AFRICAN HONEY BEE, *APIS MELLIFERA*

1.2.1 *Morphometrics*

There are three races of the honey bee, *Apis mellifera* L. in Kenya: *Apis mellifera litorea, A.m. scutellata* and *A.m. monticola*. The races differ from each other with respect to size and number of yellow abdominal bands. There is a high probabilty of race interaction during swarming and migration, which may have created hybrids of all races which remain between specified altitudes among the three races.

The honey bee races in Kenya have distinct body sizes. The samples showed a difference in their body size from locality to locality. Generally, the honey bees from Central Province and Kakamega were the largest, followed by the bees from Kinangop and Kimana, then Mwingi and Mombasa. Honey bees from Kitui were the smallest.

Size and colour classification of the honey bees indicated that the full black category is *A. m. monticola*, normally existing above an altitude of 1600 m; bees of large size with 3 yellow bands are *A. m. scutellata*, mostly occurring at altitudes of 600–1600 m; those of small size with 2 yellow bands are *A.m. litorea*, at an altitude of 600 m and below. The analysis of the body size measurements indicated that bee sizes in the altitude up to 850 m are the same and from 1250–3200 m are the same (Table 1.2.1).

In Mombasa the large, two-banded honey bee was dominant, but three-banded bees were also collected, which indicates hybridisation of the coastal *A. m. litorea* with the mid-altitude honey bee, *A. m. scutellata*. In Mwingi, the three-banded bees predominated. This honey bee population is comprised largely of *A. m. scutellata*. In Kitui, there was a predominance of the smallest, one-banded and two-banded honey bees, which appeared to be *A. m. scutellata* and *A. m. litorea* hybrids from Mombasa, Mwingi and Kimana. It is not yet clear how the one-banded bee arises in Kitui, and mitochondrial DNA studies to determine the matriline and microsatellite DNA to determine the patriline are currently underway. In Kimana, the bees showed no difference in their body length with the bees from Kinangop.

In the mid-region of Kenya, hybridisation occurred during the migration of bees between the coastal lowlands and highlands. In Kakamega, the black *A. m. monticola* bees hybridised with *A. m. scutellata*, and two-banded hybrids and black hybrids were recovered. Again, it was not clear how the three-band character was lost. Further clarification is being sought from mitochondrial DNA and microsatellite DNA studies. In retrospect, regardless of the varying climate found in diverse geographical regions, there is a close correlation between altitude and morphological size of *A. mellifera* honey bees in Kenya. Unimodal and bimodal distribution curves of the cubital index show that there are semi-pure and hybrid races.

There is a significant difference for all samples drawn from seven regions for each morphological character at P=0.05. SNK for means comparison and grouping shows that honey bee races in coastal regions and Mwingi are very close, while honey bee races at the coast and Kakamega, Mwingi and Kakamega, Central and Kimana as well as Central and Kakamega and Kinangop are different.

1.2.2 *Mitochondrial DNA variability*

Samples of white eye pupae from the wild honey bee, *Apis mellifera* colonies located in various geographic

Table 1.2.2. Mitotype frequencies at the sample locations

	Frequency of mitotype			Frequency of *DraI* haplotypes			
Location	PoQ	PoQQ	PoQQQ	A4(PoQQ)	X1(PoQQ)	A1(PoQ)	X2(PoQ)
Mombasa	0.5	0.5		0.5		0.33	0.16
Nairobi	0	1	0	1.0			
Homa Bay	0.25	0.75	0	0.75		0.25	
Eldoret	0.25	0.5	0.25	0.74	0.14	0.14	
Kinangop	0.375	0.625	0	0.75		0.25	

areas of Kenya, ranging from 50 to 3000 m above sea level were collected. The size polymorphisms in the COI-COII intergenic region of mtDNA were analysed by use of polymerase chain reactions (PCR). The restriction fragment length polymorphisms of PCR products (RFLP-PCR) were detected by *DraI*. In this region, 3 different size variants were found: PoQQ was the most common mitotype with a frequency of 0.737, PoQ-type had a frequency of 0.237, and the frequency of PoQQQ was 0.026 (Table 1.2.2). Mitotype variability was found in the coastal area of Mombasa (altitude 128 m) and in one forested mountain area (Kinangop, altitude 2760 m), with a mitotype frequency of 0.5 (PoQ), 0.5 (PoQQ) and 0.375 (PoQ), 0.625 (PoQQ) for Mombasa and Kinangop, respectively. Mitotype variability were also found in other sampling areas. This frequency distribution for mtDNA polymorphisms is unexpected, given earlier descriptions of the distribution of honey bee races in Kenya, based on both morphology and molecular biology data, and indicates an unexpectedly high gene flow over a large range of biogeographical regions.

Our results demonstrate the exchange of genetic material between bees collected in areas where this would not have been expected. Both mitotype PoQQ and PoQ were found in Mombasa, where the honey bees have been described as *A. m. litorea*, and on Kinangop at 2760 m altitude as well, where samples collected by the National Museums of Kenya have been described as *A. m. monticola*. In the six samples analysed from Mombasa, half of them had the PoQQ mitotype and half of them the PoQ mitotype. From the eight samples analysed from Kinangop, five had the PoQQ mitotype and three the PoQ mitotype. The small number of observations indicate that the distribution of honey bee subspecies in Kenya does not correspond with altitude.

Our results demonstrate that there is no reproductive isolation between bees above 2000 m and the bees on the lowlands, or even in the coastal region. One explanation of the observed results could be that the migrating swarms of African honey bees, particularly of *A. m. scutellata*, may move much further than we know. The migration patterns of African bees is largely unknown, but the swarms may move from the savanna to high altitudes in the mountains, and the lower coastal areas. In both such instances, hybridisation between *A. m. scutellata, A. m. monticola* and *A. m. litorea*, respectively, may take place and explain the observations of the same mitotypes in both Mombasa and Kinangop. Another explanation could be that the introgression of mitochondria genomes and nuclear (morphometric) were not at the same level, but are discrete. Further studies on the satellite nuclear DNA will help to answer the question.

1.3 BEE SWARMING, MIGRATION AND EXTENT OF HYBRIDISATION

The main problem in African beekeeping is swarming, aggressiveness and absconding of the bees from the colonies. The main causes of these problems are the dearth period and lack of knowledge on the part of beekeepers on colony splitting. ICIPE has developed a management plan for the beekeepers to reduce the swarming and absconding of the colonies from traditional and modern beehives. During the dry period when the African bees often abscond from the hives to look for a new food site, the management strategies can hold 80% of the colonies in the hive for the next season.

There is very little data to date to support the swarming and migration patterns in various areas in East Africa, such as the swarm movement from Embu to Mount Kenya and back from Mount Elgon to Homa Bay, Mount Meru to Aru Meru in Tanzania and from the Tigrai Mountains to the lowlands in Ethiopia. The experiment is being designed to draw from both local knowledge and the project's observations for the benefit of the beekeeping industry in East Africa.

Bees from Kitui and Mwingi have a greater proportion of two and three bands, respectively. (*See Section 1.2*) Early swarming in the months of July/August from Mwingi and Kitui towards northwest (Mount Kenya), southwest (Kimana), South (Mombasa) and East (Tana River), occurred in response to the dry season prevailing in the regions. Swarms return at the end of September to mid-November when the *Acacia* spp. flower. These movements extend to the coastal regions where the predominance of two-banded bees with small size (*A. m. litorea*) occur. A few colonies have a mixture of larger size bees with one and three banded bees.

In Kinangop, lying in the Aberdare Mountain range, the swarm movement was generally observed during the end of August to September, moving southwest towards the floral regions in Naivasha,

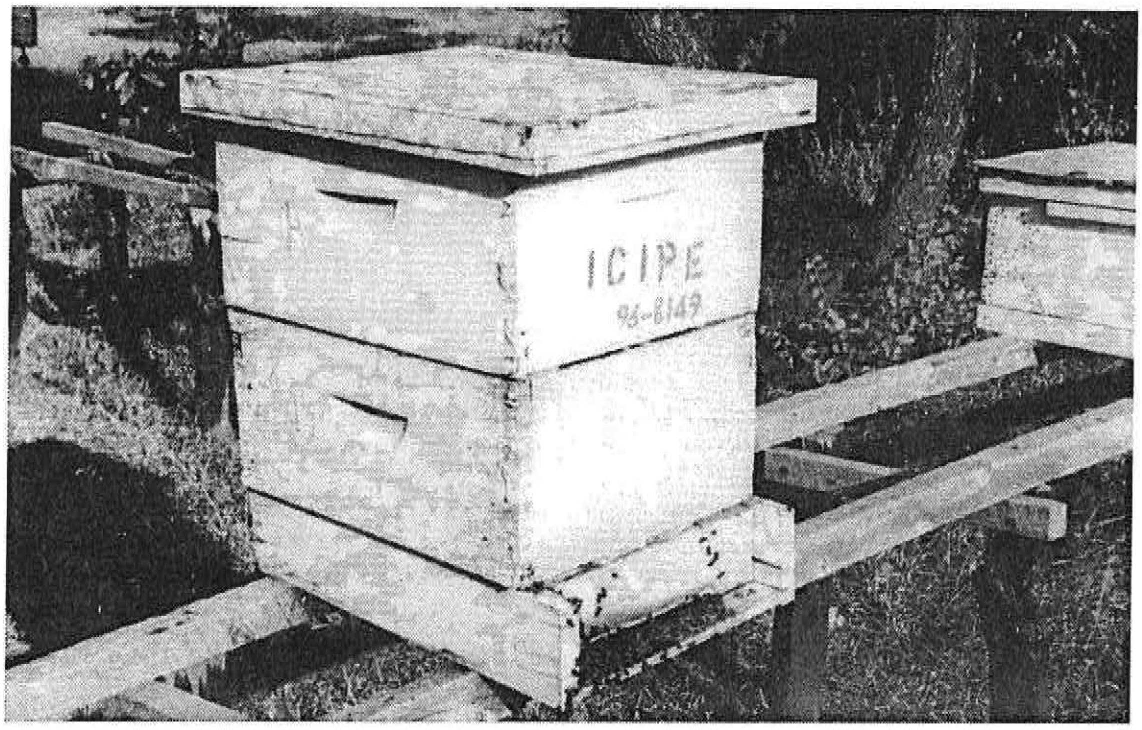

Figure 2. Modern Langstroth hives in a Mwingi District apiary

Limuru and other central areas. The returning swarms were observed during April/May from the central sites towards the Aberdare range. In Kinangop at 3200 m, very little swarming occurs, hence 95% of the bees are black with a slight mixture of one-banded bees. As the altitude decreases (1950 m) towards central Kenya regions, the samples show black and two- and three-banded mixtures of bees in various proportions and sizes.

2. INTRODUCTION OF LANGSTROTH HIVES

There are two types of hives that are used traditionally in beekeeping in Africa. The output from these hives is very low and no hive product other than honey and wax can be produced. To make beekeeping more profitable and sustainable, the 10-frame Langstroth hive was introduced into East Africa. This hive has several advantages compared with the traditional methods (Figure 2). Queen rearing becomes simplified and colony multiplication easier. Other hive products such as royal jelly, propolis, pollen and bee venom can be harvested with little difficulty to increase the income of beekeepers and smallholders. The beekeepers in Kenya, Uganda, Ethiopia and Tanzania are being encouraged with incentives to replace traditional with modern hives.

2.1 BREEDING OF AFRICAN QUEEN *APIS MELLIFERA SCUTELLATA*

A major breakthrough in African beekeeping was achieved by the Programme by developing and improving queen-rearing techniques. Queens were naturally mated (Figure 2.1) and techniques on artificial insemination with specific drones to select desirable behavioural traits in the offspring are being developed. Ideally, this technology may resolve the behavioural defects of African honey bees (such as aggressiveness and absconding), in 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 queenless 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 queenless and queen-right colonies. A comparative performance of the egg-laying rate of queens of various races is currently being assessed. A queen package for farmers is available at ICIPE. The chemical characterisation of the queen bee pheromones of the three races is planned.

The advantages of queen rearing are:

- Colony multiplication is made possible and simplified
- Colonies of desired traits such as high honey yield and less aggressiveness can be reproduced.

2.2 SELECTION OF SUITABLE RACES FOR PRODUCTION OF ROYAL JELLY AND OTHER HIVE PRODUCTS

2.2.1 *Royal jelly*

Royal jelly is 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. Fresh royal jelly has

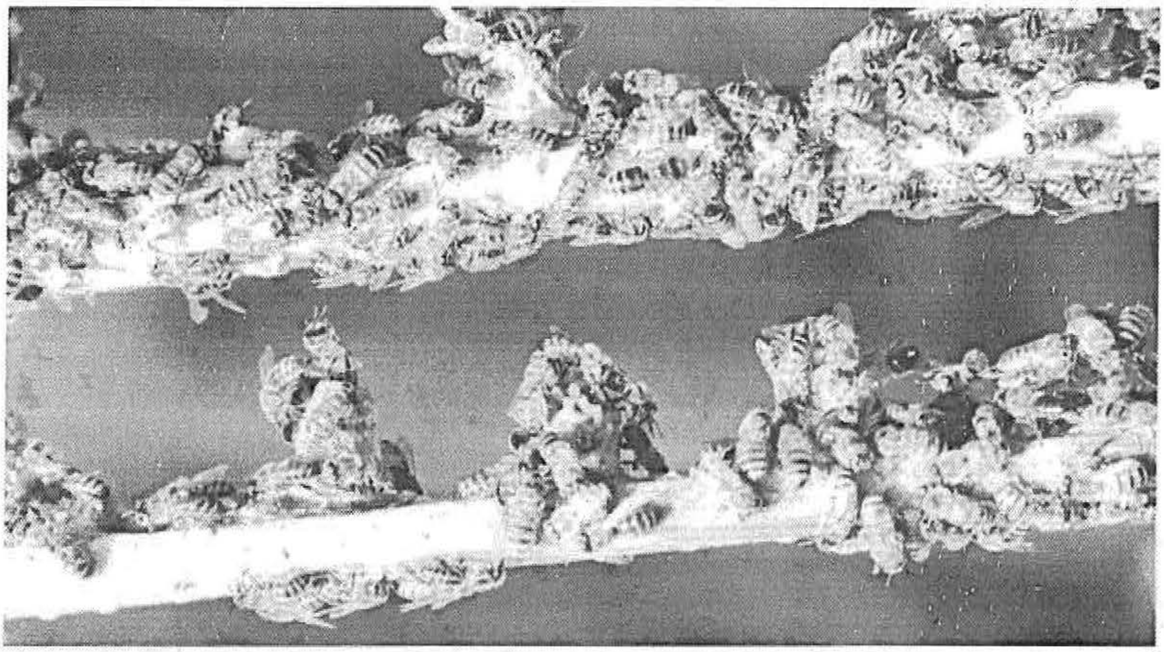

Figure 2.1. A queen cells frame

been used for centuries for its remarkable health-giving and rejuvenating properties.

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 to increase their income by augmenting the returns from bee products.

2.2.2 *Beeswax*

Beeswax is a highly complex mixture of normal paraffins and esters of monohydric alcohols and straight chain fatty acids and hydroxy acids. Beeswax is secreted by the workers and used to construct the comb. The wax- making bees feed on honey and hang in a cluster on the comb. The production of beeswax by the honey bee is not well understood. It is estimated that to produce 1 kg of wax, the workers require 3 kg of honey.

Beeswax has many practical applications and the demand for the product exceeds supply in the developed economies. Africa is the main producer and supplier of beeswax, because of the traditional method of beekeeping. The African bee is a very prolific producer of beeswax, partly because of its frequent swarming, absconding and migration behaviour. East African beeswax seems to attract a better price on the world market than wax from other areas.

The commercial uses of beeswax includes the manufacture of cosmetics, ointments, lipsticks, margarine, waterproofing, candle making, furniture polish, car polish, hot wax and painting.

2.2.3 *Propolis*

Propolis is a resinous substance, orange-brown to red in colour. It is gathered by honey bees from certain trees and from various exudates from wounds in woody plants. All cells are varnished with it before the queen lays eggs in them. There is no standard equipment for harvesting propolis. Some beekeepers scrape it off hive walls, frames, and wherever the bees deposit it, but this gives a very impure product. The use of propolis in the hive and therefore the amount harvested can be increased if wooden or metal grids are inserted, which have slots of 2–10 mm width which the bees seal up. Propolis is easier to handle at lower temperatures, when it becomes brittle. The total yield per hive in the active season could be 20–50 g. Propolis is used in medicine for treating asthma, for making putty and a special varnish used by violinmakers.

2.2.4 *Pollen*

Pollen is harvested in a 'pollen trap' (OAC trap), attached at the entrance of a movable frame hive and incorporating a single or double grid, through which the incoming bees must scramble when entering the hive. The pollen loads on the hind legs are knocked off in the process, and fall into a protected tray below, which the bees cannot enter. Pollen is the bees' source of protein and other substances they require for rearing their brood. During pollen flow it may be possible for the beekeeper to harvest 0.5 to 1 kg of pollen a day per hive.

2.2.5 *Bee venom*

The 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.

The active ingredients in bee venom are apamine, melithin, approximately 10 phospholipase and hyaluronidase enzymes, and two sulphur-rich amino acids, methionine and cystine. In humans, bee venom stimulates the heart and cortico-adrenal glands and is used in treatment of rheumatic diseases, especially arthritis. Both live bees and extracted venom have been used in treating patients. In the United States, the Food and Drug Administration has recently approved pure venoms for desensitising persons allergic to stings. Pure venom is a more effective desensitiser than the whole body extracts (ground up bodies of stinging insects) that were commonly used in the past.

In Phase I, a simple technique to collect bee venom was designed; an electrically charged grid plate (1"x1") was used that was covered on top with synthetic nylon material. A glass plate was fitted underneath the grid. A wooden box filled with bees was placed over the electric grid and the bees were stimulated with an electric current. Bees that landed on the device received a slight shock, which caused them to sting the material and release a pheromone which stimulated the stinging behaviour of the other bees in the box. Once stimulated, the bees repeatedly stung the material and released venom which was collected on the bottom glass plate. Since most of the workers stinging in this manner retained their sting, the bees could be returned to their respective colonies after one milking.

An experiment was designed to evaluate the milking capacity of *A. mellifera scutellata*. Approximately 620 bees were released in the box and current of 6μA was applied for 5 minutes. 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 underside of the nylon sheet with a razor blade. In total, 81.2 mg of bee venom was collected from 6000 worker bees.

Further research is currently underway to design a mass production kit and also evaluate the abilities of other *A. mellifera* races in Africa to produce bee venom. In China, 1 g of venom sells for US$ 100. This simple method of extracting venom from bees will provide an additional source of income to the beekeepers.

3. SURVEY OF PESTS AND DISEASES IN HONEY BEE COLONIES IN EAST AFRICA

The African bee industry is in its infant stage and not much research has been carried out on bee diseases in African countries. Samples examined from East African traditional and Langstroth colonies have no mite infestation or brood diseases. However, colonies were affected by the wax moth, *Galleria mellonella*. The use of *Bacillus thuringiensis* has given a positive result and plans are being made to conduct field releases. The honey quality after *B.t.* spraying is being tested.

4. PROCESSING, PACKAGING AND LABELLING OF HONEY AND BEESWAX

A laboratory to process and package the honey and beeswax from the traditional and Langstroth combs for the market has been established (Figure 4)and farmers are being trained in these techniques. Various pollen honey is being separated and the origin labelled. The art of candle making has been introduced for the farmers as a source of additional income.

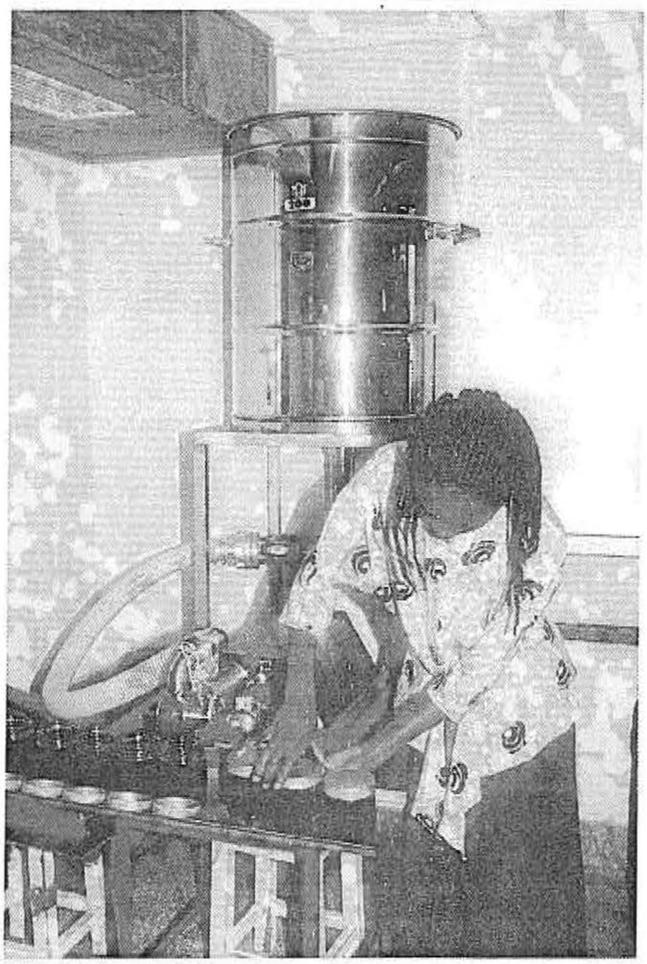

Figure 4. Honey packaging and processing in ICIPE's Apiculture unit

5. HONEY QUALITY CONTROL

A quality control laboratory has been established to analyse the honey produced by various beekeepers. The types of honey produced in the temperate zones are well documented, whereas important honey types from the tropics and sub-tropics have not yet been analysed. The different honey types of the world show great variety, especially in flavour and aroma, because the different plants from which nectar and honeydew are collected contribute their own characteristic constituents. In addition to this, honey is produced under many different climatic conditions. The main constituents in honey are, however, normally almost the same.

Table 5a. Water content, proline and acid in honey: Comparison of Eastern and Rift Valley Provinces with set limits. (N=62)

	Eastern (E)		Rift Valley (R)		
	Range	Mean ± SE	Range	Mean ± SE	Limit
Moisture (%)	16.75 - 19.6	18.05 ± 0.14	16.3 - 21.0	18.36 ± 0.18	≤ 21%
Proline (mg/kg)	267.56 - 389.24	940.9 ± 23.08	272.63 - 1155.19	586.7 ± 3.54	≥ 180 mg/kg
pH	3.78 - 4.67	4.19 ± 0.05	3.61 - 4.44	3.99 ± 0.04	
Free acidity (meq/kg)	12.25 - 116.42	50.3 ± 5.77	18.06 - 56.82	32.8 ± 1.56	≤ 40 meq/kg

Table 5b. Summary of comparison of sugar content results

	Eastern (E)		Rift Valley (R)	
	Range	Mean ± SE	Range	Mean ± SE
Fructose (%)	27.82 - 45.62	39.87 ± 0.78	25.63 - 51.03	40.48 ± 0.79
Glucose (%)	21.14 - 42.10	29.71 ± 1.08	22.60 - 42.26	29.89 ± 0.91
Sucrose(%)	Trace - 1.89	0.19 ± 0.08	Trace - 4.76	0.54 ± 0.20
Fru + Glu	60.12 - 84.91	69.57 ± 1.28	60.55 - 85.02	70.37 ± 1.17
Fru/Glu	0.69 - 1.87	1.39 ± 0.05	0.73 - 2.03	1.40 ± 0.05
Glu/moisture	1.20 - 2.28	1.65 ± 0.06	1.11 - 2.20	1.63 ± 0.05

Table 5c. Indicators of overheating compared between Eastern and Rift Valley Provinces

	Eastern (E)		Rift Valley (R)		
	Range	Mean ± SE	Range	Mean ± SE	Limit
HMF	Trace - 51.65	16.43 ± 2.49	4.9 - 22.23	6.8 ± 0.97	≤ 40 mg/kg
Diastase	5.17 - 68.52	18.52 ± 3.38	7.37 - 22.61	12.29 ± 0.47	≥ 8 S units
Invertase	43.39 - 289.08	138.5 ± 13.04	57.5 - 235.23	123.91 ± 7.14	≥ 50 U/kg

Routine chemical analysis of moisture, proline, sugar, hydroxymethylfurfural (HMF) content, diastase and invertase activity and pH and acidity, enables the detection of adulteration or poor handling of honey by monitoring certain indicators, so that what is referred to as 'table honey' is always maintained within certain limits. Tables 5a, 5b and 5c give examples of analytical work carried out in ICIPE's quality control laboratory.

Major importers and packers will only buy honey that meets the standard criteria. It is therefore only by monitoring the quality of locally produced honey and marketing only top quality produce that African countries can establish themselves in the honey market.

6. MARKETING STRATEGY DESIGNED

A marketing strategy for the beekeepers of East Africa was designed and national and international outlets were established for the sale of honey and other beehive products. All floral honey was tested for the optimum requirements of HMF, diastase enzyme, fructose, glucose, sucrose and maltose sugars and the moisture contents. ICIPE is acting as a catalyst in creating a link between traders and producers.

B. SERICULTURE

7. WILD SILKMOTH CONSERVATION AND UTILISATION

7.1 ABUNDANCE AND DISTRIBUTION OF WILD SILKMOTH SPECIES ACROSS EAST AFRICA

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 to rural communities. The survey focused only on silk cocoon-forming species in three Lepidopteran families, Lasiocampidae, Saturniidae and Thaumatopoeidae. These three moth families were selected for this study because the majority of the wild silkmoths so far utilised in other 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 indigenous species of wild silkmoths in East Africa. Field trips were made to various localities and different developmental stages of the wild silkmoths sampled together with data on their host plants. A total of 58 species occurring within 170 localities in the three countries were recorded. Uganda recorded 36 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 1 genus. Two potential species, *Argemia mimosae* and *Gonometa* sp., from two lepidopteran families (Saturniidae and Lasiocampidae, respectively) produce silk fibre of high quality.

These preliminary results indicate a high diversity of wild silkmoth species in the three countries and give a good indication of the 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 enhance the conservation of the wild silkmoth species and their host plants, by providing an extra source of income to the people.

7.2 CONSTRAINTS TO LARGE-SCALE PRODUCTION OF COCOONS IN THE WILD

The natural mortality rate in the forest of *Gonometa* sp. was monitored and the factors responsible were recorded. The main reason was egg parasitism and pupae attack by hymenopteran and dipteran parasites. This was reduced dramatically by covering the young larvae in 1–3 stages by a very fine net cloth. A bioassay is being conducted to determine attraction of the parasites to younger instars and develop a repellent to save young larvae to enhance the production of cocoons in the wild. In the previous year (1997), 65% of the cocoons in Mwingi were washed off due to unusual flooding of the river due to El Niño.

8. DOMESTICATED SILKWORM REARING

8.1 PROBLEMS OF REARING DOMESTICATED SILKWORM, *BOMBYX MORI*

Several domesticated silkmoth hybrids that flourish in the African environment and produce high quality silk have been developed by the Programme. These hybrids were selected by crossing a number of domesticated silkmoth, *Bombyx mori* strains and testing their vigour when grown on a variety of mulberry cultivars. The silkworm hybrid cross ICIPE I, when grown on the mulberry Kanva 2 cultivar, generated the highest silk yield. Other races which were developed and selected are ICIPE II, Egyptian, KxS, SxR and NB_4D_2.

Field tests are being carried out in Nyeri, Kola and Banana Hill in Kenya. The Uganda Silk Sector Association is using only SxR race and their production has reached 2–3 tonnes per year as compared to Kenya, where production was initiated in 1997 and reached 250 kg per year. Tanzania initiated the production in late 1998; one kilogram of raw silk was made with approximately 5000–6000 green cocoons. All the materials needed to rear domesticated silkworms in the field were constructed using local materials and local labour. The performance of various silkmoth *B. mori* races have been examined on the basis of their economic characteristics (Table 8.1).

Table 8.1. Comparative performance of silkmoth *Bombyx mori* races

	Race					
Economic characters	ICIPE 1	ICIPE 2	NB_4D_2	Egyptian	KxS	SxR
Average fecundity	497.67	512.00	523.98	468.00	482.26	509.00
Hatching percentage	98.70	99.00	98.00	97.52	99.00	98.20
Weight of 10 5th instar larvae (g)	50.62	49.80	47.50	41.57	51.00	50.70
Average wt. of cocoon (g)	1.89	1.63	1.71	1.58	1.89	1.80
Yield of cocoons by number per 10,000 larvae brushed	9207	8997	8956	8613	9190	8965
Yield of cocoons by wt per 10,000 larvae (kg)	17.30	14.66	15.34	13.60	17.36	16.13
Shell wt. (g)	0.35	0.32	0.35	0.28	0.41	0.33
Shell percentage	20.64	19.63	20.46	17.72	21.69	18.33
Filament length per cocoon (m)	1140	1057	1162	987	1223	989

Table 8.2a. Morphological characterisation of six mulberry cultivars (germplasm)

Cultivar	Average height of shoot (m)	Average leaf size (cm) lxb	Texture	Average internodal distance (cm) Top	Mid	Bottom
Kanva 2/M5	1.63	16x24	Smooth	3.6	4.4	5.7
Thailand	1.65	14x19	Very smooth	3.0	6.1	6.9
S-36	1.93	14x23	Semi-smooth	2.6	9.4	9.2
Embu	1.62	16x23	Rough	3.7	5.0	6.1
Thika	1.56	18x22	Smooth	2.2	2.7	2.3
S41	1.50	13x20	Rough	2.7	5.3	7.2

Table 8.2b. Performance of ICIPE IxSxR bivoltine hybrid race of *Bombyx mori* reared on different mulberry cultivars

Average wt of life stages (g)	Cultivars					
	Kanva2/M5	Thailand	Thika	S-36	Embu	S41
1-day-old 5th instar	0.78	0.76	0.81	0.73	0.60	0.62
4-day-old 5th instar	2.1	1.86	2.05	2.0	1.76	1.54
8-day-old 5th instar	4.55	4.21	4.42	4.0	3.66	2.7
Cocoon	1.8	1.71	1.62	1.67	1.45	1.27
Pupae	1.41	1.37	1.31	1.30	1.17	0.99
Shell weight	0.38	0.37	0.34	0.36	0.28	0.26
Percent survival	93	99	96	96	88	84

Table 8.2c. Filament length, shell percentage and denier of bivoltine hybrid of *Bombyx mori* (ICIPE IxSxR) raised on different mulberry cultivars

Parameters	Kanva2/M5	Thailand	Thika	S-36	Embu	S41
Average shell %	21.1	21.7	20.9	21.5	19.3	20.4
Average filament length (m)	1173	1191	1090	1125	1079	969
Average denier	2.39	2.4	2.3	2.31	1.83	1.78

Table 8.3. Postharvest performance of the bivoltine cocoons from three races of *Bombyx mori* (NB_4D_2-Dumble, KxS-Oval, ICIPE II-Notch) on various machines*

Cocoon shape	Cocoon wt (g)	Breaks in reeling	Breaks in re-reeling	Wt of raw silk (g)	Breaks in winding	Breaks in tripling	Breaks in twisting	Breaks in winding
Dumble	500	15	27	130	7	-	1	5
Oval	500	12	16	160	4	-	3	8
Notch	500	14	14	140	13	1	4	7

* There are no breaks in twist reeling. Degumming, bleaching and dyeing time was fixed to 1 h.

The major disease caused by the nuclear polyhedrosis virus (NPV) and other diseases were identified. NPV attacks the fat body of the silkworms and also multiplies in the haemolymph. The haemolymph turns milky and the worms die prematurely. Lime powder therapy with benzoic acid had brought the attack under control. Mulberry plants are subject to many diseases, particularly during the rainy seasons. Red rust was very common during the rainy season, attacking the whole field. Preventive measures were established.

8.2 SCREENING OF MULBERRY CULTIVARS

There are seven cultivars of *Morus alba* at ICIPE: Embu (local), Thailand, Kanva-2/M5, Thika, S-31, S-41 and S-36. These cultivars were screened against the silkworm races ICIPE I x ICIPE II, NB_7 x NB_{18}, NB_4D_2, and SxR. Kanva 2 was found to be superior in terms of renditta, thread length and disease resistance. This is followed by Thika and Thailand varieties. Attempts are being made to introduce Kanva-2 across East Africa in the farmers' fields. The morphological characters of six mulberry cultivars are presented in Table 8.2a.

A model farm house has been constructed at ICIPE for the farmers to replicate in their own field. Two bivoltine hybrids, ICIPE I female and SxR male were crossed and screened against 6 mulberry cultivars (Table 8.2b) and the results (Table 8.2c) obtained.

The reeling characters of the hybrid race were also recorded in terms of filament length and denier.

8.3 REELING OF BIVOLTINE AND WILD SILK COCOONS

Reeling performance of cocoons obtained from the various *B. mori* and wild silkmoth races were compared. The reeling and re-reeling units were installed at ICIPE (Figure 8.3). The length of the reeled fibre was determined on a mono-cocoon reeling unit. This helps in establishing the best silk fibre-producing race for field release. Out of the four races (ICIPE I, ICIPE II, Egyptian and Shanshi), Shanshi has 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. The renditta performance was also checked for each race.

The reeling strength of three races of *B.mori* were compared (Table 8.3).

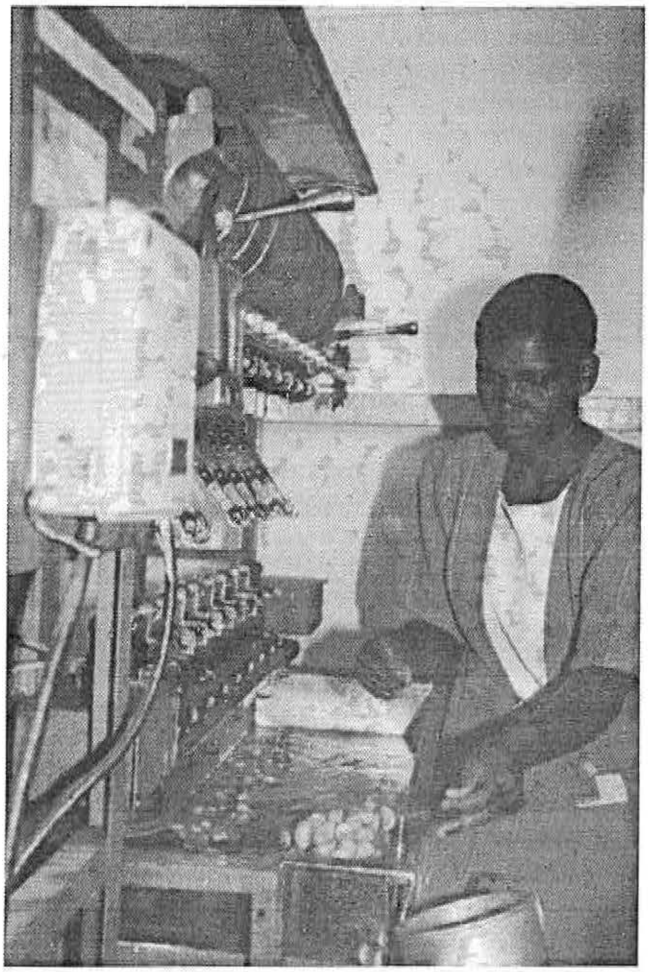

Figure 8.3. Reeling of bivoltine silk

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 handloom.

Weaving is the transformation of the yarn into fabric on a powerloom or handloom. The objective of this project activity is adoption of textile engineering to cover all aspects of manufacturing from cocoon to fabric so as to develop an outlet for farmers' raw material (Figure 8.4).

The time of each postharvest activity and required person-hours was determined as follows:

- 7.5 kg of green cocoons are required to reel 1 kg of raw silk.
- 5 to 6 h are required to reel 8 kg of cocoons and 4 h are required to re-reel the raw silk from the bobbins.
- 39 man-hours are required to reel 8 kg of raw silk.
- 8 kg of silk yarn is required to make 56 to 58 m of cloth.
- 60 man-hours are required to complete winding, twisting and doubling process of 8 kg of raw silk.
- 18 man-hours are required to degum 8 kg of yarn.
- 24 man-hours are required for warp making in both handloom and powerloon machines.
- 20 days are required to weave 56–58 m of cloth on a handloom machine.

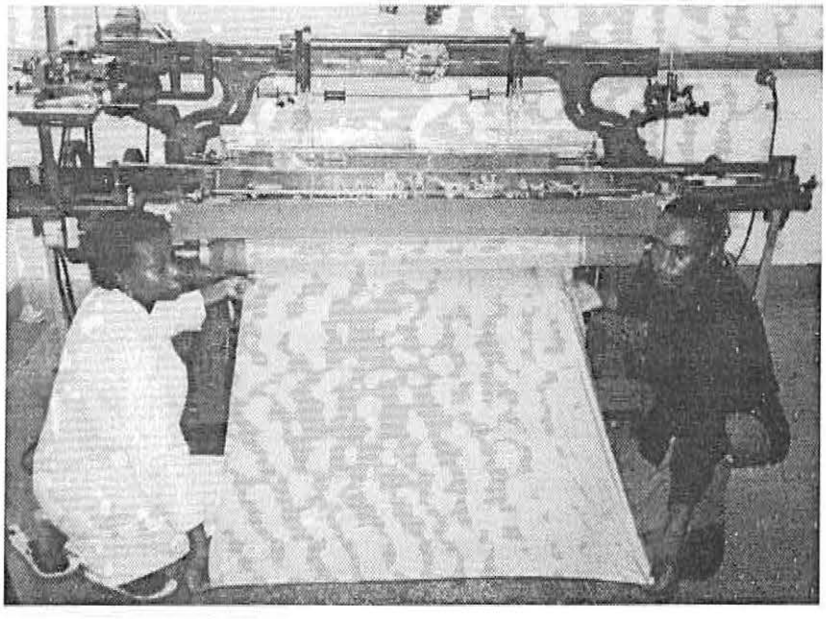

Figure 8.4. African silk comes rolling off the looms in ICIPE's Sericulture demonstration unit

8.4 POSTHARVEST COCOON TECHNOLOGY

The cocoons were reeled on bobbins and re-reeled to make skeins, which after winding, twisting, doubling and bleaching process, were tranferred into a warp.

- 6 days are required to weave 56–58 m on a powerloom machine.

If the activities are synchronised, the postharvest work can be performed in 14 days from cocoon to cloth production.

C. ON-SITE FARMER-PARTICIPATORY TECHNOLOGY TESTING AND DEVELOPMENT

On-farm trials and testing of apiculture and sericulture technologies are currently being conducted in Uganda, Tanzania, Ethiopia and Eritrea. About 5000 farmers and individuals from NGOs and government agencies received training at ICIPE and at their respective field sites in 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, the farmers will benefit economically through the use of Africa-adapted production technology designed at ICIPE to conserve and protect a fragile environment.

9. REGIONAL OUTREACH AND NETWORKING

9.1 KENYA

Several field sites have been established for both sericulture and apiculture in the country. To revive the sericulture industry, three sites were developed for domesticated silkworm farming and two for wild silk utilisation and conservation. 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 train and demonstrate to the beekeepers modern techniques of beekeeping. At least 25 NGOs have been trained on beekeeping.

9.2 UGANDA

ICIPE introduced Langstroth hives in Hoima and Kabale and beekeepers and farmers have been invited to visit ICIPE in groups for 1-day training programmes, especially designed for the farmer. IFAD's Coordinator Simon Mugaya and Mrs Teddy from Hoima and DEC, Kabale Districts, respectively, have assisted in this regard. The postharvest technology for silkworm cocoons is being established at NARO with the assistance of the Commissioner of Entomology, Mr Gersham Mugeinyi and Mr Muller of the Sericulture Development Project, EU. The improvement of beekeeping, harvesting and the marketing of honey in Uganda is being done 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 the establishment of a fixed market outlet for commercial insects products.

9.3 TANZANIA

ICIPE has initiated apiculture/sericulture farming at 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. ICIPE planted 6 acres of mulberry plantation at ABESO for silkworm farming. A model farmhouse for rearing of silkworm has been constructed and the rearing of the eggs will commence soon after the rains. Four trainers have completed their training in sericulture and apiculture techniques.

9.4 ZAMBIA

ICIPE has developed a proposal for an IFAD development project (Development of the Zambia Forest Project) for the three districts of Solwezi, Kasempa and Mwinilunga of the Northwestern Province, which are the main traditional honey producing zones. Figures given by the IFAD coordinator, Mr Munalula do not tally with the actual honey production in Zambia. ICIPE is developing ways and means to acquire the actual production figure to connect beekeepers with the market.

9.5 ZIMBABWE

Honey Processor (Pvt) Ltd., owned by Mr C.J. Coleman, a private beekeeper in Mazowe, is collaborating with ICIPE in pollination ecology.

9.6 LIBYA, TUNISIA, ALGERIA AND MOROCCO

ICIPE staff went to Tripoli on an IFAD mission to monitor the existing beekeeping constraints in North Africa and to suggest a possible solution. A project proposal was developed to rectify the disease problems, impart training and develop a quality control laboratory in the Ministry of Agriculture, Tripoli for North Africa. The project has been submitted to IFAD and has been approved and is being implemented.

9.7 TCP, FAO

Four regional TCP grants have been proposed for countries in East, South, West and Central Africa. The proposals are in the pipeline.

9.8 TRICKLE-UP PROGRAMME, UNDP

The farmers in this programme have been selected from our project areas (Baringo and Nyeri/Nanyuki in Kenya) and each given US$ 100 in two installments of $50 each. This helps in the initiation of apiculture or sericulture technologies in the farm. ICIPE is the executing agency of this project.

D. MARKETING STRATEGY FOR SERICULTURE AND APICULTURE PRODUCTS IN EAST AFRICA

In East Africa, overexploitation of natural biological resources is a major threat to sustainability. The main environmental costs of development are associated with degradation of the natural resource base occurring in Africa at an alarming rate.

10. SILK MARKETING

Among the various approaches to sustainable development, sericulture is a new phenomenon and the introduction of a marketing strategy is fairly difficult. The local market is limited and only well-to-do Africans, Europeans and limited Asian communities make use of silk garments as a luxury and cultural item, respectively. Hence, ICIPE has developed only an important bivoltine race whose silk can be exported to the international market.

Due to the scarcity of raw silk in the world market, Africa has a good opportunity to enter into the silk business to improve the income of rural communities. We have developed a small market for silk cloth in Kenya and confirmed the sale of raw silk in the Indian market with the permission and direction of the Central Silk Board, Government of India. Among the Indian traders, R.K Industries, Bangalore has accepted to buy nine tonnes of bivoltine cocoons produced and stored in Kampala, Uganda by the National Sericulture Development Centre. Thus, ICIPE has created a marketing outlet for cocoons, raw silk and cloth produced in East Africa. The prices of 1 kg of A grade cocoons is US$ 5, B grade US$ 4 and C grade US$ 3. The cloth per metre sells at US$ 8.5 and the price of a shirt is US$ 29. These prices are close to international prices.

11. MARKETING HONEY AND HIVE PRODUCTS

The marketing of honey in Kenya is promoted by middlemen who exploit the innocent rural people and compel them to sell their honey at a cheap rate. The method of harvesting the honey from the traditional hives is so crude that the natural nectar products lose value and beekeepers fail to earn a sufficient profit margin to maintain their families.

The development of a strategy for honey and beehive producers appropriate for the specific circumstances of the different regions requires an interactive communication between the partners and will take place in four different phases:

(a) Research and evaluation
(b) Organisation and coordination
(c) Operational part
(d) Monitoring and coaching

The research project examines the performance of the hive products market and employs a structure-conduct-performance framework, focusing on producers, distributors, retailers/end-users. Some of the components to be considered are as folows:

- The quality of the product
- Price
- Processing and packaging
- Placement of the commodity.

A system of purchasing honey and beeswax from beekeepers has been developed involving the beekeepers co-operatives. There is one centre in each location where ICIPE and beekeepers meet. At this centre, weighing, examination, purchase and loading is done. The labelling of containers from each beekeeper is done (including the name, number of buckets, weight, floral origin and type of combs). Only ICIPE containers are used and accepted. This is being monitored by ICIPE in cooperation with the Government, until the co-operatives can support themselves. There is a fixed day each week for honey purchase in each location where the beekeepers get their pay direct from the buyer (initially ICIPE).

ICIPE has set a uniform price for sealed comb honey from the beekeepers and wax as follows:

Comb honey from a traditional hive	Kshs 80/kg
Comb honey from a Langstroth hive	Kshs 100/kg
Processed cake of wax	Kshs 280/kg

However, the price can go down depending on the quality of comb honey.

The comb honey is refined and packed at ICIPE in 470-g bottles. To increase the sales on behalf of farmers, ICIPE is introducing other methods of packing the liquid honey, including a 250 g bottle and chunk honey. This will give customers a wide choice and increase the income to the beekeepers.

ICIPE has outlined a market strategy for honey and beeswax on behalf of beekeepers. Honey is sold locally to individuals and retailers, including yoghurt milk packers, supermarkets, shops and sweet and/or chocolate industries. Beekeepers can establish their own industry for sweets.

ICIPE has also explored the world market, but their specifications of good quality (table honey) are extremely difficult to meet and East African beekeepers at this time are unable to produce high enough quality honey. There is potential for producing large amounts of industrial honey, however and the beekeepers in East Africa prefer to sell their honey either in the local market or to the breweries. Table honey sells at almost twice the price of industrial honey. ICIPE's efforts have changed the marketing structure of East Africa, so that by changing harvesting habits, the quality of honey can be changed from industrial to table honey and then sold to the world market.

Output

Publications

The following scientific manuscripts have been communicated or published in international journals:

Adolkar V.V. and Raina S.K. (1999) Development of mulberry sericulture technology for additional income generation of small holders in Africa. (In press) *Proceedings of Second International Lepidopterists Conference of Africa*, Kirstenbosch Cape Town, South Africa 4–6 November 1999.

Adolkar V.V., Raina S.K., Adolkar V.V., Raina S. K. and Macharia R. Performance of the silkworm *Bombyx* *mori* (ICIPE x SxR) bivoltine hybrid race using cultivars of mulberry *Morus alba* sp. *Sericologie* (Communicated).

Ogola D., Lumumba J.A., Kimbu D.M. and Evelyn N. (In press) Economics of mulberry silk farming. In *Economics of Apiculture and Sericulture Modules for Income Generation in Africa* (Edited by S. K. Raina), IBRA, UK.

Kimbu D.M., Raina S.K., Adolkar V.V. and Kioko E. N. (In press) Marketing of apiculture and sericulture products. In *Economics of Apiculture and Sericulture Modules for Income Generation in Africa* (Edited by Raina S.K.), IBRA, UK.

Kioko E. N., Raina S. K. and Mueke J. M. (1999) Conservation of the wild silkmoths for economic incentives to rural communities of the Kakamega Forest in Kenya. *International Journal of Wild Silkmoth & Silk* Japan 4, 1–5.

Kioko E. N., Raina S. K. and Mueke J. M. (1999) Chorion structure and egg size of the African silkmoth, *Argema mimosae* and *Gonometa* sp. (Lepidoptera: Bombycoidea) in Kenya. *International Journal of Wild Silkmoth & Silk* 4, 43–46.

Raina S. K. and Kahoro H. M. A simple device for extraction of bee venom from the African bees. *Bee World, IBRA* (Communicated).

Raina S. K. and Kimbu D. M. (1999) Variations in races of the honey bee, *Apis mellifera* in Kenya. *Journal of Apidologie* (Communicated).

Raina S. K., Kioko E.N., Adolkar V.V., Muiru H.G., Nyagode B.A., Kimbu D.M., Lumumba J., Waruiru R. and Naguku E. (In press) ICIPE's ground work in building African commercial insects (Edited by S.K. Raina) *Proceedings of the Second International Workshop on Conservation and Utilisation of Commercial Insects*, Duduville, Nairobi, Kenya. .

Shi W., Muiru H. and Raina S. K. (1999) Queen rearing with African honey bees. *Journal of Apidologie*. (Communicated).

Slama M., Mathur S., Raina S.K., Kioko E.N., Adolkar V.V. and Kimbu D.M. (1999) Apiculture and sericulture development in Africa, wild silkmoth farming generates additional income and conserve biodiversity. In *Agricultural Technologies from IFAD-supported research. Tools for Poverty Alleviation. Advisory note No. 15.*

Slama M., Mathur S., Raina S.K., Adolkar V.V. and Kimbu D.M. (1999) Apiculture and sericulture development in Africa, mulberry sericulture as an income generating activity for rural poor. In *Agricultural Technologies from IFAD supported research. Tools for Rural Poverty Alleviation. Advisory note No. 13.*

Workshops/seminars/conferences/expos

Adolkar V.V. and Kioko E. N. (1999) Expanded Trickle up Programme Coordinators Workshop 28–29 January, Lenana house, Nairobi, Kenya

Adolkar V.V. and Kioko E. N. (1999) 2nd Intenational Lepidopterists' Conference of Africa, 4–6 November, Cape Town, South Africa.

Kioko E.N. (1999) BioNet – International Workshop, August, Cardiff Wales, UK.

Kioko E. N. (1998) 3rd International Butterfly Ecology and Evolution Symposium, 15–19 August, Creseted Butte, Colorado, USA.

Muiru H.G., Adolkar V.V., Kioko E.N., Raina S.K and Kimbu D.M. The Inaugural Conference of the African Evaluation Association.

Raina S.K. and Kioko E.N. (1998) 3rd International Conference on Wild Silkmoths. 11–14 November, . Bhubaneshwar, India.

Raina S.K., Adolkar V.V., Kioko E.N. and Muiru H.G. (1999) Exhibition of Sericulture and Apiculture Technology, COMESA TEX 99, Nairobi, Kenya.

Participated in IFAD EXPO February 1998 and exhibited sericulture and apiculture technologies to the dignitaries, school children and general public in Rome.

Exhibition on sericulture and apiculture technologies was arranged at the Freedom from Hunger NGO office in Nairobi in June 1998 to familiarise the common man on income generation options. It was arranged by UNDP Nairobi.

Lectures were delivered by the Project Leader and staff in China, USA, African countries, Australia and Germany on innovative technologies developed at ICIPE on sericulture and apiculture techniques.

Capacity building

Workshops

The First International Workshop on 'The Conservation and Utilisation of Commercial Insects' was held in August 1997 and the proceedings published in February 1999. *The Conservation and Utilisation of Commercial Insects* (Edited by S. K. Raina, E. N. Kioko and S. W. Mwanycky), 1999, ICIPE Science Press, Nairobi, 252 pp.

Short- and long-term farmers' training in Kenya

On-farm trials and testing of apiculture and sericulture technologies are currently conducted in Tanzania, Uganda, Ethiopia, Eritrea and Kenya. About 5000 farmers and individuals from NGOs and governmental agencies received 1–2 days training at ICIPE and at their respective field sites. ICIPE offered free of change two courses on honey beekeeping and silk farming, for the farming community of E. Africa with only US$ 35 as registration fee. The courses took place on 1 May to 30 November 1999.

Information dissemination

More than 4000 copies of the first fact-sheet on commercial insects were circulated among farmers, donors, NGOs, NARS and traders. Copies of the second fact-sheets on commercial insects are being developed in Arabic, English, French, Kiswahili, Kikuyu, Luo, Kamba and Luganda for the farmers of East and West African countries. A video cassette on farmers' day showing the process of sericulture from egg production to cloth and apiculture from hive setting to queen raising and honey and wax processing and packaging, has been produced and directed by Commercial Insects' Programme staff, and released and distributed.

Impact

The project trials will be conducted in all networking partner countries 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 services, thus ultimately strengthening Africa's national food security systems. Advancing the understanding of ecosystem composition, structure and function provides baseline data for environmental monitoring and linking of basic and applied apiculture and sericulture research for sustainable land use and development, and for the conservation of forest biological diversity in Africa.

CAPACITY BUILDING

CAPACITY BUILDING PROGRAMME

ICIPE's Capacity Building Programme aims to enhance the capabilities of developing countries in the tropics and subtropics, particularly in Africa, for research and training in insect science, in order to promote the development and utilisation of sustainable arthropod management technologies. The Programme provides a vibrant forum for information exchange between resource persons from national and international institutions with proactive insect scientists from various parts of the developing and developed world. Through its postgraduate and professional development schemes, the Programme makes a major contribution to ICIPE's research through the activities of postgraduate students, postdoctoral scientists and visiting research associates training at the Centre.

The implementation strategy of the Programme is consumer/constituency-driven. Since ICIPE's mandate focuses on developing countries of the Third World, the main thrust of the capacity building programme is, therefore, directed toward three major areas of activity; these are: (a) training of African nationals for leadership in insect science and to enhance interactive technology generation and adaptation; (b) building national capacities for technology diffusion, adoption and utilisation; and (c) facilitating dissemination and exchange of information. This strategy has been translated in the following themes:

- postgraduate training at PhD and MSc levels, undertaken through two main programmes:
  (i) The African Regional Postgraduate Programme in Insect Science (ARPPIS) and
  (ii) The Dissertation Research Internship Programme (DRIP) for students registered in universities abroad (or for students studying in Africa, but outside the ARPPIS programme;
- professional development schemes for scientists of any nationality;
- non-degree training, consisting of research methodology courses for scientists; practitioner training courses for pest management practitioners and industrial attachment experience for technical students in colleges and universities.

The present report summarises the capacity building activities and achievements during the 1998 and 1999 sessions, with updates where necessary for the Programme's output to date.

Capacity Building

CAPACITY BUILDING PROGRMME

Capacity Building at ICIPE

A. POSTGRADUATE TRAINING PROGRAMMES

Participants: *V.O. Musewe (Head of Capacity Building) G.P. Kaaya, A. Hassanali, Z.R. Khan, W.A. Overholt, B. Torto, N.K. Maniania, K. Ampong-Nyarko, B. Löhr, S.K. Raina, S. Essuman, S. Mihok, S. Sithanantham, A.M. Varela, P. Njagi, R.K. Saini, E. Osir, S. Miller, S. Lux, A. Ngi-Song, L. Rogo, J. Baumgärtner, J. Ssennyonga, M. Knapp, A. Odulaja, S. Kimani-Njogu, A. N. Mengech, J. Githure, M. Bashir, R. Pasquet, W. Lwande, R.C. Saxena, H. Mahamat, B. Knols*

Assistants: *L.W. Chongoti, C.A. Nyang'aya, M. Ochanda*

Donors: *German Academic Exchange Service (DAAD), European Union (EU), Gesellschaft für Technische Zusammenarbeit (GTZ), International Fund for Agricultural Development (IFAD), Jomo Kenyatta University of Agriculture and Technology (JKUAT) (Kenya), Overseas Development Administration, UK (ODA), Rockefeller Foundation, United States Agency for International Development (USAID), United States Department of Agriculture (USDA), University of Constance (Germany), Moi University (Kenya), University of Nairobi (Kenya), Kenyatta University (Kenya), University of Pretoria (RSA), African Wildlife Foundation (AWF), Direct Support to Training Institutions in Developing Countries Programme (DSO), Directorate General for International Cooperation (DGIS) (the Netherlands), Gatsby Charitable Trust, International Centre for Research in Agroforestry (ICRAF), International Crops Research Institute for the Semi Arid Tropics (ICRISAT), National Institutes of Health (NIH) (USA), Wageningen Agricultural University (WAU), Multilateral Initiative on Malaria Research in Africa (MIM) World Health Organisation-Tropical Diseases Research (WHO-TDR), United Nations Development Programme (UNDP)*

Collaborators: • *ARPPIS participating Universities (See Table 1.4)* • *National Museums of Kenya (NMK)* • *International agricultural research centres - ICRAF* • *National research organisations in African countries signatory to ICIPE Charter* • *Universities in developed countries—University of Zena (Germany), University of Bristol (UK), Swedish University of Agricultural Sciences, University of Constance (Germany), Wageningen Agricultural University (the Netherlands)*

1. THE ARPPIS PHD PROGRAMME

Background, approach and objectives

The African Regional Postgraduate Programme in Insect Science (ARPPIS) was established in 1978, with the prime objective of training arthropod scientists and pest management specialists within Africa. The programme admitted its first class of PhD students at ICIPE in 1983, with only a few universities collaborating with ICIPE on the programme. The number of participating universities grew rapidly to 30 by 1996, but is now maintained at about 25 through a more stringent review process.

In cooperation with the participating universities which register and examine students, ARPPIS releases an average of seven 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 3 years of research training. 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 is to provide additional research supervision, ensure that the research meets international academic standards, examine the students and award them with degrees. Each PhD class is composed of an average of seven students. The Programme has, at any one time, between 20 and 40 students at various stages of their thesis work at ICIPE.

Table 1. Country distribution of postgraduate students enrolled in ARPPIS PhD Programme (1983–1999 classes)

Country	Students*	Country	Students *
Benin	1	Namibia	1
Burkina Faso	1	Nigeria	14
Cameroon	1	Rwanda	2
Chad	3	Senegal	3
D.R. Congo	4	Sierra Leone	3
Egypt	3	Somalia	3
Ethiopia	10	South Africa	1
Ghana	5	Sudan	15
Kenya	47	Tanzania	7
Malagasy	1	Uganda	12
Malawi	2	Zambia	5
Mali	1	Zimbabwe	4
Mauritania	2		
Mozambique	1		
Total enrollment (1983–1999)			152*

* The total includes 11 students whose training programmes were discontinued for academic reasons or natural causes.

To date, a total of 152 scholars from various African countries have been enrolled in the programme (Table 1). The following were the major activities of the ARPPIS programme during 1998 and 1999:

1.1. SCHOLARS AWARDED PHD DEGREES AT REGISTERING UNIVERSITIES

A total of 12 ARPPIS doctoral students qualified for the award of PhD. degrees by their registering universities during the period. This brings the total number of PhDs graduated through the Programme to 103 since 1983 when the Programme started. Table 1.1 shows the particulars of these students, their thesis titles, supervisors and registering universities.

1.2 SCHOLARS COMPLETING THEIR DOCTORAL PROGRAMMES

Nine scholars of the 1995–1996 classes formally completed their 3-year training programmes during the period, under sponsorship by various donors (Table 1.2). The scholars had started their training programmes at different times and embarked on their thesis projects since the mandatory coursework had been phased out. Five of the candidates have already graduated from their registering universities, two have submitted a draft thesis to their registering universities and are awaiting oral examinations, while two are still finalising their theses at ICIPE.

1.3 NEW STUDENTS ADMITTED TO ARPPIS

Twenty-one students from various African countries were admitted to the ARPPIS Doctoral Programme on a competitive basis, based on their suitability for graduate research fellowships that are advertised each year. Eleven of the students were admitted on 1 July 1998. Eight of these students reported on time and started on remedial coursework comprised of graduate-level biostatistics, information technology and research project management. The other 10 were admitted on 1 July 1999. 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 biostatistics course was held as scheduled, while the research management course was scheduled for April 2000, to allow the new PhD students to prepare their project proposals on time. The course on information technology (IT) was not formally offered due to a shortage of staff in ICIPE's IT department and scholars were left to train themselves.

The biodata of the new scholars admitted in 1998/1999 are given in Table 1.3a. However, the Chadian student (Mr K. Pombe) did not take up his training fellowship as his employers could not release him, while the Nigerian, Mr O.O. Ajayi left ARPPIS in 1999 to take up a British scholarship. The detailed training information on all the ongoing students (as at 31 December 1999) is given in Table 1.3b.

1.4 COLLABORATION WITH PARTICIPATING UNIVERSITIES

In 1998, four universities admitted to ARPPIS earlier, concluded agreements with ICIPE and formally renewed their membership in ARPPIS. These included Addis Ababa, Dschang, Makerere and Rwanda. Two other universities applied to participate in the programme: Sokoine University of Agriculture, P.O. Box 3000, Morogororo, Tanzania and University of Qwa-qwa (Qwa-qwa campus of the University of the North), Private Bag X13, Phuthatjhaba, Republic of South Africa. Both applications were considered favourably, subject to certain clarifications. The University of Qwa-qwa is yet to clarify certain conditions for admission, while Sokoine University has now joined the ARPPIS Network. In 1999, Jomo Kenyatta University of Agriculture and Technology (JKUAT) concluded its earlier agreement with ICIPE and was admitted to ARPPIS, bringing to 25 the total number of ARPPIS participating universities to date (Table 1.4).

1.4.1 *ARPPIS Academic Board*

The ARPPIS Academic Board, which is constituted of representatives from participating universities and members of ICIPE's ARPPIS Secretariat, held its 29th meeting at Addis Ababa University on 16 October 1998. The meeting coincided with the inauguration of the Centre for Eastern and Northeastern Africa of the ARPPIS Sub-Regional Masters Programme. (*See section 2 following*). The Centre is hosted by the Department of Biology at Addis Ababa University and is coordinated by Dr Masresha Fetene, who is also head

Table 1.1. List of ARPPIS PhD recipients during 1998/1999

Name	Sex	Class	Nationality	Sponsor	Title of thesis	Registering university	Supervisors	Date of examination/award
E. Sebitosi	F	1993	Ugandan	DGIS	The physiology of the tick, *Rhipicephalus appendiculatus* in relation to the transmission of *Theileria parva*	Ahmadu Bello University, Zaria, Nigeria	Dr G.P. Kaaya Dr T. Musoke Dr A. Young Prof. R.I.S. Agbede	July 1998
G.M. Zimba	M	1994	Malawian	DAAD/ ICIPE	Synthesis of a lectin-trypsin complex and its role in *Trypanosoma brucei* differentiation in the tsetse fly, *Glossina* spp.	University of Malawi, Malawi	Dr E. Osir Dr M. Imbuga Dr T. Ngwiri	December 1998
Z. Njagu	F	1994	Kenyan	DAAD/EU	Role of the monitor lizard, *Varamis niloticus* in trypanosome epidemiology	Kenyatta University, Kenya	Dr S. Mihok Dr M. Ahmed Dr N. Massamba Dr E. Kokwaro	November 1998
F.A. Demas	M	1994	Namibian	DAAD/ ICIPE	Mechanisms of location of *Amblyomma variegatum* and other ticks by the parasitoid, *Ixodiphagus hookeri*	University of Zimbabwe, Zimbabwe	Dr E. Mwangi Prof. A. Hassanali Dr E. Kunjeku Mrs A. Mabveni	March 1998
V.C. Ofomata	F	1994	Nigerian	DAAD/ DGIS	Investigations into the mechanisms of displacement of *Chilo orichalcociliellus* Strand by *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) on the Kenya Coast	Nnamdi Azikiwe University, Nigeria	Dr W. Overholt Dr S. Lux Prof. R. I. Egwuatu	June 1998
M.N.S. Sallam	M	1994	Egyptian	DAAD/ DGIS	Comparative evaluation of *Cotesia flavipes* and *Cotesia sesamiae* (Hymenoptera: Braconidae) for the management of *Chilo partellus* (Lepidoptera: Pyralidae) in Kenya	Kenyatta University, Kenya	Dr W. Overholt Dr E. Kairu	October 1998
J.A. Kongoro	F	1991	Kenyan	UNDP	Susceptibility of tsetse, *Glossina* spp. to trypanosome infection in relation to midgut trypsin-like enzymes and other molecules	Kenyatta University, Kenya	Dr E. Osir Dr I. Imbuga Dr P. Majiwa Dr N. Oguge	November 1998
R. O. Maranga	F	1995	Kenyan	DAAD/ ICIPE	Innovative control methods for *Amblyomma variegatum* (Fabricius, 1994)	Jomo Kenyatta University of Agriculture and Technology (JKUAT), Kenya	Dr G.P. Kaaya Prof. Hassanali Prof. J. Mueke	April 1999

Continued next page

Table 1.1. Continued

Name	Sex	Class	Nationality	Sponsor	Title of thesis	Registering university	Supervisors	Date of examination/award
J. P. Mbugi	M	1995	Kenyan	DAAD/ Gatsby	Movement of stemborers, *Busseola fusca* Fuller (Lepidoptera: Noctuidae) and *Chilo partellus* Swinhoe (Lepidoptera: Pyralidae) moths between wild and cultivated habitats	Kenyatta University, Kenya	Dr Z.R. Khan Dr W.A. Overholt Prof. J. Mueke	October 1999
S. Ekesi	M	1995	Nigerian	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	Ahmadu Bello University, Nigeria	Dr N. K. Maniania Dr Ampong-Nyarko Dr B. Löhr Dr I. Onu Dr A.D. Akpa	January 1999
E. Kioko	F	1996	Kenyan	IFAD	Biodiversity of wild silkmoths (Lepidoptera) and their potential for silk production in East Africa	Kenyatta University, Kenya	Dr S. K. Raina Prof. J. Mueke	October 1999
J. Songa	F	1996	Kenyan	Rockefeller	Temporal dynamics, economic importance and management of stemborers in maize production systems of Eastern Kenya	Kenyatta University, Kenya	Dr W. Overholt Prof. J. Mueke	October 1999

Table 1.2. Training information on the ARPPIS scholars of 1995/1996 who completed the PhD programme in 1998/1999

Name	Sex	Nationality	Class	Sponsor	Thesis title	Supervisors	Registering university
R.O. Maranga	F	Kenyan	1995	DAAD/ ICIPE	Innovative control methods for *Amblyomma variegatum* (Fabricius, 1994)	Dr G. Kaaya Prof. A. Hassanali Prof. J. Mueke	Kenyatta University, Kenya
J. P. Mbugi	M	Kenyan	1995	DAAD/ Gatsby	Movement of stemborers, *Busseola fusca* Fuller (Lepidoptera: Noctuidae) and *Chilo partellus* Swinhoe (Lepidoptera: Pyralidae) moths between wild and cultivated habitats	Prof. J. Mueke	Kenyatta University, Kenya
A. G. Malual	M	Sudanese	1995	DAAD/ IFAD	The effect of plants density on gregarisation of desert locust, *Schistocera gregaria* (Forskal)	Prof. A. Hassanali Dr B. Torto Dr E. E. Ali	University of Khartoum, Sudan
S. Ekesi	M	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	Dr N.K. Maniania Dr I. Onu	Ahmadu Bello University, Nigeria
E. N. Kioko	F	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. Mueke Dr E.D. Kokwaro	Kenyatta University, Kenya
D. Pacho	F	Mozambican	1996	DAAD/ GTZ	Biology of tomato leafminers in Kenya	Dr B. Löhr Dr A. M. Varela Dr S. Sithanantham Dr M. McGeoch	University of Pretoria, S. Africa
E.A. Misiani	F	Kenyan	1996	DAAD/ KARI-ODA	The role of arthropod vectors in the transmission of lumpy skin disease in cattle	Dr E. Osir Dr C. Gichabe Prof. R. S. S. Orago	Kenyatta University, Kenya
N. K. Gikonyo	M	Kenyan	1996	DAAD/EU	Semiochemical basis of non-preference in some wild animals by the *Glossina morsitans* group of tsetse	Prof. A. Hassanali Dr P. Njagi Dr R. K. Saini Prof. G. Gitu Prof. J. Midiwo	University of Nairobi, Kenya

Table 1.3a. Biodata of new students admitted to the ARPPIS PhD Programme in 1998/1999

Name and admission date	Sex	Age	Nationality	Qualifications	Employment status
M.M. Brandford, 1998	M	33	Ghanaian	BSc Botany and Zoology, Lower Second, Cape Coast, 1990 MSc Entomology, Cape Coast, 1997 Thesis title: The distribution and species composition of lepidopterous maize stemborers in Southern Ghana	Tutor, University of Cape Coast, Ghana
O.O. Ajayi, 1998	M	33	Nigerian	BSc Statistics, 1st class honours, 1994 MSc Statistics, Ibadan, 1997 Thesis title: Fitting and comparatively assessing the behaviour of growth models on animal weight in varying treatment conditions	Assistant Lecturer, Dept. of Statistics, University of Ibadan, Nigeria
L. M. Wekesa, 1998	M	29	Kenyan	BSc Zoology (GPA 3.20), Baraton, 1994; Dip.Edu (1st Class) MPhil Ecology, Moi University, 1997 Thesis title: Species diversity, spatial distribution and food preference of tropical lowland forest butterflies	Unemployed
A.M. Akol, 1998	F	30	Ugandan	BSc Zoology and Botany, Upper Second, Makerere, 1990; Postgrad. Dip. Edu. Second Class, Makerere, 1991 MPhil Biological Sciences, Cambridge, 1994 Thesis title: The significance of superparasitism and host discrimination in *Encarsia formosa* Gahan, a parasitoid of the greenhouse whitefly, *Trialeurodes vaporarium*	Lecturer, Dept. of Zoology, Makerere University, Uganda
M. H. Mohamoud, 1998	M	34	Somali	BSc Agricultural Sciences, 1986 MSc Zoology, Kenyatta, 1997 Thesis title: Survival and development of the stemborer, *Chilo partellus* Swinhoe (Lepidoptera: Pyralidae)	Unemployed
L.U. Abubakar, 1998	F	34	Kenyan	BSc Zoology and Biochemistry, 1st class honours, Nairobi, 1985 MSc Biochemistry, Nairobi, 1993 Thesis title: Purification and characterisation of a trypanoagglutinin from the midguts of the tsetse fly, *Glossina longipennis*	Research Officer, Kenya Marine Research Institute, Kenya
E.G. Degaga, 1998	M	33	Ethiopian	BSc Plant Science (Grade 2.97), Alemaya, 1982 MSc Crop Protection, Alemaya, 1994 Thesis title: Distribution and control of Angoumois grain moth, *Sitotroga cerealella*	Maize Entomologist, Awasa Research Centre, Institute of Agricultural Research, Ethiopia

Continued next page

Table 1.3a. Continued

Name and admission date	Sex	Age	Nationality	Qualifications	Employment status
D. Wanyama-Masinde, 1998	F	33	Kenyan	BSc Agric. and Home Economics, 1st class hons. Egerton University, 1993 MSc Agriculture, Cornell, 1996 Thesis title: Gender and extension: A training programme for extension agents	Research Assistant, Kenya Agricultural Research Institute (KARI). Kenya
I. G. Nzuma, 1998	F	25	Zimbabwean	BSc Crop Science, upper second, Zimbabwe, 1994 MSc Crop Protection (with merit), Zimbabwe, 1996 Thesis title: Oviposition behaviour of *Helicoverpa armigera* (Lepidoptera: Noctuidae) on mange tout peas (*Pisum sativum*) and bioassays to evaluate the table formulation of deltamethrin	Entomologist, Plant Protection Research Institute, Zimbabwe
I. Sarr, 1998	M	28	Senegalese	BSc Agricultural Sciences, Upper second, Dakar, 1991 MSc Crop Protection, Dakar, 1996 Thesis title: Construction of a partial life-table of the millet headminer	Unemployed
B. Nyagode, 1999	F	28	Kenyan	BSc Chemistry and Zoology, Upper second, Egerton University, 1993 MSc Chemistry, Egerton University, 1998 Thesis title: Attractants of the brown ear tick, *Rhicephalus appendiculatus* found in cow ear washes	Research Assistant, ICIPE, Nairobi, Kenya
M. Billah, 1999	M	30	Ghanaian	BSc Botany and Zoology, Lower second, University of Ghana, 1992 MPhil University of Ghana, 1998 Thesis title: Revision of the members of the Afrotropical genus *Kiefferulus goetgebuer*, 1922 and a description of one new species (Diptera: Chironomidae)	Research Assistant, University of Ghana, Ghana
P. Chinwada, 1999	M	31	Zimbabwean	BSc Crop Science, Upper second, University of Zimbabwe, 1991 MPhil University of Zimbabwe, 1994 Thesis title: The bean bruchids, *Acanthoscelides obtectus* (Say) and *Zabrotes subfasciatus* (Boheman): Distribution patterns in Zimbabwe, resistance levels in *Phaseolus vulgaris* L. (common bean) lines and control	Research Officer, Plant Protection Research Institute, Zimbabwe
P. Nemeye, 1999	M	41	Ugandan	BSc Botany and Zoology, Lower second, Makerere University, 1982 MSc Applied Entomology, University of London, 1988	Research Associate, IITA, Uganda

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Table 1.3a. Continued

Name and admission date	Sex	Age	Nationality	Qualifications	Employment status
S. Dimbi, 1999	F	27	Zimbabwean	BSc Agriculture, Upper second, University of Zimbabwe, 1994 MSc Crop Protection, University of Zimbabwe, 1996 Thesis title: Efficacy of Trichoderma isolates as biological control agents of soil borne fungal pathogens and their plant enhancing properties in selected solanaceous and graminaceous crops	Services Manager, Boka Tobacco Auction Floors, Zimbabwe
W, Ayiemba, 1999	M	30	Kenyan	BSc University of Nairobi MSc Biology of Conservation, University of Nairobi, 1997 Thesis title: A study of the butterfly diversity in the Arabuko-Sokoke Forest, Kenya	Manager, Kipepeo Project, Kenya
C. Kane, 1999	M	30	Mauritanian	BSc Agriculture, Second class, L'ecole nationale d'agriculture de Meknes, 1993 MSc Agricultural Engineering, L'ecole nationale d'agriculture de Meknes, 1995 Thesis title: Utilisation of alternate methods of controlling locusts, *Schistocerca gregaria* (Forskal, 1775) (Orthoptera: Acrididae) in their natural habitat, Akjout, Mauritania	Research Fellow, Integrated and Biological Locust Control GTZ Project
B. Okech, 1999	M	26	Kenyan	BSc Zoology, Jomo Kenyatta University of Agriculture and Technology (JKUAT), 1995 MSc Parasitology, University of Nairobi, 1998 Thesis title: Effects of *Ricinus communis* Linneaus (Euphorbiaceae) extracts on *Leishmania major* promastigotes and on infected Balb/c mice	Assistant Research Officer, KEMRI, Kenya
S.O. Ely, 1999	M	33	Mauritanian	BSc University of Fez, Morocco, 1990 MSc Natural Sciences, University of Barcelona, 1996 Thesis title: Les coccinellides indigénès et introduites, predatrices de la cochenille blanche en Mauritanie	Research Fellow, Integrated and Biological Locust Control GTZ Project
A. Ochieng, 1999	M	25	Kenyan	BSc Botany and Zoology MSc Botany, University of Nairobi, 1999 Thesis title: Identification of the key pollinators of the eggplant (*Solanum melongena* L.) in Nguruman	Unemployed

Table 1.3b. Training information on ARPPIS PhD students of 1997–1999, currently on training

Name and country	Sex	Admission date	Sponsor	Thesis title	ICIPE supervisors	University supervisors	Registering university
S. G. Weldessemayat (Ethiopia)	M	15 Jul 1997	DAAD/ICRAF	Insect pests of *Sesbania sesban*, with a focus on *Mesoplatys* beetle as a potential pest in improved fallow technology in southern Africa	Dr S. Sithanantham Dr M. Rao (ICRAF) Dr J.A. Maghembe (ICRAF)	Dr C. Ogol	Kenyatta University, Kenya
V. O. Oduol (Kenya)	M	1 Jun 1997	DAAD/ Rockefeller Foundation	Research study on 'Genetic biodiversity in banana weevil', *Cosmopolites sordidus*	Dr E. Osir Dr C. Gould (IITA)	Dr F. Mulaa	University of Nairobi, Kenya
A. T. Haile (Ethiopia)	M	27 Sep 1997	DAAD/USAID	Effects of host plant, host insect and climatic factors on the parasitisation potential of *Trichogramma* species in Kenya	Dr S. Sithanantham	Dr C. Ogol	Kenyatta University, Kenya
S. T. Kandji (Senegal)	M	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	Dr S. Miller Dr L.M. Rogo	Dr C. Ogol	Kenyatta University, Nairobi, Kenya
S. A. Mohamed (Sudan)	F	13 Feb 1998	DAAD/USDA	Biological control of fruit flies with particular attention to fruit fly parasitoids	Dr S. Lux Dr W. Overholt	Dr E. M. Eltoum Dr R.M. Khafagi	University of Gezira, Sudan
M. M. Brandford (Ghana)	M	1 July 1998	DSO/DGIS	Physiological and genetic diversity in populations of the larval parasitoid, *C. sesamiae*	Dr W. Overholt	Dr M. Botchey	University of Cape Coast, Ghana
L. M. Wekesa (Kenya)	M	1 Jul 1998	DSO	Assessment of impacts of land use activities on indicator insect assemblages in Taita Hills Forest complex	Dr L.M. Rogo	Dr F.M. Wanjala	Moi University, Kenya
A. M. Akol (Uganda)	F	19 Jul 1998	DSO	Bioefficiency and non-target interaction of neem formulations in control of key pests of French bean and snowpea	Dr S. Sithanantham	Prof. J. Mueke Prof. R.O. Okelo	Kenyatta University, Kenya
M. H. Mohamoud (Somalia)	M	1 Jul 1998	DAAD/ Gatsby	Stemborers-host plants interactions in *Striga*-infested/uninfested hosts and their semiochemical bases	Dr Z.R. Khan Prof. A. Hassanali	Prof. J. Mueke	Kenyatta University, Kenya
L. U. Abubakar (Kenya)	F	1 Jun 1998	DAAD/TDR	Molecular characterisation of the factors involved in the development of trypanosomes in the tsetse midgut	Dr E.O. Osir	Dr F. Mulaa	University of Nairobi, Kenya

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Table 1.3b. Continued

Name and country	Sex	Admission date	Sponsor	Thesis title	ICIPE supervisors	University supervisors	Registering university
E.G. Degaga (Ethiopia)	M	1 Jul 1998	DAAD/DGIS	Optimisation of parasitoid release strategy against cereal stemborers in Ethiopia	Dr W. Overholt Dr C. Omwega	Dr E.W. Kairu	Kenyatta University, Kenya
D. Wanyama-Masinde (Kenya)	F	1 Jul 1998	DAAD/Gatsby	Impact of farmer participation on technology adoption and diffusion: An assessment of a collaborative project in Trans Nzoia, Kenya on the use of fodder host plants for the control of stemborers in maize	Dr J. W. Ssennyonga Dr Z.R. Khan	Dr P. Chitere Dr R.M. Ocharo	University of Nairobi, Kenya
I.G. Nzuma (Zimbabwe)	F	1 Aug 1998	DAAD/ GTZ-IPMH	Study on bioecology and environmentally sound control of red spider mites on tomatoes in Zimbabwe	Dr B. Löhr	Dr E. Kunjeku Mrs A. Mabveni	University of Zimbabwe, Zimbabwe
I. Sarr (Senegal)	M	10 Sep 1998	GTZ-IPMH	Studies on bioecology and environmentally sound control of red spider mites on tomato in Kenya	Dr B. Löhr Dr M. Knapp	Dr C. Ogol	Kenyatta University, Kenya
B. Nyagode (Kenya)	F	1 Oct 1999	IFAD	Investigations on the pollination ecology of the honey bee *Apis mellifera* on chosen crops of economic importance	Dr S. Raina Prof. A. Hassanali Dr P. Njagi	Dr I. Ndiege	Kenyatta University, Kenya
P. Chinwada (Zimbabwe)	M	8 Aug 1999	DAAD/ DGIS	Partial niche partitioning and complementarity of stemborer parasitisation by *Cotesia sesamiae* and mechanisms of seasonal carryover in unimodal rainfall climatic zones as typified by Zimbabwe	Dr C. Omwega Dr W. Overholt	Prof. Mueke Dr C. Ogol	Kenyatta University, Kenya
M. Billah (Ghana)	M	13 Aug 1999	DSO	Biosystematics of *Psytallia* species complex (Hym: Braconidae), parasitoids of Tephritidae	Dr S. Kimani-Njogu Dr S. Miller Dr W. Overholt	Dr Wilson Ms Cobbleh	University of Ghana, Ghana
P. Nemeye (Uganda)	M	7 Aug 1999	DSO/IFAD	Distribution and macroecology of two indigenous African fruit flies, *Ceratitis cosyra* and *C. rosa* in Kenya, Tanzania and Uganda and their implications for strategies and tactics of fruit fly management in Africa	Dr S. Lux Dr J. Baumgärtner	Prof. J. Kaddu	Makerere University, Uganda

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Table 1.3b. Continued

Name and country	Sex	Admission date	Sponsor	Thesis title	ICIPE supervisors	University supervisors	Registering university
S. Dimbi (Zimbabwe)	F	1 Jul 1999	DAAD/IFAD	Exploration for the assessment of the local pathogens of indigenous African fruit flies, *C. cosyra* and *C. rosa* and prospects for their use to manage immature and adult stages of fruit flies	Dr N. Maniania Dr S. Lux	Prof. J. Mueke	Kenyatta University, Kenya
W. Ayiemba (Kenya)	M	1 Mar 1999	DSO/AWF	Ecological monitoring and sustainable utilisation of butterflies at Arabuko-Sokoke Forest, Kenya	Dr L. Rogo Dr S. Miller	Prof. R. Okello	Kenyatta University, Kenya
C. Kane (Mauritania)	M	22 Jul 1999	DSO/IFAD	Optimisation of use of phenylacetonitrile in enhancing susceptibility of gregarious nymphal desert locust, *Schistocerca gregaria* (Forsk.) to insecticides and pathogens	Dr P. Njagi Dr B. Torto Prof. A. Hassanali	Dr C. Ogol	Kenyatta University, Kenya
B.Okech (Kenya)	M	1 Jul 1999	DSO/NIH	Vector competence of African malaria vectors	Dr J. Githure Dr B. Knols Dr J. Beier	To be appointed upon formal regiistration	Kenyatta University, Kenya
S.O. Ely (Mauritania)	M	26 Jul 1999	DSO/IFAD	Relative oviposition preferences of solitarious desert locusts on different *Heliotropium* spp.and their semiochemical basis	Prof. M. Bashir Prof. A. Hassanali Dr B. Torto Dr P. Njagi	Dr S. el Tom	University of Khartoum, Sudan
A. Ochieng (Kenya)	M	1 Nov 1999	DSO	Cowpea, *Vigna unguiculata* pollination and risk assessment linked to the future release of genetically transformed cowpea breeding lines	Dr R. Pasquet	Dr B. Gemmill	University of Nairobi , Kenya

Table 1.4. List of universities participating in ARPPIS and their representatives in the ARPPIS Academic Board

Name of university	Effective date	Signatory and title	Representative and department
Addis Ababa University, Ethiopia	15 Apr 1998	Dr Mogessi Ashenafi President	Dr Masresha Fetene Dept of Biology
University of Agriculture, Makurdi	1 May 1992	Dr B. Idachaba	Prof. Gyeng Vice Chancellor
Ahmadu Bello University Nigeria	11 Dec 1991	Prof. D.I. Sarou Vice Chancellor	Prof. Abdullahi Mahadi Vice Chancellor
Alemaya University of Agriculture, Ethiopia	7 May 1997	Dr Desta Hamito President	Dr M. Hulluku Academic Vice President
Assiut University, Egypt	11 May 1996	Prof. Dr M.R. Mohmoud President	Dr S.H. Ismail Zoology Department
University of Cape Coast, Ghana	6 Jun 1997	Prof. S.K. Adjengpong Vice Chancellor	Dr M. Botchey Zoology Department
Universite de Dschang, Cameroon	25 Mar 1998	Prof. M. Tchuente Rector	Dr I. Par Zoology Department
Egerton University, Kenya	5 Dec 1997	Prof. A.M. Mutema DVC (Academic)	Prof. M.K. Limo Dept of Biochemistry
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 Gezira, Sudan	10 Jul 1997	Dr M.A. Magzoub Vice Chancellor	Dr M. Zeinelabdin Crop Protection
University of Ghana, Ghana	13 Aug 1996	Prof. G. Benneh Vice Chancellor	Prof. J.N. Ayertey Crop Science
University of Ibadan, Nigeria	22 Feb 1996	Prof. O. A. Ojengbede Vice Chancellor	Prof. J. A. Odebiyi Crop Protection
Jomo Kenyatta University of Agriculture and Technology,Kenya	10 May 1999	Prof. R. W. Michieka Vice Chancellor	Prof. R. W. Michieka
Kenyatta University, Kenya	6 Sep 1996	Prof. G.S. Eshiwani Vice Chancellor	Dr C. Ogol Zoology Department
University of Khartoum, Sudan	15 Jun1996	Prof. H.M. El Hadi Vice Chancellor	Prof. I. El Khidir Crop Protection
Makerere University, Uganda	2 Sep 1999	Prof. P.M.P. Ssebawufu Vice Chancellor	Prof. J. Kaddu Zoology Department
University of Malawi, Malawi	1 Apr. 1996	Prof. B.B. Chimphamba Vice Chancellor	Dr V.W. Saka Bunda College of Agric.
Moi University, Kenya	9 Apr. 1996	Prof. J. Munavu Vice Chancellor	Prof. Ole Karei Chief Academic Officer
University of Nairobi, Kenya	5 Jun 1997	Prof. F.J. Gichaga Vice Chancellor	Prof. W. Ogana Faculty of Science
Nnamdi Azikiwe University, Nigeria	13 Jun 1996	Prof. F.A. Nwako Vice Chancellor	Prof. R.I. Egwatu Applied Entomology
Ogun State University, Nigeria	19 Nov 1996	Prof. O.Y. Oyeneye Vice Chancellor	Dr V.A. Awoderu Biological Sciences
University of Pretoria, Republic of South Africa	2 Feb 1996	Prof. P. Smit Vice Chancellor	Prof. C. Scholtz Department of Zoology
Rivers State University of S & T, Nigeria	30 Sep 1996	Prof. A.I. Ahiazu Vice Chancellor	Dr B.A. Okwakpam Biological Sciences
Universite Nationale du Rwanda, Rwanda	24 Nov 1999	Dr Emile Rwamasirabo Rector	Dr Muhinda Mugunga Zoology
Sokoine University of Agriculture	3 Aug 1999	Prof. A. B. Lwoga	Prof. B. S. Kilonzo Vice Chancellor
University of Zambia, Zambia	22 Jul 1997	Prof. A.A. Siwela Vice Chancellor	Prof. A.A. Siwela Faculty of Science
University of Zimbabwe, Zimbabwe	13 May 1996	Prof. F.W.G. Hill Ag. Vice Chancellor	Dr B. N. Dube Biological Sciences

of department. The Academic Board was chaired by Dr Akke van der Zjipp, then Deputy Director General of ICIPE, who inaugurated the Centre. The inauguration ceremony was hosted by Dr Mogessie Ashenafi, Vice Chancellor of Addis Ababa University.

The ARPPIS Academic Board was scheduled to hold its 30th meeting at the University of Pretoria, South Africa in November 1999. However the meeting was rescheduled for 23 February 2000, at the same venue. It will be chaired by Dr Hans Herren, Director General of ICIPE.

2. ICIPE SUPPORT TO THE ARPPIS SUB-REGIONAL MASTERS PROGRAMME

Three Centres of the ARPPIS Sub-Regional Masters Programme which are now fully operational received substantial support from the ARPPIS secretariat in 1998. In addition to ARPPIS scholarships, each Centre received a cash grant of US$ 7,500 for departmental support to enable the Centres to improve their teaching facilities. Further grants of variable amounts were disbursed to the Centres to support student research projects and visiting lecturers and examiners. The Centres of the ARPPIS Sub-Regional Masters Programme are currently hosted by three African universities as follows:

- The Sub-Regional Centre for Western Africa is hosted by the departments of crop science and zoology at the University of Ghana, Legon. The Centre has admitted 10–15 students annually since 1994.
- The Sub-Regional Centre for Southern Africa is hosted by the Department of Biological Sciences at the University of Zimbabwe, Harare. This Centre has admited an average of 6 students every other year since 1992.
- The Sub-Regional Centre for Eastern and Northeastern Africa is hosted by the Department of Biology at Addis Ababa University. The Centre admits 5–10 students annually and started in 1997.

Scholarships and departmental support to the ARPPIS Sub-Regional Masters Programme are provided from ICIPE's human resource development project sponsored by the Royal Netherlands and the ICIPE-DAAD Scholarship Programme of the German Academic Exchange Service (DAAD). The 1998/1999 and 1999/2000 intakes into the ARPPIS Masters Programmes are shown in Table 2. To date, the three centres have admitted a total of 81 masters students.

3. DISSERTATION RESEARCH INTERNSHIP PROGRAMME (DRIP)

The Dissertation Research Internship Programme (DRIP) provides 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 coursework requirements of the registering universities, are enrolled for thesis research at ICIPE. The students receive scholarship support (personal expenses and university fees) from their sponsors, while ICIPE provides them with a research project, facilities and supervision up to thesis preparation. Depending on the sponsor and nature of project, ICIPE may or may not charge training fees under this Programme. Also, where the thesis project is part of ICIPE's on-going research activities, all research costs are met by the ICIPE.

A unique feature of this Programme is its flexibility with respect to subject matter of student projects. For instance, 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. The Programme is also gaining popularity as a base for research training in tropical arthropod science for students enrolled at universities in the developed countries. In 1998–1999, 37 students (20 PhDs and 17 masters) were on training at ICIPE under the DRIP (Table 3). Out of these, 15 were continuing students, while 22 (15 Kenyans, 2 Dutch, 1 Briton, 1 Chinese, 1 Ugandan, 1 Sudanese and 1 Tanzanian) were admitted in 1998–1999.

B. PROFESSIONAL DEVELOPMENT PROGRAMMES

4. POSTDOCTORAL FELLOWS, VISITING SCIENTISTS, RESEARCH ASSOCIATES, INTERNS

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/Internship Scheme. Table 4 shows the list of beneficiaries of these schemes during the years 1998–1999.

C. TECHNOLOGY DISSEMINATION

5. INTERNATIONAL GROUP TRAINING COURSES AND WORKSHOPS

Three international training courses and workshops were held in 1998 and 1999 as follows:

(i) International course on 'Novel Approaches to the Management of Livestock Ticks' was held from 1–30 September 1998. This was the first in a series of 5 courses sponsored by the Royal Netherlands under the project 'Human Resource Development for Scientific and Technological Capability in Arthropod Science in Africa, Phase II'. A total of 20 NARS scientists from 13 African countries participated in the course (Table 5a).

Table 2. ARPPIS MSc output by sub-regions, 1998–1999

Name/Sub-regional centre	Sex	Class	Nationality
Addis Ababa University (Eastern & Northeastern Africa)			
Luwangula Yosuf	M	1998	Ugandan
Melaku Wale	M	1998	Ethiopian
Salome Munissi	F	1998	Tanzanian
Peter Chege	M	1998	Kenyan
Abebe H. Mariam	M	1999	Ethiopian
Alamayehu Abate	M	1999	Ethiopian
Meshesha Balkew	M	1999	Ethiopian
Yirgalem Negash	M	1999	Ethiopian
Getachew Bezabih	M	1999	Ethiopian
Lakew Wondimu	M	1999	Ethiopian
Mekonnen Muleta	M	1999	Ethiopian
Merid Negash	M	1999	Ethiopian
Belayneh Admasu	M	1999	Ethiopian
University of Zimbabwe (Southern Africa)			
Abraham Chawanji	M	1999	Zimbabwean
Seth Eiseb	M	1999	Namibian
Caston Makaka	M	1999	Zimbabwean
Caesar Mkandawire	M	1999	Malawian
University of Ghana (Western Africa)			
Kofi Adasi	M	1998	Ghanaian
Nobert Ndaah Amuna	M	1998	Ghanaian
Francis Adjei Antwi	M	1998	Ghanaian
Alphonse Ayitey Armah	M	1998	Ghanaian
Peter Maxwell Biney	M	1998	Ghanaian
Martin S.T. Bonu-Ire	M	1998	Ghanaian
Eric Bertrand Fokam	M	1998	Cameroonian
Adam Mohamed A. Galelseed	M	1998	Sudanese
Fatmata Kaiwa (Nee Mambu)	F	1998	Sierra Leonian
Veronica Lum Nyenti	F	1998	Cameroonian
Ime Okon Udo	M	1998	Nigerian
Isaac Ekow Aidoo	M	1999	Ghanaian
Daghela Herve Bertin Bisseleua	M	1999	Cameroonian
Victor Boadu	M	1999	Ghanaian
Emanuel Clottey	M	1999	Ghanaian
Janet Theresa Midega	F	1999	Kenyan
Daniel Kwame Lawluvi	M	1999	Ghanaian
Emmanuel Odai Nii-Arku	M	1999	Ghanaian
Albert Tuolong	M	1999	Ghanaian

Table 3. Training information on DRIP scholars in training in 1998/1999

Name and country	Title of thesis project	Registering university	Degree	Supervisors	Duration	Sponsors
Mrs H. L. Kutima (Kenya)	Biochemical interactions between trypanosomes and haematophagus insects other than *Glossina*	Jomo Kenyatta University of Agriculture and Technology (JKUAT), Kenya	PhD	Dr E. Osir	2 years Jan 1996–Jan 1998	JKUAT, Kenya
Mr S. M. Gitahi (Kenya)	Pollution and food chain bioaccumulation of some organochlorinated and organophosphorus insecticides in Lake Naivasha, Kenya	Moi University, Kenya	MSc	Dr W. Lwande Prof. M. Tole	9 months Nov 1997–Jul 1998	Moi University/ ICIPE
Mr J.K. Kang'ethe (Kenya)	Isolation of antigens from the bont-legged tick, *Amblyomma variegatum* and an assessment of their vaccine potential	University of Nairobi, Kenya	MSc	Dr Essuman	1 year Sept 1997–Aug 1998	University of Nairobi/ ICIPE
Mr Z. Otieno-Ayayo (Kenya)	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	Dr S. Sithanantham Dr R. C. Saxena Dr J.B. Okeyo-Owuor	9 months Aug 1997–Mar 1998	Moi University/ ICIPE
Mr Marco Brese (Germany)	Lethal insect technique	University of Zena, Germany	MSc	Dr H. Mahamat	1 year Oct 1997–Sept 1998	Self/ICIPE
Mr Philip Berry (Britain)	Population dynamics of stemborer complex on wild grasses	University of Bristol, UK	MSc	Dr Z.R. Khan	5 months May 1998–Oct 1998	Self
Mrs Rose Odhiambo (Kenya)	Coaching and assistance in data analysis for PhD thesis	Egerton University, Kenya	PhD	Dr A.Odulaja	3 months May 1998– Aug 1998	ICIPE
Mr Elnour A. Elnour (Sudan)	The study of *Trichogramma* production and impact assessment	University of Gezira, Sudan	MSc	Dr S. Sithanantham	3 months Jul 1998– Oct 1998	ICIPE
Mr L. M. Gitonga (Kenya)	Biotechnology of thrips in French bean growing systems	Jomo Kenyatta University of Agriculture and Technology (JKUAT), Kenya	PhD	Dr Overholt	3 years July 1996–1999	DAAD
Mrs Shi Wei (China)	Breeding and genetic selection of the African honey bees, *Apis mellifera* and *cutellata*	Swedish University of Agricultural Sciences, Sweden	PhD	Dr S. Raina	3 years Apr 1996–1999	IFAD

Continued next page

Table 3. Continued

Name and country	Title of thesis project	Registering university	Degree	Supervisors	Duration	Sponsors
Mr M.K. Tsanuo (Kenya)	Studies on *Striga hermonthica* seed germination stimulants/inhibitors exuded by the roots of selected fodder legumes	Jomo Kenyatta University of Agriculture and Technology (JKUAT), Kenya	PhD	Prof. A. Hassanali Dr Z.R. Khan Prof. J. Pickett (UK)	3 years Apr 1997–Mar 1999	DAAD/JKUAT/ICIPE-Gatsby
Mr T. N. Njuguna (Kenya)	Whitefly ecology	Kenyatta University, Kenya	MSc	Dr S. Sithanantham	2 years Nov 1997–Aug 1999	ICIPE/USAID Exp. Veg. Proj/Self
Mr H. I. Boge (Kenya)	Chemical analysis on the gut microflora of soil feeding termites	University of Constance, Germany	PhD	Dr W. Lwande Dr L. Rogo Dr Brune	3 years Apr 1997–Mar 2000	DAAD/Univ. of Constance
Mr C. M. Mboya (Kenya)	Ecology of major pests of cucurbits and yield losses	Kenyatta University, Kenya	MSc	Dr S. Sithanantham	2 years Sept 1997–Aug 1999	ICIPE/USAID Veg. Proj/Self
Mr S. M. Kagunda (Kenya)	Pests of Asian vegetables in Nguruman	Kenyatta University, Kenya	MSc	Dr S. Sithanantham	2 years Sept 1997–Aug 1999	ICIPE/USAID Veg. Proj/Self
Mr C. Matoka (Kenya)	Ecology of major pests of cucurbits and yield losses	Kenyatta University, Kenya	MSc	Dr S. Sithanantham	2 years Sept 1997–Aug 1999	ICIPE/USAID Veg. Proj/Self
Mr J. M. Baya (Kenya)	Entomopathogenic viruses and control of vegetable caterpillars	Kenyatta University, Kenya	MSc	Dr C. Kariuki (KARI) Dr S. Sithanantham	2 years Sept 1997–Aug 1999	ICIPE/USAID Veg. Proj/Self
Ms R. K.Gathu (Kenya)	Use of neem formulation for pest control on export vegetables	Kenyatta University, Kenya	MSc	Dr S. Sithanantham	2 years Sept 1997– Aug 1999	ICIPE/USAID Veg. Proj/Self
Mrs M. W. Ndungu (Kenya)	The studies on the role of riboflavin (vitamin B_2) in sericulture	JKUAT, Kenya	PhD	Dr S. Raina	3 years Jul 1998– Jun 2001	JKUAT/Self
Mrs A. Wangai (Kenya)	Coaching in isolation of nucleic acid from rosette virus, being part of the project 'Detection and Management of Groundnut Viruses in Africa	KARI, National Plant Breeding Centre, Kenya	PhD	Dr E. Osir	1 year Aug 1998– Jul 1999	Rockefeller Foundation
Mrs E. Ndhine (Kenya)	Evaluation of *Bacillus thuringiensis* and botanical extracts for the IPM of African armyworm, *Spodoptera exempta*	Egerton University, Kenya	PhD	Dr N.K. Maniania	3 years Sept 1998– Aug 2001	Self

Continued next page

Table 3. Continued

Name and country	Title of thesis project	Registering university	Degree	Supervisors	Duration	Sponsors
Mr A. O. Ochieng (Kenya)	Identification of the key pollinators of the eggplant *Solanum melongena* in the Nguruman area of Kenya, with an aim of earmarking them for conservation	University of Nairobi, Kenya	MSc	Dr S. Miller Dr B. Gemmill	2 years Sept 1998–Aug 2000	ICIPE/UoN
Ms E. W. Kamunya (Kenya)	Ground-dwelling arthropod biodiversity in agroecosystems: Case study, Mtwapa	Kenyatta University, Kenya	MSc	Dr S. Miller	2 years Dec 1998– Dec 2000	Self
Mr C. A. Midega (Kenya)	Biocontrol of maize stemborer using the parasitoid, *Cotesia flavipes* and other indigenous parasitoids	Kenyatta University, Kenya	MSc	Dr W. Overholt	2 years Dec 1998– Dec 2000	Self
Mr E. Niyibigira (Uganda)	Genetic variability in *Cotesia flavipes* Cameron and its significance for population establishment in the biological control of lepidopteran stemborers	Wageningen Agricultural University The Netherlands	PhD	Dr W. Overholt	4 years Sept 1998– Aug 2002	Wageningen Agric. University, The Netherlands
Mr Petra Schneider (The Netherlands)	Entomological risk factors that affect the transmission of malaria under environmental changes in W. Kenya	Wageningen Agricultural University The Netherlands	PhD	Dr J. Githure	6 months Mar 1999– Sept 99	Wageningen Agric. University, The Netherlands
Mr C. Koenraadt (The Netherlands)	Entomological risk factors that affect the transmission of malaria under environmental change in W. Kenya	Wageningen Agricultural University, The Netherlands	PhD	Dr J. Githure	6 months Mar 1999–Sept 1999	Wageningen Agric. University, The Netherlands
Ms S. Kashenge (Tanzania)	Comparative efficacy of neem (*Azadirachta indica*) and amitraz (Mitac) against red spider mite, *Tetranychus urticae* on tomato, *Lycopersicon esculentum*	Sokoine University of Agriculture, Tanzania	MSc	Dr M. Knapp	11 months Feb 1999– Dec 1999	GTZ
Ms Lucy Kamau (Kenya)	The role of skin bacteria in the production of volatiles that attract malaria mosquitoes	Kenyatta University, Kenya	PhD	Dr B. Knols	2 years Mar 1999– Feb 2002	DAAD
Ms Mary Gikungu (Kenya)	Assessing biodiversity enrichment and impoverishment due to invasion of alien weeds using *Odonata* as indicators of habitat quality in Lake Naivasha, Kenya	University of Nairobi, Kenya	PhD	Dr S. Miller	2 years Feb 1998– Jan 2000	University of Nairobi

Continued next page

Table 3 .Continued

Name and country	Title of thesis project	Registering university	Degree	Supervisors	Duration	Sponsors
Mr I.O. Ogwayo (Kenya)	An instrumental method for the determination of the quality of Kenyan coffee flavour	Kenyatta University, Kenya	PhD	Prof. A. Hassanali	3 years Sept 1999– Aug 2002	Kenyatta University, Kenya
Mr R. Mukabana (Kenya)	Characterisation of human odour causing differential attractiveness of humans to malaria mosquitoes	Wageningen Agricultural University, The Netherlands	PhD	Dr B. Knols	1 year Apr 1999– Mar 2000	WHO/TDR
Mr E. Mathenge (Kenya)	Development of an exposure-free bednet trap for afrotropical malaria mosquitoes	Nairobi University, Kenya	PhD	Dr B. Knols	3 years Jun 1999– May 2002	WHO/TDR
Ms L. Gohole (Kenya)	Effects of molasses grass (*Melinis minutiflora*) on parasitisation of cereal stemborers in cereal-based cropping systems	Wageningen Agricultural University, The Netherlands	PhD	Dr W.A. Gohole	2 years 5 months Mar 1998– Aug 2000	NUFFIC/WAU
Mr Nelson Mwangi (Kenya)	Investigations on the population dynamics of the potato tuber moth *Phthorimaea operculleia* in Kenya	Kenyatta University, Kenya	MSc	Dr M. Knapp	1 year Nov 1999– Oct 2000	GTZ
Ms M. Waiganjo (Kenya)	Studies on ecology and preventive management strategies on onion thrips *Thrips tabaci* (Thripidae: Thysanoptera)	Kenyatta University, Kenya	PhD	Dr S. Sithanantham	3 years Sept 1999– Aug 2002	USAID/DSO
Ms E. Omulokoli (Kenya)	Isolation of anti-arthropod pests natural products derived from soil microorganisms	Jomo Kenyatta University of Agriculture and Technology (JKUAT), Kenya	PhD	Dr W. Lwande	3 years Jun 1999– May 2002	JKUAT

Table 4. Beneficiaries of ICIPE's Professional Development Schemes in 1998–1999

Nationality	Host department/programme		Sponsoring project/Name institution
Postdoctoral Fellows			
Dr Adele Josee Ngi-Song	Cameroonian	PEES /Stemborer Research Project	Netherlands DGIS
Dr Susan Kimani - Njogu	Kenyan	PEES/Stemborer Research Project	Netherlands DGIS
Dr Vijay Vishnu Adolkar	Indian	PEES/Commercial Insects	IFAD Commercial Insects
Dr Markus Alois Knapp	German	PEES/GTZ Horticulture	Red Spider Mite
Dr Zhou Guofa	Chinese	PEES/Stemborer Project	Netherlands DGIS
Dr Mohamed A.M. Ali	Sudanese	PEES/Export Vegetables	USAID Export Vegetables
Dr Girma Melaku	Ethiopian	BCED	EU Project, ICIPE
Dr Paul N. Ndegwa	Kenyan	PEES	EU Project, ICIPE
Dr Joseph Mworia	Kenyan	Social Sciences	Social Sciences Department, ICIPE
Dr Shiffaw Ballow	Ethiopian	PEES/Biovillage	EU Project, ICIPE
Dr Nikolaus Zenz	German	BCED/Fruit Fly	IFAD Fruit Fly
Dr Sunday Ekesi	Nigerian	Entomopathology Unit	African Fruit Fly Project, ICIPE
Dr Esther Kioko	Kenyan	PEES/Commercial Insects	Commercial Insects Programme, ICIPE
Dr Remy Pasquet	French	MBBD	ORSTOM, France
Visiting Scientists			
Dr Satoshi Nakamura	Japanese	BCED	JIRCAS
Dr Noburu Minakawa	Japanese	PEES/Biodiversity	JSPS
Dr Neil Springate	American	PEES/Biodiversity	National Museums (History) (USA)
Dr Lisbeth Riis	Dutch	PEES/Whitefly	Royal Veterinary University, Denmark
Dr Barbara Frei	Swiss	BCED	Swiss Federal Institute of Technology
Dr James Lazell	American	PEES/Biodiversity	The Conservation Agency, USA
Dr Guyan Yan	Chinese	PEES/Malaria	WHO/TDR
Dr Thomas Wagner	German	PEES/Biodiversity	Zoological Research Institute and Zoology Museum, Germany
Dr Taro Adati	Japanese	BCED Mbita	JSPS
Research Associate			
Dr Marieke Bonhof	Dutch	PEES/Stemborer	Netherlands DGIS
Internship scheme			
Dr Randal Jeske	American	PEES/Stemborer	Netherlands DGIS
Dr Joseph Okello-Onen	Ugandan	MBBD	Netherlands DSO
Dr Solomon Gebre	Ethiopian	MBBD	Netherlands DSO
Dr Timothy Epidi	Nigerian	BCED	Netherlands DSO
Dr Stephen G. Mwangi	Kenyan	MBBD	Netherlands DSO
Dr Esther Sebitosi	Ugandan	MBBD	Netherlands DSO
Dr Eucharia U. Kenya	Nigerian	MBBD	Netherlands DSO
Dr Yousif Assad	Sudan	BCED	Netherlands DSO

Table 5a. International group training course on 'Novel Approaches to the Management of Livestock Ticks' List of participants (1–29 September 1998)

Name	Position/Institution	Country
Mr Gerard Septime	Researcher, National Institute of Agricultural Research (INRAB)	Benin
Dr A.D. Agyei	Senior Research Officer, Animal Research Institute (CSIR)	Ghana
Mr J. Futse	Agricultural Research Station	Ghana
Dr R. Rufus Mburea	Research Officer, National Veterinary Research Centre	Kenya
Mr Wilson Kiptisia	District Tick Control Officer, Baringo, Department of Veterinary Services	Kenya
Dr P. Mugo Mbatha	Veterinary Officer, Acaricide Laboratory, Veterinary Research Laboratories	Kenya
Mr Issa Baradji	Head, Tick Borne Diseases Research, Central Veterinary Laboratories	Mali
Dr Alsacia Atanasio	Parasitologist, National Veterinary Research Institute (INIVE)	Mozambique
Dr Sonia Maria de Santana Afonso	Deputy Dean for Teaching, Veterinary Faculty, Eduardo Mondlane University	Mozambique
Mr Paul Musoni	Head, Protozoology Dept. National Veterinary Laboratory (ISAR)	Rwanda
Mr Motseki Hlatshwayo	Research Assistant, Zoology Dept. University of the North, Qwa-qwa Campus	South Africa
Mr Mohamed A. Bakheit	Teaching Assistant, Parasitology Faculty of Veterinary Science, Univ.of Khartoum	Sudan
Mr Ahmed H. El Iman	Vet. Research Officer, Parasitology Faculty of Veterinary Science, Univ. of Khartoum	Sudan
Mr Kamilius A.M. Mamiro	Research Officer, Animal Disease Research Institute	Tanzania
Mr Athanasious Gumisiriza	Entomologist, Makerere University	Uganda
Ms M. M. Kawambwa	Livestock Officer, Central Veterinary Research Institute	Zambia
Dr Stephen Mutoloki	Senior Veterinary Research Officer (Parasitology)	Zambia
Dr Yusuf Haji Khamis	Veterinary Surgeon, Commission of Agriculture and Livestock, Ministry of Agriculture, Livestock and Natural Resources	Zanzibar
Ms Thokozani Hove	Lecturer, Veterinary Parasitology, University of Zimbabwe	Zimbabwe
Mr Morgan Matingo	Veterinary Research Officer, Central Veterinary Laboratories	Zimbabwe

(ii) The second course titled 'Integrated Management of Pests and Diseases of Vegetable Crops in Africa' was held from 31 May–25 June, 1999 and was attended by 23 NARS scientists drawn from 11 African countries (Table 5b).

(iii) A third course titled 'Fourth International Course on the Use of *Bacillus thuringiensis*-Based Biopesticides for Pest/Vector Management' was held from 10–19 November 1999. It was attended by 20 NARS scientists from 13 African countries (Table 5c).

Two courses are scheduled for 2000. The fourth course under the Dutch-funded project will be on 'Ecological Management of Tsetse and Trypanosomosis in Livestock and Wildlife' scheduled for September 2000.

6. CONSUMER AWARENESS TRAINING

Activities under this category of training were limited to training of farmers on sericulture and apiculture technology. Several 1-day courses were offered at ICIPE Duduville as reported under the Commercial Insects section of this report. Farmers Days were held on 27 November 1998 and 30 November 1999, at which an exhibition of honey and silk technologies were staged; over 700 farmers and extension officers from Kenya, Uganda and Tanzania attended. Under the Dutch-funded project on Human Resource Development, a farmers' training course on 'Ecological and Economical Strategies in Smallholder Beekeeping in Eastern Africa/ Sericulture Technology for the Development of Cottage Silk Industry' will be held on 13 November–8 December, 2000.

7. DEVELOPMENT OF TRAINING MATERIALS

Experience from the ARPPIS graduate coursework and practitioner training courses at ICIPE has revealed the deficiency of training materials relevant to the African situation. It is for this reason that one of the main objectives of ICIPE's Capacity Building Programme is to coordinate the preparation of books and training manuals for use in training courses for graduate students and insect pest management practitioners. In 1998, the programme produced *Insect Functional Morphology—A Laboratory Manual*. The manual, which is intended for postgraduate teaching was written for ARPPIS by Professor Keith J. Mbata of the Department of Biological Sciences, University of Zambia. Professor Mbata had the advantage of having taught the course to ARPPIS doctoral students over several years and was able to draw from his practical experiences in the Programme.

Other teaching manuals are at an advanced stage of preparation:

- 'Taxonomy of African Ticks: An Identification Manual' by J. Okello-Onen, S.M. Hassan and S. Essuman was initiated as a sequel to the practitioner training course on Novel Approaches to the Management of Livestock Ticks held during 1998.
- Three pest management manuals on integrated management of vegetable pests were initiated as a sequel to the course on Integrated Management of Pests and Diseases of Vegetable Crops in Africa.
  - (i) 'Pest Management Manual for Brassicas' by A.M. Varela and A.A. Seif
  - (ii) 'Pest Management Manual for Tomatoes' by A.M. Varela and A.A. Seif
  - (iii) Pest Management Manual for French Beans' by S. Michalik and A.A. Seif

The fully illustrated manuals, now in their first draft, are intended for use in training and field identification of ticks of livestock, and pests and diseases in vegetable crops in Africa. The final versions will be available in print; it is intended to reproduce the manuals in CD-ROM to facilitate easy access and wide usage internationally.

8. INSTITUTION BUILDING AND INTRA-AFRICA COOPERATION

A number of activities were undertaken under the Dutch-sponsored project on Human Resource Development in Africa.

8.1 ARPPIS SYMPOSIA

The first of three ARPPIS Symposia was held from 30 November–2 December 1998; 31 ARPPIS-trained scientists of 13 nationalities participated in the Symposium. The scientists agreed to the formation of the ARPPIS Scholars Association which is now registered in Kenya. Proceedings of the First ARPPIS Symposium held in 1998 have been published and are now available.

The second ARPPIS Symposium was held from 6–9 December 1999. ARPPIS-trained scientists (26) of 12 nationalities participated in the Symposium under the theme 'Planning for Cooperation in Science-led Development in Africa'. The aim of the symposium was to formulate policy and a long term strategic vision and business plan for the ARPPIS Scholars Association (ASA) which is now spearheading the activities of the alumni.

8.2 RE-ENTRY RESEARCH GRANTS

Seven re-entry research grants have been awarded to ARPPIS scientists working in NARS or African Universities:

- Dr Esther Ndaisi Kioko (National Museums of Kenya) for the project 'Survey and taxonomic study of the African wild silkmoths genus *Gonometa* (Lasiocampidae: Lepidoptera) in Kenya'.
- Dr Dorrington Ogoyi (University of Nairobi, Kenya) for the project 'Biochemical characterisation of trypanolysin from non-vector insects'.

Table 5b. International group training course on 'Integrated Management of Pests and Diseases of Vegetable Crops in Africa' (31 May–25 June 1999) List of participants

Name	Position/Institution	Country
Mr Mohamed Yesuf	Plant Pathologist, Ethiopian Agricultural Research Organisation (EARO)	Ethiopia
Mr Gashawbeza Ayalew	Entomologist, Ethiopian Agricultural Research Organisation (EARO)	Ethiopia
Mr Vanderpuye Isaac	Extensionist, Ministry of Agriculture, Amasaman	Ghana
Ms Rachel T. Washisino	Extensionist, Horticultural Crops Development Authority (HCDA)	Kenya
Mr Paul Onano Ong'ang'o	Extensionist, Taita Taveta Agricultural Project, Wundanyi	Kenya
Mr Peter Muriuki Kimotho	Technical Officer, Association for Better Land Husbandry (ABLH) Kerugoya	Kenya
Ms Lillian Wanjiku Gatubu	Assistant Lecturer, Egerton University	Kenya
Ms Florah Musanga	District Crops Officer, Kakamega	Kenya
Ms Margaret Mkandawire	Horticulture Officer, Lilongwe, A.D.D.	Malawi
Mr Chikosa Mkandawire	Field Supervisor (Pest Management), Farming Systems IPM Project, Bvumbwe Agricultural Research Station	Malawi
Ms Christine Mtambo	Agricultural Research Scientist, Ministry of Agriculture, Makoka Research Station	Malawi
Mr Jose Sancho Cumbi	Research Assistant (Crop Protection), Instituto National de Investigacao	Mozambique
Mr George B. Rhodes	Chief Agricultural Extension Officer, Ministry of Agriculture, Water and Development	Namibia
Mr Menno Keizer	Horticultural Research Officer, Ministry of Agriculture, Water and Rural Development	Namibia
Mr Anas Ahmed Elmula	Research Scientist, (Entomology Research Section) Agricultural Research Corporation, Crop Protection Research Centre	Sudan
Mr William S. Mwakio	Agricultural Officer-Entomologist, IPM project Horti Tengeru, Arusha	Tanzania
Mr Leone Mrosso	Agricultural Research Officer, Makutupora Agriculture and Research Training Centre	Tanzania
Ms Adeltruda A. Massawe	Agricultural Research Officer, Horti Tengeru, Arusha	Tanzania
Ms Florence Nagawa	Research Assistant (IPM-Horticulture), Kawanda Agricultural Research Institute	Uganda
Mr Sina Watson Luchen	Senior Agricultural Research Officer-Vegetable Crops National Irrigation Research Station	Zambia
Ms Dhaiyya Rashid Abdalla	Extension Officer (IPM Vegetable Coordinator) Plant Protection Division	Zanzibar
Ms Asha Ali Hussein	Subject Matter Specialist on Vegetables Commission of Cash Crops & Fruits	Zanzibar
Mr Walter Mayangarirwa	Senior Research Officer (Plant Pathology) Plant Protection Research Institute	Zimbabwe

Table 5c. International group training course on 'The Use of *Bacillus thuringiensis*-based Biopesticides for Pest/ Vector Management in Africa' (10–19 November, 1999) List of participants

Name	Position/Institution	Country
Mr Thio Bouma	Researcher, INERA, Laboratory of Plant Protection	Burkina Faso
Mr Traore A. K. Aboubakar	Researcher, West African Development Association (WARDA)	Côte d'Ivoire
Mr Mekasha C. Wessene	Associate Researcher/Head Crop Protection, Debre Zeit Agricultural Research Centre	Ethiopia
Ms Selome Tibebu	Junior Researcher, Entomology, Melkassa Agricultural Research Centre	Ethiopia
Mr Refera S. Alemayu	Associate Researcher, Ethiopian Agricultural Research Organisation (EARO)	Ethiopia
Mr Vincent Yao Eziah	Technician, University of Ghana	Ghana
Mr Vincent M. Kega	Entomologist, Matuga Agricultural Research Sub-Centre	Kenya
Ms Teresa Njoki Mwangi	Research Officer, Kenya Agricultural Research Institute (KARI)	Kenya
Mr David Irungu	MSc student, Moi University	Kenya
Mr Joseph Baya Msanzu	MSc student, Kenyatta University	Kenya
Mr Hamidou Djibo	Trainer, Gender and Crop Protection Network	Niger
Mr E. Elsiddig Elmubarak	Lecturer, University of Gezira	Sudan
Mr Haule John Bosco	Research Officer, Banana Research, Horti Tengeru	Tanzania
Mr Nyamador Wollali	Faculte de Sciences, Universite du Benin	Togo
Ms Clare Mukankusi	MSc student, Makerere University	Uganda
Mrs J. K. Tumutegyereize	Assistant Lecturer, Department of Crop Science	Uganda
Mrs C. Kyomukama Murekezi	Plant Protection Officer, Ministry of Agriculture, Animal Industries and Fisheries	Uganda
Mr Petan Hamazakaza	Agronomist, Msekera Research Station, Chipata	Zambia
Mr Sharif Maalim	Head, Field Services Section, Plant Protection Division, Pemba	Zanzibar
Mr Thobekile Nondo	Technician, University of Zimbabwe,Department of Biological Sciences	Zimbabwe

- Dr Samuel Kyamanywa (Makerere University, Kampala, Uganda) for the project 'Ecological management of the leaf beetles, *Ootheca* sp. on common beans (*Phaseolus vulgaris*) in Lira and Apach Districts of Uganda'.
- Dr J. B. Okeyo-Owuor (Moi University, Eldoret, Kenya) for the project 'Studies on diversity, distribution and abundance of malaria mosquitoes in areas invaded by water hyacinth (*Eicchornia crassipes*) in Nyanza Gulf'.
- Dr Rosebella Orangi Maranga (Jomo Kenyatta University of Agriculture and Technology, Kenya) for the project 'Assessment of the efficacy of a biological tick trap for the control of *Amblyommr variegatum*'.
- Dr Arop Leek Deng (Egerton University, Njoro, Kenya) for the project 'Identification of kairomones of the variegated grasshopper, *Zonocerus variegatus*'.
- Dr Samuel Idrisa Kamara (Rice Research Station, Rokupur, Freetown, Sierra Leone) for the project 'Effect of various rice-based cropping practices on pest profiles, damage incidence and yields in farmers' fields'.

8.3 RESEARCH INTERNSHIPS

Eight research internships at ICIPE have been awarded:

- Dr Solomon Gebre (Ethiopia), 6 months, 7 February–August 1999
- Dr Okello-Onen (Uganda), 9 months, March–November 1999
- Dr Stephen Githiri Mwangi (Kenya), 5 months, 2 June–31 October 1999
- Dr Timothy Epidi (Nigeria) for 5 months, 26 April–17 July 1999
- Dr Abdoulaye Niassy (Senegal) for 5 months, March–5 August 1999

- Dr Eucharia Unoma Kenya (Nigeria) for 8 months, 4 August 1999–March 2000
- Dr Esther Sebitosi (Uganda) for 6 months, May–November 1999
- Dr Yousif Assad (Sudan) for 4 months, 4 February–June 2000.

8.4 MEETINGS AND TRAINING

Four scientific exchange and training fellowships at ICIPE have been awarded:

Dr Susan Kimani-Njogu (Kenya) visited the University of Zimbabwe from 20 March to 31 April 1999, where she taught insect taxonomy to ARPPIS masters students in the MTE programme, discussed collaborative projects with Mrs Audrey Mabveni and visited museums of interest in Zimbabwe.

Dr Baldwyn Torto (Ghana) visited Dr Dona Dakouo in Burkina Faso from July 12 to 31 August 1999, where he participated in the 13th Meeting and Scientific Conference of the African Association of Insect Scientists (AAIS) and the 1st Congress of the Entomological Society of Burkina Faso in Ouagadougou. He also participated in formulating various collaborative projects at the Institut de l'envirotudes et recherches agricoles, station de recherches agronomique (INERA) at Farako-Ba in Bobo-Dioulasso.

Dr Syprine Akinyi (Kenya) and Ms Deolinda Pacho (Mozambique) attended a research Management course at the Namanga Management Centre, Swaziland in 1999.

9. PRACTICAL TRAINING ATTACHMENT FOR TECHNICAL AND UNDERGRADUATE STUDENTS

This scheme provides practical laboratory training to university undergraduates from Africa and abroad, and trainees from technical training colleges and government ministries. The trainees gain practical skills as part of the requirements of their training programmes, and help provide valuable research assistance to ICIPE projects and laboratories. In 1998–1999, training opportunities were offered to 242 trainees in various departments (Table 9).

Table 9. Beneficiaries of ICIPE's Field Attachment Scheme (1999)

Area of training	No. of males	No. of females	Total
Animal rearing and quarantine	5	2	7
Commercial insects technology	12	10	22
Arthropod biosystematics	0	0	0
Behavioural and chemical ecology	13	12	25
Biostatistics and data management	2	1	3
General agriculture	4	2	6
Information science and computer applications	4	3	7
Science editing and publishing	3	2	5
Medical laboratory technology	0	0	0
Molecular biology and biotechnology	37	17	54
Population ecology and ecosystems science	18	10	28
Social science in pest and vector management	2	1	3
Catering and hotel management	4	28	32
Physical plant maintenance and engineering	4	3	7
Administration and finance	16	12	28
Total enrollment	132	110	242

Behavioural and Chemical Ecology Department

Background, approach and objectives

The Department hosts scientists with expertise in behaviour, sensory physiology, analytical chemistry, chemical ecology and natural products chemistry. Its primary role is to undertake research on semiochemicals and other signals that mediate ecological interactions and to exploit these for the development of monitoring tools and control tactics for target pests. The Department works closely in multidisciplinary programmes of different divisions to conceptualise and develop research that falls within its disciplinary breadth. It is primarily responsible for overseeing and undertaking projects or project components that fall within its mandate.

In addition, the Department (or its predecessor) has undertaken exploratory work on a variety of anti-insect natural products from local plants, including antifeedants, repellents, acaricides and insecticidal compounds. This is now being re-shaped into a Bioprospecting Initiative focused on malaria and malaria vectors (with the Human Health and Environmental Health Divisions, respectively), and biodiversity conservation (with the Environmental Health Division).

New questions and ideas relating to specific behavioural and other biological traits of target insects often emerge. These are prioritised and treated as part of exploratory research of the Department. If results are promising, the activities are then integrated into the appropriate programmes.

The Department also hosts the Laboratory Management Unit (LMU) with a mandate to initiate and coordinate improvements of laboratory practices at the Centre. (*See report under Research Support Units*).

Participating scientists: *A. Hassanali*, W. Lwande, B. Torto, S. Nakamura (JIRCAS), P. Njagi, A. Taro (JSPS)*
*(*Head of Department)*

Assistants: *B.O.K. Wanyama, E. Nyandat, D. Mbuvi, L. Moreka*

Funding: *WHO/ MIM/TDR, World Laboratory, Arab Organisation for Agricultural Development*

Collaborators: *Discipline-related collaborators (in addition to those listed under Divisions): • International Organisation of Chemical Sciences in Development (IOCD) • Rothamsted Experimental Station, UK • Universities of Nairobi, Dar-es-Salaam, Addis Ababa, Cape Coast, Makerere, Kenyatta, Jomo Kenyatta, Egerton in Africa • Swiss Federal Institute of Technology • Universitaet Bayreuth (Germany) • Arab Organisation for Agricultural Development*

Work in progress

Most of the Department's activities undertaken in collaboration with programmes in the different divisions are reported there. Brief highlights are as follows:

1. **Plant Health Division**
   - Identification of pheromones of the desert locust and conceptual development underlying their use, particularly that of aggregation-maturation pheromones in solitarising gregarious stages and pre-disposing them to toxication by low doses of chemo- or bio-pesticides.
   - Contribution to the science underlying the action of repellent and trap plants to suppress stemborers.
   - Elucidation of the mechanism underlying the action of *Desmodium* in the suppression of *Striga*.

2. **Animal Health Division**
   - Design of a potent repellent of savanna tsetse, based on structure-activity studies of existing attractants and identification of candidate repellents from an unpreferred wild host (water buck).
   - Identification of some of the chemical signals used by the tsetse *Glossina f. fuscipes* (vector of human sleeping sickness) to locate its preferred host (monitor lizard) for use in bait technologies for this species.
   - Behavioural demonstration of mediation of semiochemicals associated with location of preferred feeding site by the brown ear tick, *Rhipicephalus appendiculatus*, vector of East Coast fever (ECF).

1998 –1999

- Conceptual development and field evaluation of a pheromone trap baited with pathogen for off-host control of *Amblyomma variegatum*.

3. **Human Health Division**
- Identification of mosquito-repellent and larvicidal plants and characterisation of the active components; conceptual development of their potential uses.
- Launching of WHO/MIM/TDR-funded collaborative project on mosquito repellents and mosquitocides from local plants.
- Conceptual contribution to oviposition behaviour of *Anopheles gambiae* and possible mediation of semiochemicals (project to be undertaken by an ARPPIS student).

4. **Environmental Health Division**
- Identification of potentially useful plant sources of anti-insect and medicinal products and development of a concept on their commercial exploitation by rural communities in biodiversity conservation projects.
- Setting up of a World Laboratory-funded project to assist selected active African scientists in the region to undertake part of their research in natural products at ICIPE and to provide access to ICIPE's spectral facilities.
- Organising a workshop and a 3-week training course to build awareness at ICIPE and among potential collaborating institutions in the complex area of bioprospecting including value-adding opportunities in bioprospecting, sharing of benefits and intellectual property issues.
- Launching of WHO/MIM/TDR-funded project on bioprospecting for anti-mosquito plants.

5. **Specific international collaborative projects**
- The ICSC-World Laboratory (Switzerland/ granted ICIPE US$ 70,000 for the period 1998–1999) to help the Centre to assist African scientists and institutions to undertake bioprospecting. The specific objectives of the project were to:
  (a) provide spectral analyses (mainly mass spectra) of natural product samples
  (b) host selected African scientists for short durations at ICIPE to enable them to undertake their research work using ICIPE facilities
  (c) promote the growth of collaborative networks of scientists and institutions engaged in bioprospecting
  (d) build awareness in value-adding opportunities in bioprospecting, benefits sharing and related IPR issues.

  During the year, about 30 samples from different sources were analysed, and three scientists from Ghana, Uganda and Kenya with research interests in anti-insect limonoids, anti-malarials and essential oils, respectively were hosted.
- The Department, together with the Population Ecology and Ecosystems Science Department, is assisting the Arab Organisation for Agricultural Development (AOAD) in specific areas of red palm weevil control. Specifically, the Department is contributing toward the optimisation of semiochemical-based mass trapping techniques and in semiochemical-based characterisation of date palm varieties and those at different stages of infestation.
- As part of a collaborative project on banana pests with IITA, the Department hosted a postgraduate student from Uganda to explore the use of HPLC-generated profiles (coupled with multivariate analysis) to discriminate between banana varieties of different susceptibilities to the banana weevil. The results were promising and provide a basis for identifying potential secondary compounds associated with resistánce to the weevil.
- WHO/MIM/TDR provided an initial sum of US$ 145,360 in June 1999 to set up a collaborative network to bioprospect for mosquito-repellent and insecticidal plants from eastern Africa, to share facilities and improve capacity building in participating institutions. Department-based scientists coordinate the Project, which brings together ICIPE and the Universities of Dar-es-Salaam, Kenyatta, Makerere, Jomo Kenyatta and Addis Ababa. Currently, 2 PhD and 4 MSc students from different institutions are participating in the Project.

Output

Publications (in addition to those reported under respective Divisions and Programmes)

Lwande W., Ndakala A.J., Hassanali A., Moreka L., Nyandat E., Ndungu M., Amiani H., Gitu P.M., Malonza M.M. and Punyua D.K. (1999) *Gynandropsis gynandra* essential oil and its constituents as tick (*Rhipicephalus appendiculatus* Neumann) repellents. *Phytochemistry* 3, 401–405.

Mahamat H. and Hassanali A. (1998) Cuticular composition analysis for taxonomic differentiation of phlebotomine sandfly species (Diptera: Psychodidae) in Kenya. *Journal of Medical Entomology* 35, 778–781.

Mwangi J.W., Achola K.J., Lwande W. and Hassanali A. (1998) Aromatic plants of Kenya: Volatile constituents of *Sphylathus fuaveolens* and *S. bullatus*. *The East & Central African Journal of Pharmaceutical Sciences* 1, 24–26.

Mwangi J.W., Thoithi G.N., Addae-Mensah I., Achenbach H., Lwande W. and Hassanali A. (1998) Aromatic plants of Kenya III: Volatile and some non-volatile constituents of *Croton sylvaticus*. *The East &*

Central African Journal of Pharmaceutical Sciences 1, 41–43.

Mwangi J.W., Thoithi G.N., Addae-Mensah I., Achenbach H., Lwande W. and Hassanali A. (1999) Aromatic plants of Kenya IV: Volatile and some non-volatile constituents of the stem bark of *Synadenium compactum* N.E. Br, Var, *Compactum*. *The East & Central African Journal of Pharmaceutical Sciences* 2, 5–7.

Ndungu M.W., Chhabra S.C. and Lwande W. (1999) *Cleome hirta* essential oil as livestock tick (*Rhipicephalus appendiculatus*) and maize weevil (*Sitophilus zeamais*) repellent. *Phitoterapia* 70, 514–516.

Torto B. and Hassanali A. (1998) Progress in the search for anti-arthropod botanicals, pp. 475–488. In *Recent Research Developments in Phytochemistry* (Edited by S.G. Pandalai). Research Signpost, Trivandrum.

Capacity building

MSc students supervised in 1998/1999

B. Nyagode (Egerton University): *Rhipicephalus appendiculatus* attractants from cattle. (Supervisor: W. Lwande)

E. Ngumbi (Kenyatta University): Assessments of kairomones as a monitoring tool for *Cotesia flavipes*. (Supervisor: B. Torto)

S. Barasa (Kenyatta University): Stereoselective synthesis and stereostructure - activity studies of p-menthane-3,8-diols against *Anopheles* spp. (Supervisor: A. Hassanali)

I. O. Ogwayo (Kenyatta University): An instrumental method for the determination of the quality of Kenyan coffee flavour. (Supervisor: W. Lwande)

M. Omolo (Kenyatta University): Bioprospecting for mosquito larvicidal and insecticidal plants. (Supervisor: W. Lwande)

D. Okinyo (Kenyatta University): Bioprospecting for mosquito repellent and insecticidal plants. (Supervisor: W. Lwande)

F. Nyongesa: (Supervisor: A. Hassanali)

PhD students supervised in 1998/99

A. M. Akol (Kenyatta University): The effects of two neem formulations on the parasitoids of diamondback moth, *Plutella xylostella*. (Supervisor: P. Njagi)

M. Hassan (Kenyatta University): Stemborers host plants interactions in *Striga* infested / uninfested hosts and their semiochemical basis. (Supervisor: A. Hassanali)

R.O. Maranga (JKUAT): Innovative control methods for *Amblyomma variegatum* (Fabricius, 1794), using entomopathogenic fungi, *Beauveria bassiana* and *Metarhizium anisopliae* in traps baited with the attraction-aggregation-attachment pheromone. (Awarded PhD) (Supervisor: A. Hassanali)

N.K. Gikonyo (Nairobi University): Semiochemical basis of non-preference in some wild animals by the *Glossina morsitans* group of tsetse (Submitted) (Supervisor: A. Hassanali)

M.K. Tsanuo (JKUAT): Studies on *Striga hermonthica* seed germination stimulants and growth inhibitors exuded by the roots of selected fodder legumes. (Supervisor: A. Hassanali)

E. Omulokoli (JKUAT): Isolation and identification of bioactive microbial metabolites. (Supervisor: W. Lwande)

M. Ndungu (JKUAT): Isolation and characterization of anti-mosquito compounds from selected East African Meliaceae plants. (Supervisors: B. Torto and A. Hassanali)

B. Nyagode: Investigations on the pollination ecology of the honey bee *Apis mellifera* on chosen crops of economic importance. (Supervisors: A. Hassanali and P. Njagi)

Internship scheme

A. Niassy: The effects of the locust aggregation pheromone phenylacetonitrile on nymphal and adult migratory locust, *Locusta migratoria migratorioides* (R&F). (Supervisor: P. Njagi)

(See also the reports under the Biodiversity and Conservation Programme; Habitat Management of Stemborers and Striga; Malaria Mosquitoes; Molecular Biology and Biochemistry Unit, and Tsetse and Ticks Programmes, and Population Ecology and Ecosystems Science Department.)

Population Ecology and Ecosystems Science Department

Background, approach and objectives

The Population Ecology and Ecosystems Science (PEES) Department is charged with the responsibility to:

(a) coordinate ICIPE's research and implementation work on the levels of populations, communities and ecosystems;

(b) synthesise and disseminate results according to the level of users on the basis of information technologies;

(c) provide quality control and capacity building (in-house training in both biostatistics and insect informatics);

(d) offer expert advice in the disciplines of insect informatics, biostatistics, GIT, population ecology and system analysis;

(e) develop statistical and mathematical models to represent spatio-temporal dynamics and population interactions.

In late 1999, the Biostatistics and Insect Informatics Units were integrated into the PEES Department. *(See reports on these Units under Research Support Units.)*

Participating scientists: *J. Baumgärtner*, Y. Xia, A. Odulaja, J. Greiling, C. Mutero, J. Githure, G. Zhou, G. Tikubet, M.O. Bashir (*Department Head)*

1. DEPARTMENT CORE ACTIVITIES

Work in progress

The following concepts have been reviewed and evaluated with international partners, discussed in departmental meetings, used in research activities and in project proposal preparations:

- The temporal dynamics of single species
- The spatial dynamics of single species populations
- Population interactions
- Multi-species population interactions
- Ecosystem processes
- Knowledge integration

1.1 TEMPORAL DYNAMICS CONCEPT

The temporal dynamics concept is used to develop a generic model for growth and development of plants and arthropods. The model will be used for strategic planning of crops and modelling of insect population dynamics. In collaboration with the University of Nairobi, an age-structured tick population model has been developed and used for optimising control strategies. The local dynamics of the red palm weevil has been studied in Saudi Arabia. The purpose of this work is to improve control and monitoring techniques, such as the use of biological control agents for inundative releases.

Participating scientists: *J. Baumgärtner, Y. Xia*

Donors: *Arab Organisation for Agricultural Development (AOAD), ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark), USAID*

Collaborators: *• Arab Organisation for Agricultural Development (AOAD), Saudi Arabia • University of California at Berkeley, USA • University of Nairobi, Kenya • ENEA, Rome, Italy • IITA, Cotonou • EMBRAPA, Brazil*

1.2 SPATIAL DYNAMICS CONCEPT

The spatial dynamics concept has been used in the analysis of tsetse fly movements in southern Kenya. The results show how to set up a barrier system to reduce population movements into the area under study. The dispersal of the red palm weevil was studied for the purpose of population monitoring, mass trapping and use of biocontrol agents. Moreover, the concept is being used in mosquito research, and in writing project proposals.

Participating scientists: *J. Baumgärtner, A. Odulaja, G. Zhou*

Donors: *AOAD, ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark)*

Collaborators: *AOAD team, Saudi Arabia*

1.3 POPULATION INTERACTION CONCEPT

The population interaction concept is considered in various projects at ICIPE, such as red spider mite control on tomatoes, stemborer control and work on the diamondback moth. The structure of the stemborer community and its dynamics under the influence of an exotic parasitoid was the subject of detailed studies.

Participating scientists: *J. Baumgärtner, W. Overholt, M. Knapp, S. Sithanantham, G. Zhou*

Donors: *ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark), GTZ, Government of the Netherlands*

1.4 KNOWLEDGE INTEGRATION CONCEPT

The knowledge integration concept was used in the design of an integrated management system for arthropods and natural resources (Biovillage Project). ICIPE scientists were asked to design control systems for mosquitoes and tsetse fly with local communities. The health status of humans is not only affected by vector-transmitted diseases, but also by limited natural resources such as food from livestock and crops. In collaboration with external partners, an adequate resource management system has been discussed and is being implemented in the Biovillage. (*See Section 2 of this report*) The Department Head was invited to present the concept at the World Bank, UNEP and IDRC, and discussed it at SDC, ETH and the universities of Milan and Rome, Italy.

Participating scientists: *J. Baumgärtner, J. Greiling, G. Tikubet*

Donors: *ADC, SDC, ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark), IDRC, World Bank*

Collaborators: • *ETH/Zürich, Switzerland* • *ENEA, Italy*

Outputs

*Publications**
(Other publications by ICIPE scientists)

Baumgärtner J. and Hartmann J. (1999) The use of phenology models in plant conservation programmes: The establishment of the earliest cutting date for the wild daffodil *Narcissus radiiflorus*. *Biological Conservation* (in press).

Baumgärtner J., Schilperoord P., Basetti P., Baiocchi A. and Jermini M. (1998) The use of phenology model and of risk analyses for planning buckwheat (*Fagopyrum esculentum*) sowing dates in Alpine areas. *Agricultural Systems* 57, 557–569.

Bonato O., Schulthess F. and Baumgärtner J. (1999) Simulation model for maize crop growth based on acquisition and allocation processes for carbohydrate and nitrogen. *Ecological Modelling* 124, 13–28.

Di Cola G., Gilioli G. and Baumgärtner J. (1999) Mathematical models for age-structured population dynamics, pp. 503–536. In *Ecological Entomology*, Second edition (Edited by C.B. Huffaker and A.P. Gutierrez). John Wiley, New York.

Di Cola G., Gilioli G. and Baumgärtner J. (1998) Mathematical models for age-structured population dynamics: An overview, pp. 45–61. In *Population and Community Ecology for Insect Management and Conservation* (Edited by J. Baumgärtner, P. Brandmayr and B.F.J. Manly). A. A. Balkema Publishers.

Fouque F., Delucchi V. and Baumgärtner J. (1998) La démoustication de la plaine de Magadino. II. Ecologie générale des moustiques *Aedes vexans* (Meigen) et propositions de lutte intégrée. *Mitt. Schweiz. Ent. Ges.* 71, 439–447.

Roux O. and Baumgärtner J. (1998) Evaluation of mortality factors and risk analysis for the design of an integrated pest management system. *Ecological Modelling* 109, 61–75.

Proceedings

Akol A.M., Sithanantham S., Baumgärtner J., Varela A., Njagi P. and Mueke J.M. (1999) Evaluation of impact of neem formulation on some population parameters of the diamondback moth in cabbage ecosystem, p.5. In *Integrated Pest and Vector Management and Sustainable Development in Africa: Abstracts.* Joint congress of the African Association of Insect Scientists (13th Congress), and the Entomological Society of Burkina Faso, Ouagadougou, Burkina Faso, 19–23 July 1999. ICIPE Science Press, Nairobi.

Haile A.T., Sithanantham S., Hassan S.A., Monje C., Zebitz C.P.W., Baumgärtner J., Löhr B. and Ogol C.K.P.O. (1999) Studies on *Trichogramma* parasitoids towards potential utilisation for biological control of lepidopteran pests on vegetable crops in Kenya, p.6. In *Integrated Pest and Vector Management and Sustainable Development in Africa: Abstracts.* Joint congress of the African Association of Insect Scientists (13th Congress), and the Entomological Society of Burkina Faso, Ouagadougou, Burkina Faso, 19–23 July 1999. ICIPE Science Press, Nairobi.

Xia Y.L. and Baumgärtner J. (1999) Web-based intelligent insect management information system. 2nd International Conference on Multiple Objective Decision Support Systems, Brisbane, Australia, 1–6 August 1999.

Xia Y.L. and Baumgärtner J. (1999) ICIPE Insect Informatics Initiative: An Integrated Approach for Insect Information Generation, Processing and

Dissemination. EFITA 99. Second European Conference of the European Federation for Information Technology in Agriculture, Food and Environment, 27–30 September 1999, University of Bonn.

Conferences attended

Baumgärtner J. (1999) Tropical Soil Biology : Opportunities and Challenges for African Agriculture, an International Workshop, 16–19 March 1999, Nairobi. (invited).

Baumgärtner J. (1999) Population Models: Bases for the Design of Control, Utilization and Conservation Strategies. Metodi numerici, statistici e informatici nella difesa delle colture agrarie e delle foreste, Sassari, Italy, 19–22 May 1999. (invited).

Baumgärtner J.,(1999) World Bank/Global IPM Facility meeting of 'Expert Consultation Meeting Defining the Strategy of a Combined Approach of Integrated Pest Management and Integrated Soil Fertility Management', World Bank, Washington DC, 15–16 June 1999. (invited).

Baumgärtner J., Bieri M., Buffoni G., Gilioli G., Gopalan H.N.B., Greiling J., Mares V.M. and Tikubet G. (1999) Human Health Improvement Through Integrated Management of Arthropod Transmitted Diseases and Natural Resources, a Joint IDRC/UNEP International Workshop on 'Ecosystem Approach to Human Health: Communicable and Emerging Diseases', Rio de Janeiro, 8–12 November 1999. (invited).

Hugo Li-Pun, Baumgärtner J., Greiling J., Jabbar M. and Mares V. (1999) Linking Natural Resources, Agriculture, and Human Nutrition and Health: Case Study from East Africa, a Joint IDRC/UNEP International Workshop on 'Ecosystem Disruption and Human Health Consultation' Ottawa, Canada, 14–17 November 1999. (invited).

Proposals

The Biovillage Initiative: A community driven, integrated and sustainable development approach — funded by the Austrian Development Corporation (ADC).

Consortium project on the development of integrated strategies for the management of livestock ticks in Africa—submitted to NORAD.

Knowledge discovery in databases (KDD): Extracting previously unknown, but potentially useful information from the ICIPE EU-funded tsetse project databases—submitted to EU.

Integrated human and animal health management in Uganda for economic growth and rural development—submitted to USAID.

Strategic planning of vegetable production in East Africa: A synoptic analysis for assessing land use potential—submitted to USAID.

Insect Informatics Initiative workshop proposal—to be submitted to Rockefeller Foundation.

Capacity building

The following ARPPIS postgraduate scholars have been supervised:

- Abera Teklemariam Haile: 'Effects of host plant, host insect and climatic factors on parasitisation potential of *Trichogramma* species in vegetable crops in Kenya'.
- Sileshi G. Weldessemayat: 'Studies on insect pests of *Sesbania sesban* (L.) Merr. with special emphasis on *Mesoplatys ochroptera* and *Exosoma* sp. (Chrysomelidae: Coleoptera) in agroforestry systems in southern Africa'.
- Anne Margaret Akol: 'The effects of two neem formulations on the parasitoids of the diamondback moth, *Plutella xylostella* L.'

2. BIOVILLAGE INITIATIVE

Background, approach and objectives

The Biovillage Initiative is a comprehensive, community-driven integrated approach, combining several strategies aimed at addressing economic development problems of rural communities in Ethiopia. It operates in three *woredas* (Districts) of the Gurage Zone—Cheha, Enemor and Goro—with approximately 490,000 inhabitants. It is designed to create a powerful model with potential for strategic application in other locations in sub-Saharan Africa.

The Biovillage Initiative embraces complementary strategies aimed at improving livestock and human health by creating appropriate infrastructures. These include market outlets and projects aimed at exploiting the potential for income generation and capacity development for resource utilisation and conservation. Insects are within the focus of interest, as is ecology.

The objectives of the project are to:

- improve human and livestock health by integrating preventive vector control methods and measures to correct nutritional imbalances and deficiencies in the community;
- initiate sustainable development and natural environmental protection through integration of resource management techniques, i.e. biogas;
- alleviate poverty by introducing income-generating activities;
- build capacity in all components of the Biovillage.

From a technical/administrative/sustainability point of view, it is noteworthy that a Biovillage Team lives and works permanently on site and that all activities are conducted with the full participation of the farmers. The Biovillage Initiative was established following a successful ICIPE-led massive, community-sustained tsetse suppression effort, carried out in Sodo Bedessa and Gurage Zones during 1995 to 1997, using the ICIPE NGU trap. The satisfactory results obtained in this project resulted in gaining community trust in a bottom-up approach to tackling other development issues. This laid the basis for the future Biovillage Initiative.

Participating scientists: *J. Baumgärtner, M. Bieri, J. Greiling, G. Tikubet*

Donors: *ADC, SDC, University of Hohenheim, GTZ (for apiculture), ESRDF (for infrastructure and education), ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark), Andrea Golder*

Collaborators: *• ETH, Zurich, Switzerland (Resource Management) • Italian Agency for New Technology, Energy and Environment (ENEA), La Spezia, Italy (Modelling) • University of Hohenheim, Stuttgart, Germany (Socioeconomics, Apiculture, Nutrition) • GTZ-LUPO, Ethiopia (Resource Management, Apiculture) • EARO, Ethiopia (Apiculture) • EHNRI, Ethiopia (Human Health & Nutrition) • Addis Ababa University (Apiculture, Tsetse) • ILRI, Ethiopia (Animal Health & Animal Disease Vectors)*

Work in progress

2.1 INFRASTRUCTURAL AND ORGANISATIONAL DEVELOPMENTS

A number of Biovillage components are operational in two demonstration units which exist as integrated parts of two (future) Biovillages—Mamede and Luke. These settlements, with 2200 and 2645 inhabitants, respectively, are located in the vicinity of Welkite, the capital city of Gurage Zone in the Southern Nations Regional State of Ethiopia.

Work in progress includes infrastructural/technical and scientific components. After completing the basic components discussed later, the zero grazing units were stocked, in order to make the biogas plant operational. Water prospecting by developing shallow wells and springs, harvesting of roof water and rainwater in micro-dams is also progressing.

The agricultural offices, health and veterinary services have been integrated and work together with the ICIPE team. It is particularly important to note that the Ethiopian Social Rehabilitation and Development Funds (ESRDF) has invested heavily in the Biovillage by financing most of the access roads to Mamede, by giving a substantial grant to the Biovillage school in Mamede, and by massively supporting an apiculture project in northern Ethiopia which was initiated by Biovillage.

Memoranda with the two important national research organisations in Ethiopia, the Ethiopian Agricultural Research Organisation (EARO) and the Ethiopian Health and Nutrition Research Institute (EHNRI), are to be signed shortly.

Cooperation with other national and international agencies and research institutions has been strengthened, as exemplified by the integration of MSc students from Europe, the United States and Ethiopia. This collaboration is one important cornerstone of the programme's sustainability. This is further strengthened by the replication of various project components in other regions of Ethiopia. Last but not least, a private investment group with substantial land holdings and infrastructures close to the Biovillage has started copying components and will engage in commercial production of Biovillage type beehives.

2.2 SCIENTIFIC PROGRESS

The scientific components include:

- identifying disease vectors (tsetse flies, filth flies and mosquitoes) and assessing their population dynamics as a basis for later manipulation;
- developing tools for the manipulation of traps and odour baits for tsetse, and control of breeding sites for mosquitoes and filth flies; the latter through organic waste management including compost and pit latrines);
- building capacity at farm level for the production of better quality food and utilisation of scarce natural resources (microdrip irrigation, organic fertiliser), as part of the protection of a fragile ecology on the one hand and human health (nutrition) on the other;
- more sustainable use of insects, such as bees, for income generation and food. Modern apiculture techniques are being implemented, largely under farmer-managed research conditions, with MSc students on site, to create income and improve pollination.

The scientific highlights can, in brief, be summarised as the successful initiation of data collection on disease vectors and diseases, the execution of a detailed socioeconomic baseline survey and the initiation of MSc projects covering the Biovillage components: animal health (tsetse), human health, resource management and income generation. The titles of the individual projects are listed under 'Development of Project Proposals'. This shows clearly that, having prepared the ground, Biovillage is now embarking on research in various areas, complementing ICIPE's efforts for capacity building in the framework of ARPPIS (3 ARPPIS students are already involved).

Important observations and results so far are:

- a disparity between the catch of tsetse and the occurrence of trypanosomosis in cattle (suggesting a modification of the community-based trapping);
- occurrence of various vector-transmitted haemo- and endoparasites in cattle, resulting in extremely

low PCVs (suggesting that the zero grazing concept will have an excellent potential);

- a dramatic change in present malaria cases and malaria vector occurrence, apparently owing to rainfall irregularities (suggesting that breeding site management will be a powerful tool);
- an enormous potential to increase honey quantities and quality through introduction of modern hives and modern processing technologies, in an area where honey bee flora is abundant;
- the potential to transform organic waste into high quality organic fertiliser, with minimal odour and with very little attraction for filth flies (suggesting that the proposed and tested concept will help restore soil fertility and at the same time eliminate large numbers of disease transmitting vectors);
- presence of under- and malnutrition, particularly vitamin A and micro-nutrient deficiencies, rendering the population more prone to infectious diseases.

Output

Project proposals

- Sustainable urban sanitation and waste management as a measure of filfth fly and other disease control in Ethiopia—submitted to EPB, ESRDF, UNEP and European Diplomatic Missions in Addis Ababa, Ethiopia.
- The potential of vermicomposting methods to improve plant nutrition and combating disease vector insects in intensive small scale farming systems in the Gurage area, Ethiopia—a joint project with University of Kassel, Germany and ETH Zürich, Switzerland. Jointly funded by ICIPE and University of Kassel.
- Assessment of the suitability of modern beehives for income generation of smallscale farmers in different agroecological zones of Ethiopia—a joint project with EARO and GTZ (Ethiopia) and the University of Hohenheim, Germany. Funding will be requested from different sources, the major one being the EU Local Food Security Unit.
- Identification of honey bee plants and establishment of a floral calendar—a joint project with the Tigray Agricultural Bureau and Addis Ababa University. Main source of funding ICIPE /ARPPIS.
- Baseline nutrition survey in the Biovillage project area in Welkite, Ethiopia: nutritional status of young children and their mothers; child health, breast feeding and dietary habits; and food availability at household levels—a joint project with University of Hohenheim, Germany and the EIHNR (Ethiopia). Financed by International Foundation for Nutrition Research and Education through the University of Hohenheim, Germany.
- The altitudinal distribution of *Glossina pallidipes, G. morsitans submorsitans* and *G. fuscipes* and their genetic and physiological variation in Gurage, Southern Ethiopia—a joint project with Addis Ababa University and Yale University, USA. Financed by Yale University and ICIPE / ARPPIS.
- Evaluation of trapping devices including odour baits for different tsetse species in Gurage, Southern Ethiopia—a joint project with Addis Ababa University. Mainly financed by ICIPE/ ARPPIS.

(See also project reports on the Red Spider Mite, Tsetse, Ticks, Malaria Mosquitoes, Behavioural and Chemical Ecology Department and the following reports on the Biostatistics and Insect Informatics Units.)

Molecular Biology and Biochemistry Unit

This Unit conducts goal-oriented research in the areas of biochemistry, immunochemistry, molecular biology and population genetics pertinent to the goals of ICIPE's Research Divisions. The Unit also offers specialised services in light/electron microscopy and bloodmeal identification.

The Unit's research areas and highlights of involvement include the following:

- Arthropod population genetics (ticks, mosquitoes, banana weevil, fruit flies)
- Molecular taxonomy (ticks, fruit flies, others)
- Gene flow in cowpea
- Parasite–vector relationships (tsetse–trypanosomes)
- Bloodmeal identification (tsetse and mosquitoes)
- Microscopy services (transmission and scanning).

Most of the Unit's research activities are reported under the project reports pertaining to the respective target pest. Below is a summary of the Unit's work on the population genetics of the banana weevil and development of a bloodmeal identification service for haematophagous insects.

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

Background, approach and objectives

The banana weevil, *Cosmopolites sordidus* Germar evolved in Asia and is now widely distributed in all the major banana growing regions of the world. The geographical dispersal of the weevil is not well documented. However, in most localities, the weevil is believed to have been present for at least 100 years. Due to the restricted mobility and monophagy of the weevils, it is expected that discrete populations confined to banana plantations will develop. Local selection and a build-up of genetically distinct weevil biotypes may occur in these isolated populations.

The importance of studying intra-specific diversity of insect pests goes beyond the realm of basic genetics. In the case of the 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 can also contribute to a better understanding of population dynamics, habitat characteristics, dispersal patterns and resource utilisation. Secondly, the existence of biotypes may suggest the need for multi-location testing with respect to germplasm resistant to different fungal strains. Differences in pest behaviour may influence efficacy of biological control agents.

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

The following activities were proposed under the project:

(i) Collection of adult weevils from different banana growing tropical countries
(ii) Optimisation of conditions for DNA extraction and analysis of samples by random amplified polymorphic DNA-polymerase chain reaction (RAPD-PCR)
(iii) Establish population genetic structure of banana weevils based on information obtained under activity (ii)
(iv) Use of mitochondrial DNA for a more detailed analysis of banana weevil populations.
(v) Compilation of data for project reports and dissertations.

Participating scientist: *E. O. Osir (Unit Head)*

Student: *V. O. Oduol*

Funding: *The Rockefeller Foundation, ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark)*

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, Tanzania, Cameroon, Costa Rica, Honduras, South Africa, Uganda, Ghana and Kenya, preserved and shipped to the International Centre of Insect Physiology and Ecology (ICIPE) in 70% ethanol. Total DNA was extracted by cetyl trimethyl ammonium bromide (CTAB) method (Doyle and Doyle, 1987) from the head and appendages of 50 individual weevils derived from each location. DNA samples were then analysed by random amplified polymorphic DNA-polymerase chain reaction (RAPD-PCR). Amplifications were performed in a total volume of 25 µl that contained 1X PCR buffer, 2 mM $MgCl_2$, 0.2 mM dNTP mix and Taq polymerase (2 units). A drop of mineral oil was added to the samples and amplified in a model PTC-100 PCR machine (MJ Research Inc., USA). 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, and the gels stained using ethidium bromide and visualised under UV light.

RAPDs were scored as presence (1) or absence (0). It was assumed that genotypic frequencies at RAPD loci are in Hardy-Weinberg proportions. The frequency of recessive allele "a" was estimated as the square root of the frequency of homozygous recessive individuals, i.e. if "q" is the frequency of the "a" allele then "1-q = p" is the frequency of the dominant allele "A". FORTRAN program (Neighbor-Joining tree construction form allele frequency data - NJBAFD) (Takezaki, 1998) estimated the "A" and "a" using a cnvdat. exe data set. From the frequency data, njbafd test .dat -d1 -distance -o test.dis was used to output a distance matrix. This matrix was used in cluster analysis with an option of UPGMA (unweighed pair group method, arithmetic average) to construct a dendrogram that depicted the hierarchical structure of RAPD affinity among the different weevil populations.

Forty primers (Operon 10-mer Kits A and O) were screened. Of these, 5 produced discrete band patterns suitable for subsequent analysis of variability in weevil populations. The primers selected were OPO-14 (5'-AGCATGGCTC3'), OPO-18 (5'-CTCGCTATCC-3'), OPO-19 (5'-GGTGCACGTT-3'), OPO-20 (5'-ACACACGCTG-3') and OPA-17 (5'-GACCGCTTGT-3') and a total of 28 polymorphic bands resulted from the 13 populations. From the results, five well separated clusters were observed (Figure 1a). These were:

(i) Australia; USA (Florida); Kenya (Mbita) and Tanzania
(ii) Cameroon
(iii) Costa Rica; Honduras and South Africa
(iv) France; Uganda and Ghana
(v) Kenya (Embu).

Nei's genetic distance is a measure of cumulative mutations between the population being examined and the ancestral population. The genetic distance matrix reveals how similar the populations being compared are, and is related to the time the populations diverged from a single ancestral population. It is zero if there are no differences, but takes the value of 1 for populations with no common alleles. From the UPGMA cluster, the first cluster including Ghana, Uganda and France had a distance of 0.105, followed by South Africa, Honduras and Costa Rica, with a distance of 0.136. Only Cameroon was in the third cluster with a distance of 0.183, whereas Mbita, Florida, Australia and Tanzania were in the fourth cluster and Embu in the last cluster.

The highest cumulative mutation was observed in the fourth cluster. Using the genetic distance matrix (Figure 1b), it was observed that the largest distance of 0.4089 was between Florida and Embu, followed by 0.3849 between Embu and Australia. Florida and Ghana had a distance of 0.3612. The lowest values were observed between Mbita and Tanzania, a distance of 0.0447 and between France and Ghana. The two banana weevil populations collected from Australia were closely related genetically. Similarly, the weevil populations collected from Costa Rica and Honduras were the same. The greatest genetic diversity was observed between Embu and Florida, Embu and Australia. Tanzania/Embu, Ghana/France showed the least genetic diversity.

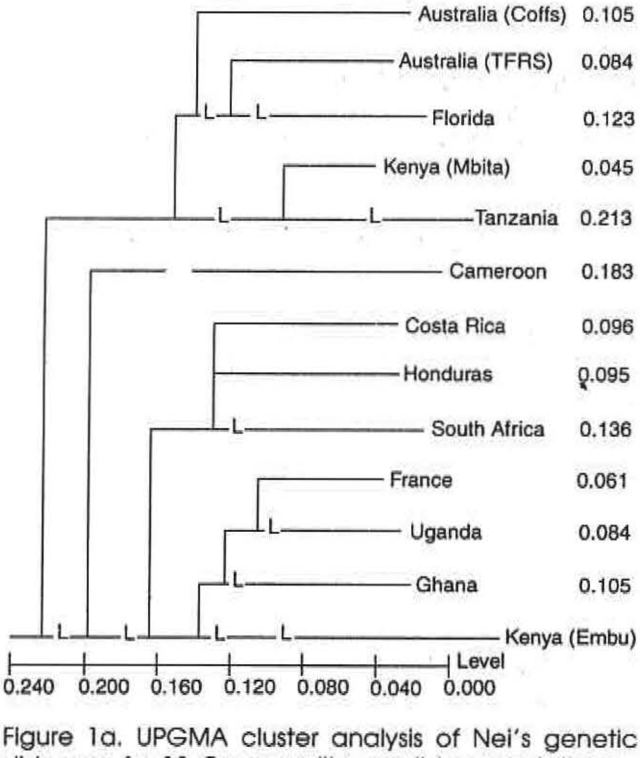

Figure 1a. UPGMA cluster analysis of Nei's genetic distances for 13 *Cosmopolites sordidus* populations

	1A	2A	CA	CR	FR	FL	GH	HO	MB	EM	SA	TZ	UG
1A	.0000												
2A	.0915	.0000											
CA	.1762	.2099	.0000										
CR	.2193	.2292	.1074	.0000									
FR	.1783	.2149	.1487	.1269	.0000								
FL	.1192	.0839	.2265	.2441	.2298	.0000							
GH	.3368	.3433	.2001	.1450	.0694	.3612	.0000						
HO	.2612	.2962	.2011	.0954	.0913	.3333	.0968	.0000					
MB	.1174	.1054	.1568	.1600	.1136	.1118	.1825	.1980	.0000				
EM	.3341	.3849	.2669	.1705	.1030	.4089	.0947	.1227	.1929	.0000			
SA	.1567	.1520	.1439	.0964	.0886	.1608	.1514	.0948	.1228	.2138	.0000		
TZ	.1548	.1250	.1747	.1313	.0966	.1219	.1299	.1578	.0447	.1678	.1136	.0000	
UG	.1855	.2513	.2143	.1835	.0615	.2585	.0989	.1245	.1292	.1164	.1199	.1330	.0000

1A= Australia (COFFS), 2A= Australia (TFRS), CA= Cameroon, CR= Costa Rica, FR= France, FL= Florida, GH= Ghana, HO= Honduras, MB= Mbita, EM= Embu, SA= South Africa, TZ= Tanzania, UG= Uganda.

Figure 1b. Nei's genetic distance matrix for the 13 *Cosmopolites sordidus* populations

Polymorphic bands have been identified and purified from the gels and are being cloned. The cloned bands will be labelled and used directly as probes in hybridisation assays. Alternatively, the bands will be sequenced using standard DNA sequencing methods. Primers based on these sequences will be used in PCR-based assays to differentiate between different weevil populations. In addition, mitochondrial DNA is being used for a more detailed analysis of genetic variability in weevil populations from different banana growing regions of the world.

2. BLOODMEAL IDENTIFICATION SERVICE

Background, approach, and objectives

Identification of bloodmeals in arthropods is an important aspect of the epidemiology of vector-borne diseases. Tsetse flies prefer to feed on certain animal host species and this host preference determines, among other factors, whether an individual fly species is an efficient vector of human or animal trypanosomosis. Knowledge of the preferred hosts is also important for 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 species in question. In general, bloodmeal identification can contribute towards the development of effective vector and disease control strategies.

The overall objective of this project is to analyse animal host preferences of the major tsetse fly species in Africa. The service is offered at cost to tsetse scientists in Africa.

Participating scientist: *E. O. Osir*

Assistant: *J. Kabii*

Funding: *Direct charges to ICIPE projects and other clients; ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark)*

Collaborators: *• Kenya Trypanosomiasis Research Institute (KETRI) • Kenya Wildlife Service (KWS) • University of Nairobi, Kenya • Natural Resources Institute (NRI) • University of Greenwich, UK • Ol Jogi Ranch (Nanyuki, Kenya)*

Work in progress

The following conjugates have so far been tested and can be used to identify these hosts to group or species level: baboon, buffalo, bush pig, camel, cattle, crocodile, donkey, eland, elephant, giraffe, goat, Grant's gazelle, hippopotamus, human, lion, monitor lizard, oryx, ostrich, pig (domestic), rhino, sheep, Thomson's gazelle, warthog, waterbuck and wildebeest.

Production of new antisera to the following animal species has been completed: bushbuck, kudu, impala, sable antelope, cheetah, leopard, dik dik, wild dog, kongoni and hirola. Purification of the antibodies and conjugation is in progress.

Over 850 tsetse blood meals drawn from Tanzania and Zimbabwe, and 225 mosquito blood meals collected from Ethiopia have been analysed for the Natural Resources Institute (NRI) and the Centre for Tropical Veterinary Medicine, respectively. In addition, the serum bank has received new sera samples for the following animal species with the help of Ol Jogi Ranch (Nanyuki): spotted hyena, black rhino, white rhino, lion, warthog and buffalo.

Future work will involve: (i) expanding the range of conjugates to other likely important tsetse hosts such as ant bear, duiker, hyena, jackal, monkeys, porcupine, rabbit and hare; (ii) boosting the ICIPE animal reference serum bank with sera collection, assisted by the Kenya Wildlife Service (KWS), Ol Jogi Ranch (Nanyuki) and Athi River Game Ranch; (iii) analysis of incoming blood meals according to demand.

(See also the reports under Tsetse, Ticks, Malaria Mosquitoes, Fruit Flies and Biosystematics Unit.)

Entomopathology Unit

The Entomopathology Unit (EU) carries out research and development of technologies which promote the utilisation of arthropod pathogens and products of biotechnologies which contribute to sustainable agriculture, improvement in livestock and human health, conservation of natural resources and preservation of the environment.

The Unit is involved in research activities across the gamut of ICIPE's programmes, including the following:

Animal Health

- Lethal insect technique (LIT): Developing, testing and validating a system for contaminating tsetse flies with entomopathogenic fungi in the field.
- Evaluating entomopathogenic fungi and nematodes for the management of the major African ticks.

Plant Health

- Development of entomopathogenic fungi as biocontrol agents for the control of thrips in high-value horticultural crops;
- Exploring and evaluating African fruit fly pathogens for biological control.
- Development of microbials for termite control in Africa.
- Developing biopesticides for locust and grasshopper control in sub-Saharan Africa;
- R&D towards implementation of a sustainable IPM programme for the African armyworm, *Spodoptera exempta.*

Products:

- Mass production of entomopathogenic fungi for field trials.
- Maintaining a germplasm centre.

1. ICIPE GERMPLASM CENTRE

ICIPE has recently established a Germplasm Centre as a repository for arthropod pathogens (fungi, bacteria, viruses and protozoans), for use against a wide range of target pests. These pathogens will be made available upon request to investigators in other institutions.

The activities of the Germplasm Centre include isolation, culture, identification, and preservation. Samples from Africa and elsewhere are being solicited for inclusion in the collection.

The culture collection is being designed to international standards. In order to achieve this, ICIPE is establishing a central information system on strains held in the Centre that will be readily accessible by all users. This is designed with a standard format for describing and recording data on accessions and computerised data storage and retrieval. A network of international and regional organisations holding reliable culture collections of arthropod pathogens is also being formed.

Biostatistics Unit

Background, approach and objectives

Based within the Population Ecology and Ecosystems Science Department, during 1998 and 1999 the Biostatistics Unit provided scientific support to all projects and departments at ICIPE, in terms of efficient design and analysis of experiments. These included assisting staff and students in design of experiments, data analysis, results verification and interpretation, manuscripts/thesis review, and statistical software installation, upgrading and teaching, and exploring available databases statistically for detailed information contributing to the general objectives of the different projects. The Unit also provided essential statistical ideas to many research project proposals during this period.

Three students were on attachment in the Unit during the review period for training in statistics and computing. The Unit also contributed to capacity building by conducting a 5-week course in biostatistics for the new classes of ICIPE's PhD ARPPIS students and by providing a resource person for the International Group Training Course on Novel Approaches to the Management of Ticks. A PhD student was admitted into the Unit through the ARPPIS programme during the year and the Unit carried out training for ICIPE scientists as well.

Close partnership existed between the Unit and the biometrics units in the Consultative Group of International Agricultural Research (CGIAR) Centres during the review period with the ILRI Biometrician participating in the teaching of the biostatistics course to ARPPIS students. The Unit played active roles in the Nairobi Cluster Modelling Group and the International Biometric Society, and ICIPE's Biostatistics Unit currently coordinates the sub-Saharan Africa Network of the International Biometric Society.

Work in progress

The following are the highlights of the Biostatistics Unit's research achievements:

1. SPATIAL AND TEMPORAL DYNAMICS OF TSETSE FOLLOWING SUPPRESSION

For the first time, we critically investigated the spatial and temporal dynamics of rapidly-growing populations of tsetse flies at Nguruman, southwest Kenya during 1993–1995, following six years of intensive population suppression with traps over a roughly 100 km^2 area. Our results suggest that the phenomenon of 'reinvasion' at Nguruman occurs from the southwest at the base of the escarpment when both resident and neighbouring populations increase and disperse widely during favourable conditions (the rainy seasons). The results also serve as a guide to the optimum distances between traps in further ecological studies (at least in Nguruman), to ensure that spatial autocorrelations are negligible.
(*See the full report under the Tsetse Programme.*)

2. OPTIMAL TRAP POSITION FOR TSETSE

To address these issues of lack of predictive ability, and the inability of conventional analysis methods to quantify the dependency of trap catches on multiple factors, we constructed practical mathematical models to describe a set of data on optimal trap position for *Glossina f. fuscipes* along the shores of Lake Victoria, Kenya in relation to two vegetation types. The log-linear model was used to ascertain the pattern of association between vegetation type, distance of a trap from the vegetation edge, and sex composition of trap catches. The log-logistic probability distribution function was employed to model trappability with respect to distance from the edge of the two types of vegetation. Simulation techniques were then used to estimate the radius of attraction of the unbaited biconical trap for the fly, taking the efficiency of the trap into consideration.
(*See the full report under the Tsetse Programme.*)

3. MODELLING TECHNOLOGY ADOPTION BY FARMERS IN SUB-SAHARAN AFRICA

Background, approach and objectives

Acceleration of agricultural production to meet the needs of an ever-growing population remains a central issue today in world agriculture. Various national and international agricultural research centres around the world have invested much effort in developing new technologies with great potential for increasing crop yield, but the level of farmers' adoption of these, which is crucial to the much-needed increased production rates, has been quite low. Rather, increasing the harvested area has been an important source of agricultural growth in most developing countries. This is no longer sustainable, however, in view of the present day population pressure and its attendant problem of land degradation.

In sub-Saharan Africa, inadequate understanding of small farmers' goals and their resource limitations has been identified as the major reason for this lack of farmers' adoption of improved technologies. There is therefore increasing interest among agricultural policy and research institutions in the process of adoption of new technologies, the impediments to that adoption and the possible measures to promote it.

Various factors are known to influence adoption. The relative importance of these varies, depending on geographical boundaries, the characteristics of the newly generated technology, farming practices, the state of the infrastructure and the level of available information. It is essential to understand how all these factors interact and contribute to the overall adoption of a technology. In this study, we developed models that relate technology adoption rate to these factors. In general terms, the model should give a very quick knowledge of expected adoption rate, while its estimated parameters will give hints on optimum paths to improving that rate.

Participating scientists: *A. Odulaja*, O.O. Ajayi (*Unit Head)*

Donor: *ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark)*

Collaborators: *• IITA*

Work in progress

The probability of adopting a technology is a function of the time, t, after introducing it. It is, however, shaped by many socioeconomic factors. Given n factors, with factors i represented as x_i, the probability of adoption, P_a, may be defined as

$$P_a = f(t, x_i),\ i = 1, .., n$$

where f is a function.

Let $x_i = \{R: 0, .., 1\}$
with increasing values depicting increasing favourability to adoption.

Function f must be a probability distribution function (pdf), since it seeks to estimate probabilities. We assume that the domain of f is t, whereas the parameters of f are determined by x_is. Hence, f should be distributed on $(0, \infty)$. It is desirable that f has both shape and scale parameters, which will be driven by the x_is. We used the two-parameters Weibull pdf, which satisfies these properties, to represent the distribution. This enabled the computation of the instantaneous adoption rate at any given time. The pdf was parameterised and standardised to enable comparisons across technologies.

To illustrate the use of this model, we carried out a simulation with varied values of the parameters. Optimum values of the parameters were then determined for given threshold probabilities and/or times of adoption. It was also possible to identify factors that need to be improved to enhance adoption.

Further exploratory statistical research on data collected at ICIPE will be carried out during year 2000. Collaboration with scientists in the different projects will be intensified and more efforts will be put into giving quality biostatistical services. A proposal for further development and application of the adoption model to insect science will be developed for donor funding.

Output

Publications

Odulaja A., Mihok S. and Abu-Zinid I. M. (1998) The magnitude of site x time interaction effect in tsetse flies (Diptera : Glossinidae) trap catches. *Bulletin of Entomological Research* 88, 59–64.

Maniania N.K., Saxena K.N. and Odulaja A. (1998) Influence of sorghum host plant cultivars on the activity of the entomopathogenic fungus *Metarhizium anisopliae* (Metsch.) Sorok. against *Chilo partellus* (Swinhoe). *Insect Science and Its Application* 18, 45–52.

Maniania N.K. and Odulaja A. (1998) Effect of species, age and sex of tsetse (Diptera: Glossinidae) on response to infection by *Metarhizium anisopliae* (Deuteromycetes: Moniliales). *BioControl* 43, 311–323.

Mutero C.M., Mosha F., Odulaja A., Knols B.G.J. and Bos R. (1999) Livestock management and malaria prevention in irrigation schemes. *Parasitology Today* 15, 394–395.

Knols B.G.J. and Odulaja A. (1999) Book review: Parasites in social insects, by P. Schmid-Hempel. *Parasitology Today* 15, 394–395.

Odulaja A. (1999) Description of non-precision in experimental field scores. *Discovery and Innovation* 11 (In press).

Seminar/conference papers

Ajayi O.O., Odulaja A., Nokoe S. and Bamiduro T.A. (1999) 'Gender-specific factors affecting agricultural output of small-scale farmers in western Kenya: A case study'. 6th Scientific Meeting of the sub-Saharan Africa Network (SUSAN) of the International Biometric Conference, IITA, Ibadan, Nigeria, 23–27 August 1999.

Odulaja A. (1998) 'Efficient evaluation of intercropping advantage'. ICIPE Internal Seminar, Mbita, Kenya, 26 February 1998.

Odulaja A. (1998) 'The biometric profession: Coping with modern threats'. International Biometric Society (Group Kenya) Seminar, University of Nairobi, Nairobi, Kenya, 17 June 1998.

Odulaja A. (1998) 'Repeated measures analysis'. Training for ICIPE scientists, Nairobi, Kenya, 24 June 1998.

Odulaja A. (1998) 'The trap-elusive tsetse: How many are they?' ICIPE Internal Seminar, Nairobi, Kenya, 7 July 1998.

Odulaja A. (1998) 'Experimental design for tick research'. International Group Training Course on Novel Approaches to the Management of Ticks'. ICIPE, Nairobi, Kenya, 1–29 September 1998.

Odulaja A. (1998) 'Practical use of statistical models in insect pest management'. Joint Nairobi Cluster (Modelling Group) and International Biometric Society (Group Kenya) Seminar, ILRI, Nairobi, Kenya, 22 October 1998.

Odulaja A. (1998) 'How friendly are environment-friendly methods of controlling insect pests?: A conceptual model'. Environmetrics Conference on 'Biometry at Work towards Environment 2000', Victoria Falls, Zimbabwe, 7–11 December 1998.

Odulaja A. (1998) 'Modelling the performance of insect traps'. XIXth International Biometric Conference, Cape Town, South Africa, 14–18 December 1998.

Odulaja A., Ajayi O.O. and Nokoe S. (1999) 'Conceptual model for estimating probability of adopting a farming technology'. 6th Scientific Meeting of the sub-Saharan Africa Network (SUSAN) of the International Biometric Conference, IITA, Ibadan, Nigeria, 23–27 August 1999.

Odulaja A. (1999) 'The role of the Sub-Saharan Africa Network (SUSAN) of the International Biometric Society (IBS) in enhancing capacity in applied biometry in East and Southern Africa'. Workshop on the Enhancement of Capacity in Applied Biometry in East and Southern Africa. The International Livestock Research Institute (ILRI), Nairobi; 7 to 9 December 1999.

Conferences/workshops attended

Odulaja A. (1998) Planning Workshop for Multi-Site Trials of Locust Pheromones and Sublethal Doses of *Metarhizium flavoviride* and Insecticides, ICIPE, Nairobi, Kenya, 12–14 August 1998.

Odulaja A. (1998) Environmetrics Conference on 'Biometry at Work towards Environment 2000', Victoria Falls, Zimbabwe, 7–11 December 1998.

Odulaja A. (1998) XIXth International Biometric Conference, Cape Town, South Africa, 14–18 December 1998.

Odulaja A. (1999) Sixth Scientific Conference of the Sub-Saharan Africa Network (SUSAN) of the International Biometric Society, Ibadan, Nigeria, 23–27 August 1999.

Odulaja A. (1999) Workshop on the Enhancement of Capacity in Applied Biometry in East and Southern Africa. The International Livestock Research Institute (ILRI), Nairobi, 7 to 9 December 1999.

(See also the report on the Population Ecology and Ecosystems Science Department and Social Sciences Unit.)

Social Sciences Unit

Background, approach and objectives

The Social Sciences Unit (SSU) is mandated to undertake research facilitating the development and tailoring of technology to the conditions, needs and demand of ICIPE's clientele, especially resource-limited farmers in the tropics. It is intended to elucidate the socioeconomic dimensions of research in insect science and its application by participating in priority and policy setting, and by contributing to ICIPE's capacity building and training programmes. Social science research is carried out in partnerships with biologists, extensionists, NGOs and farmers in all phases of technology development. These range from diagnosis of the problem, to design, testing, evaluation, assessment of impact and adoption potential and the recommendation domain.

Substantive areas of research include the following:

- indigenous knowledge and technology
- characterisation of production and health systems of end-users
- determination of economic viability (costs, benefits and affordability) of technology
- user-participatory research
- assessment of adoption potential of technology,
- assessments of marketing outlets of P/V/M technologies
- ex-ante and ex-post impact assessments in economic, social and environmental terms.

The SSU also participates in ICIPE's training programmes such as ARPPIS, short-term attachments, supervision of students and farmers' training courses.

During 1998–1999 the focus of the Unit was on three projects implemented in two research Divisions, namely Plant Health (two projects) and Animal Health (one project). A short overview of the SSU projects on evaluation of banana pest technologies follows.

1. DEVELOPMENT, TESTING AND DISSEMINATION OF TECHNOLOGIES FOR CONTROLLING PESTS AND DISEASES OF BANANA UNDER BANANA-BASED CROPPING SYSTEMS, UGANDA, 1997–2001

Background, approach and objectives

Globally, bananas are the fourth most important food crops after rice, wheat and maize. In the Great Lakes Regions of East/Central Africa, they are the most important food staple. Bananas are of strategic importance to food security in Uganda. However, productivity is decreasing due to three mutually reinforcing factors: pests and diseases, declining soil fertility and socioeconomic factors such as labour, infrastructure and marketing problems. In response to these trends and constraints, a series of measures to improve banana production were taken, including the development of a research agenda by the Uganda National Banana Research Programme (UNBRP) of the Uganda National Agricultural Research Organisation (NARO), the International Institute of Tropical Agriculture and the African Highland Initiative (AHI). In 1997 the collaboration was extended to ICIPE to provide an input in farmer-participatory research and technology adoption with special reference to banana IPM.

Participating scientists: *J.W. Ssennyonga*, E. Katungi*
(Project Leader)*

Technician: *J.M. Muchiri*

Donor: *Rockefeller Foundation*

Collaborators: *• Uganda National Banana Research Programme of NARO • International Institute of Tropical Agriculture, Uganda*

Work in progress

1.1 UNDERSTANDING CURRENT BANANA PRODUCTION

The consensus among researchers is that cultural control of pests and diseases of banana offers the best hope of increasing productivity. In any case, farmers in the study were widely using most of the conventional control methods. Work focused on cultural control at two contrasting benchmark sites. The major aim was to determine: (a) cultural practices chosen by farmers, those abandoned temporarily or for good, or taken up again; (b) criteria used; (c) factors influencing the decisions; and (d) the results obtained and why.

We hypothesised that four factors were crucial for an understanding of farmers' strategies and decisions: (a) the importance of banana, (b) the availability of production resources, (c) farmers' knowledge of the pests and diseases of banana and their use, and (d) the economic factors.

1.1.1 *Importance of banana*

Banana, the chief food staple—over 70% of bananas produced are consumed on the farm—contributes 39.3% of total household income. Land allocated to banana production is high (57%) and rises by socioeconomic strata. Actual use is the reverse, due to labour scarcity in the bottom stratum. Banana is mostly (83%) grown as a primary intercrop.

1.1.2 *Farmers' knowledge and control of pests and diseases of banana*

Knowledge of the biology and damage caused by the banana weevil is low. Farmers (58%) think the larva and adult weevil are different 'insects'. Similarly, knowledge of control is low, and use of control is even lower: only 20% of farmers apply control at the medium to high intensity levels. Eight factors influencing the use of banana IPM technologies were examined: age, education, farm income, pest knowledge, household size, off-farm income, experience in banana farming and risk. Results show that education has positive relationships with virtually all the IPM components. Risk is negatively correlated (-0.335), with the use of mulch, but it is positively correlated (0.248) with the use of chemicals. Age is negatively correlated (0.260) with trapping, but is positively correlated with sanitation practices.

1.1.3 *Economic analysis of IPM technologies*

Major funding include: (a) family members, mainly women, who provide 75–100% of labour for IPM technologies, (b) banana production in general and banana IPM in particular, are labour intensive and (c) labour scarcity is a major constraint (each economically active person supports two dependants and 65% of male farmers have part-time off-farm employment). Despite the high labour budget, use of banana IPM has higher benefit/cost ratios (BCR) than those of other crops grown except coffee. The BCR of use of sanitation, grass mulch and manure is 1.24 compared to 1.83 for coffee, 1.1 for beans and 1.05 for sweet potatoes.

The challenge for subsequent research is to lower the costs of IPM, especially for the bottom socioeconomic stratum. Research should also focus on combinations of IPM controls.

(The full report and another on banana technology evaluation is found in the Horticultural Crop Pests section in the Plant Health Division.)

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

Background, approach and objectives

Work under this second phase of the Project was designed to build on the achievements of phase I from 1989–1994, and focused on testing, validation, dissemination and adoption of technologies developed in the first phase. The dissemination model built into the project was as follows: ICIPE researchers and collaborators (IR&C) were to disseminate the technology to the public and NGO extension staff, who would in turn disseminate the same to farmers using participatory approaches. Socioeconomic research would assess the dissemination and adoption of the technologies. However, since no socioeconomic research was carried out in phase I, essential baseline socioeconomic information was also compiled.

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

Assistant: *M. W. Ochieng*

Donor: *BMZ*

Collaboborators: • *Federal Biological Research Centre for Agriculture and Forestry, Germany* • *IITA (Uganda)* •*KARI (Kenya)* • *Ministry of Agriculture, Livestock Development and Marketing, Kenya*

Work in progress

2.1 PROFILE OF BANANA FARMING IN RACHUONYO AND KISII DISTRICTS, WESTERN KENYA

2.1.1 *Importance of banana*

Crop production is by far the most important economic enterprise in the study area. Farmers grow banana for food (34%), livestock feed (19%), food security (10%) and environmental protection (9%), among other reasons. Banana comes second after maize, followed by sweet potatoes (13 PRWS) as a food staple but it contributes the most of any activity (17%) to cash income, followed by coffee (14%) and livestock (12%). Off-farm enterprises contribute 29%. Banana is principally (66%) grown as a pure stand and secondarily as an intercrop (34%).

2.1.2 *Resources allocated to banana production*

Maize is allocated the single largest percentage of resources (29%), compared to 14% for banana, and 7% and 5% for beans and sweet potatoes, respectively. The family supplies 60% of labour for banana production (LBP), which has the highest cost per acre among all crops produced (33.6% of total labour costs of the top 5 crops). Banana has also the highest input costs. IPM strategies have to be targeted to these production conditions.

2.1.3 *Farmers' knowledge of pests and diseases of banana*

Pests and diseases are perceived as part of a syndrome of "problems of banana production". There are no concepts of disease or pests of banana, but farmers know on average, a high number (5.8%) of controls of pests and diseases of banana. The best known controls are: paring (74.4%), hot water treatment (46.1%), trapping (33.9%), and use of chemical pesticides (38%). Half the number of respondents did not know the damage caused by banana weevils. The most frequently cited damage (19.4%) is the loss of productivity.

2.2 DISSEMINATION AND ADOPTION OF IPM

Prior to the Project, friends and relatives were the source of information on banana production and IPM for the vast majority. After the Project, the range of sources of information rose from 4 to 6%. ICIPE, although not expected to play a direct role in technology dissemination to farmers, came first (37%), as a source of information, followed by fellow farmers (24%), public extension agents (21%), farmers' own experience and observation (15%). This shows that the dissemination model failed. In addition, only 50% of extension agents disseminated the technology to fellow extension agents, the rest trained farmers but did not address several important controls. Adoption was high only for paring (68%) among the direct weevil control measures. However, there was a high ratio of farmers abandoning direct controls such as trapping (100%) and hot water treatment (78%).

2.3 FACTORS DETERMINING THE ADOPTION OF BANANA IPM (FDABIPM)

The factors were categorised into dependent and independent variables. The dependent variables comprise: (i) IPM components adopted, (ii) application intensity level, and (iii) abandonment of banana IPM practices. The independent variables identified include, (i) personal charatcteristics of the farmer (sex, education, age, etc.), (ii) bunch size, (iii) distance from the banana IPM diffusion centres, (iv) extension, (v) age of banana mat, (vi) pest/disease status, (vii) damage level, (viii) knowledge of pests/diseases and controls, and (ix) marketing infrastructure. Pearson correlation analysis reveals strong relationships between pest/disease level and adoption (0.0550); adoption and damage level (0.0146); adoption and farmer's education (0.0010); adoption and intensity of application of controls (0.0016); application intensity and farmer's age (0.04169); farmers' age and adoption (0.0016); extension and farmer's education (0.0098); adoption (0.0001); pest/disease level (0.0413) and intensity of application of control (0.0274). The relationships between these factors and other variables (bunch size, gender, etc.) were weak. Further analysis will establish other relationships not presented here.

2.4 ECONOMIC ANALYSIS

Mean household income per acre is highest for banana (Kshs 23,000) and maize (Kshs 13,218), intermediate for sweet potatoes (Kshs 8560) and cassava (Kshs. 8510), and lowest for beans (Kshs 6905). Income from cash crops is generally higher than that from food crops. Benefit/cost analysis showed that banana had the highest ratio (1.44), despite high production costs. Returns to inputs for banana production are far higher (10.94%) than those for labour (1.65), implying that there is greater opportunity for investing in inputs. Asked to assess the benefits of using IPM, the majority (63.3%) cited various productivity parameters. The rest cited better control of pests and diseases (26.8%), environmental benefits (5.3%) and direct economic gains, higher profits and labour saving (4.6%). Estimates made by researchers showed an aggregate 52% increase in bunch weight.

Since the conventional dissemination model failed while farmers performed better, subsequent work should invest more in direct farmer-to-farmer extension. At the same time, further research should aim to reduce the labour budgets of IPM.

Output

Publications

Ssennyonga J. W., Bagamba F., Gold C., Tushemereirwe W. K., Karamura E. B. and Katungi E. (1999) Understanding current banana production with special reference to integrated pest management in southwestern Uganda, pp. 291–310. In *Mobilising IPM for Sustainable Banana Production in Africa*. Proceedings of a workshop on Banana IPM held in Nelspruit, South Africa, 23–28 November 1998. (Edited by E. A. Frison, C. S. Gold, E. B. Karamura and R. A. Sikora). International Network for the Improvement of Banana and Plantain, Montpellier, France.

Bagamba F., Ssennyonga J. W., Gold C. and Tushemereirwe W. K. (in press). The competitiveness

of banana production in Uganda. *Proceedings of a Conference on Banana and Food Security*, held in Douala, Cameroon, 10–14 November 1998.

Conferences attended

Ssennyonga J. W. (1998) Workshop on Baseline Data Collection and Management for Research on Banana Production and Pest Management in East, Central and Southern Africa, organised by the Banana Research Network for East and South Africa (BARNESA), 16–19 February 1998, Kampala, Uganda. Paper presented, 'Socioeconomic approaches to the generation of baseline information: Illustrations from socioeconomic baseline information for the development of low-cost, safe tick controls'.

Ssennyonga J. W. (1998) Workshop on Mobilising IPM for Sustainable Banana Production in Africa, organised by INIBAP, 23–28 November 1998, Nelspruit, South Africa. Paper presented, 'Understanding current banana production with special reference to IPM in southwestern Uganda'.

Ssennyonga J. W. (1999) Workshop on Farmer Participatory Banana Technology Testing in Uganda, organised by the Uganda National Banana Research Programme and the International Development Research Centre (IDRC), 15–19 February 1999, Kampala, Uganda. Papers presented, 'Approaches to farmer participatory research on banana production and pest management'; 'The role of sociology in research on banana production and pest management'.

Capacity building

J.W. Ssennyonga, participated in training policy and extension workers in East Africa at a workshop on Banana IPM Technologies, organised by ICIPE (BMZ-funded Banana IPM Project), 4–7 October 1998, Oyugis, W. Kenya. Presented two papers: 'Tailoring IPM technologies to producers' objectives, conditions and demand'; and, 'Approaches to the dissemination of banana IPM technologies'.

Supervision of PhD students: (ARPPIS, University of Nairobi)

Dorothy M. Wanyama, supervised by J.W. Ssennyonga, P. Chitere, R. M. Ocharo and Z. Khan is carrying out field work in Kitale, W. Kenya, on socioeconomic factors influencing technology adoption.

Impact

Results were used as a basis for launching on-farm adoptive research managed and financed by researchers with farmer participation, starting in May 1999. Similarly, provisional results form the basis for interventions currently being planned for the districts experiencing severe decline in production. ICIPE's socioeconomist is chairman of a committee set up to prepare action plans for the latter interventions.

J. W. Ssennyonga was appointed to the steering committee of the Banana Research Network for East and South Africa (BARNESA) in 1999.

J. W. Ssennyonga was co-opted in 1999 by UNBRP to provide a backstopping input into the IDRC-funded 'Outreach On-farm Farmer Participatory Banana Technology Testing in Uganda'.

(See under the Tsetse programme and Habitat Management programme for reports of other SSU research.)

Biosystematics Support Unit

Background, approach and objectives

The Biosystematics Laboratory combines service and research activities in providing basic taxonomic infrastructure at ICIPE to support both identification and targeted taxonomic research. This infrastructure includes a reference collection, literature, laboratory facilities and expertise at research and technical levels. The Laboratory also provides networking to the world taxonomic community.

Participating scientist: *S. W. Kimani-Njogu (Unit Head)*

Technicians: *T. Ondiek, H. Mburu*

Donor: *ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark) and recharges*

Collaborators: Primary in-country collaboration: • *National Museums of Kenya (MOU signed).* Primary external collaborations: • *Natural History Museum, London (MOU in progress)* • *Royal Museum of Central Africa, Tervuren (MOU signed)* • *Plant Protection Research Institute, Pretoria (MOU signed).* The Biosystematics Support Unit (BSU) has also established a network of taxonomists in the following institutions who collaborate in the identification of the specimens: • *National Agricultural Research Laboratories (NARL)* • *Kenya Agricultural Research Institute* • *Coffee Research Foundation (CRF) Kenya* • *Agricultural Research Council, South Africa* • *CAB International, London, UK* • *Texas A&M University, Texas, USA* • *South African Museum, Cape Town* • *Wageningen Agricultural University, The Netherlands*

Work in progress

1. SYSTEMATICS SERVICES

During the review period, the Biosystematics Unit performed identifications, expanded its reference collection and trained parataxonomists as listed in Table 1.

2. RESEARCH ON SYSTEMATICS OF INDIGENOUS PARASITOIDS OF FRUIT FLIES IN AFRICA

Morphometrics studies indicated that geographic populations of the *Psyttalia* complex are morphologically distinct. Consequently, colonies of these populations were established in collaboration with the African Fruit Fly Initiative and hybridisation experiments were conducted to test their biological validity. It is anticipated that biochemical tests will be conducted as well. A manuscript on the findings has been prepared for publication.

A PhD student, Ms Marcia Trostle from Texas A&M University was attached to the Biosystematics Laboratory during the months of August to December in 1998 and 1999. She conducted various experiments under the same project. She discovered that it was possible to control squash flies in a subsistence garden by bagging the older pollinated bloom for about a week or until the squash is past the infestation stage (only very young squash are attacked).

Capacity building

ARPPIS scholars

Maxwell Billah, an ARPPIS PhD Scholar, joined BSU last year to study/conduct research on the revision of the genus *Psyttalia* (Hymenoptera: Braconidae) (Supervisors: S. Kimani-Njogu, W. A. Overholt and S. Miller).

MSc students (five) from the USAID Export Vegetable Project were attached to the Unit on 20 – 21 August 1998 and were trained on methods of collecting, handling, rearing, preservation and basic identification.

Attachments – Technical level

Daniel Muia—Technical Assistant, Commercial Insects, received instructions at the Unit on insect sampling, curation and basic identification techniques.

Jabros Kabinda of Jomo Kenyatta University of Agriculture and Technology was attached to the Unit

Table 1. Curation and identification services

User	Title of project	No. of specimens submitted in 1998–1999
ICIPE/WAU	1. Field monitoring of the establishment and dispersal of *C. flavipes* at the Coast Province, Kenya	51,231
	2. Phenology of stemborers and natural enemies in Eastern Province, Kenya	7790
	3. Impact of predators on cereal stemborers at the Kenya Coast	2584
	4. Survey of stemborer and natural enemies in Ethiopia, Somalia, Zanzibar and Uganda	3609
	5. Genetic variability in *Cotesia flavipes* and its effect on establishment for control of stemborers	2520
	6. Physiological and genetic diversity of selected populations of the larval parasitoid, *Cotesia sesamiae*	162
	7. Optimisation of the release strategy of *Cotesia flavipes* Cameron (Hymenoptera: Braconidae) for the classical biological control of *Chilo partellus* in Ethiopia	4180
Gatsby Graminae Project	1. Effects of *Melinis minutiflora* on the foraging behaviour and searching efficiency of stemborer parasitoids in cereal-based cropping systems	1920
IPM Horticulture	1. Pests and natural enemies of cabbage in eastern and southern Africa	2615
	2. MSc projects (five) on export vegetables	908
	3. Immigration and emigration of whiteflies	2
African Fruit Fly Initiative	1. Survey pests and natural enemies of fruits	14,364
ARQU	1. Quality control – insect cultures are checked regularly to ensure that they are free from contaminants from other insect cultures	86
OUTSIDERS Cadbury (Kenya) Ltd	Infested chocolate bars and peanuts—insects reared from them	18
Rhone Poulenc	Infested bamboo	12
Homegrown Kenya Ltd	Pests and natural enemies of horticultural crops	6
GTZ Muhugu	Bukavu Project, Rwanda	20
Total specimens		92,059

in February 1999. He received instructions on identification of tephritids and their natural enemies and also on general insect curation.

Maurice Odoyo Okomo, a technical assistant in the ICIPE/WAU project in Muhaka, Coast Province was attached to the BSU for 2 weeks in March 1999. His training was on identification of insects associated with stemborers.

Constance Andeyo Muholo, a temporary employee (technical level) of the USAID export vegetable project was trained on identification of *Trichogramma*. This included preparation and slide mounting of insect parts.

Hellen Heya, a temporary technical staff of the ICIPE African Fruit Fly Initiative was attached at the BSU during the months of November and December 1999 (ongoing) and trained on identification and curation of fruit flies and their parasitoids.

Community education

In April 1998 the Unit participated in a project carried out by ICIPE and KEMRI on a survey of knowledge about the staphylinid beetle, *Paederus sabaeus* Erichson, commonly known as the 'Nairobi eye fly' that causes blisters on human skin. The Unit provided 10 boxes of different groups of insects morphologically similar to *Paederus*. The aim of the project was to create awareness and identification of the harmful insect.

Output

Publications

Polaszek A. and Kimani-Njogu S.W. (1998) Scelionidae, pp. 259–264. 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.

Kimani-Njogu S.W., Overholt W. A., Woolley J. B. and Omwega C. (1998) Electrophoretic and phylogenetic analysis of selected allopatric populations of *Cotesia flavipes* complex (Hymenoptera: Braconidae) parasitoids of cereal stem borers. *Biochemical Systematics and Ecology* 26, 285–296.

Conferences/workshops

Kimani-Njogu S. (1999) BIONET—International Workshop on Identifying and Understanding of the World's Biodiversity, Cardiff, UK, 22–29 August 99.

Kimani-Njogu S. (1999) ICIPE African Fruit fly Initiative Workshop, 17–21 November 1999. Presented a report on the status of fruit flies and parasitoids systematics.

Kimani-Njogu S. (1999) Maize Streak Virus Workshop, KARI, Headquarters, Nairobi, 15–17 September 1999. Paper presented, 'Systematics of leafhoppers'.

Mburu H. W. (1998) Training Workshop on Collecting, Preservation, Identification and Control of Mites of Agricultural Importance, Pretoria, South Africa, 3–10 May 1998.

Workshops organised

The Unit assisted the GTZ in the preparation of insect specimens and data for the planning workshop on pests and natural enemies of Brassicae in the eastern and southern Africa region, 18–22 May 1998.

The Unit participated in the ICIPE/WAU workshop and group training course on the management of cereal stemborers in eastern and southern Africa by providing insect specimens, technical support and lectures, 12–23 October 1998.

Consultancies undertaken

Susan Kimani-Njogu taught the Systematics Unit of the Masters degree course in Tropical Entomology at the University of Zimbabwe in March 1999.

Impact

The output of projects that received identification services at the Unit reflects the impact of the Unit. Identification services to other institutions, especially agrochemical industries like Rhone Poulenc and Cadbury Kenya Ltd, have a direct impact on the choice of control method and the results.

Insect Informatics Unit

Background, approach and objectives

The Insect Informatics Unit is aimed at generating, processing and disseminating insect-related information for sustainable development through the use of modern information and communication technology (ICT). It also contributes to capacity building in Africa through partnership, networking and training. The development of web-based intelligent insect management information systems is geared toward meeting the needs and challenges of the post-PC era. The Unit has been based in the Population Ecology and Ecosystems Science Department since late 1999.

Participating scientist: *Y. Xia (Unit Head)*

Donors: *USAID and ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark)*

Collaborators: *• NSF Centre for IPM, North Carolina State University, USA • Virginia Polytechnic Institute and State University (Virginia Tech), USA • Centre for Pest Information Technology and Transfer (C-PITT), The University of Queensland, Australia • German Centre for Documentation and Information in Agriculture (ZADI), Germany • IITA (CGIAR SP-IPM) • Africa IPMLink • IPMNet/CICP • IPM/CRSP • IPM Europe • IPM Forum • IPM Global Facility*

Work in progress

1. IPM AFRICA

The Africa IPM Forum Project has developed a web-based product, IPMAfrica (**http://informatics.icipe.org/IPMAfrica/**). The IPMAfrica supports unlimited users, discussion forums/topics and messages/posts. Powered by Active Server Pages (ASP) and written in server side Java, IPMAfrica features many handy functions, such as rich HTML messages (supporting picture, sound, video and links); threaded or linear messages; file attachment; automatic-Cookie login; email integration; full search; and private messages. The IPMAfrica was hacked in September 1999 together with the Africa Remote Sensing Data Bank and lost all its previous registration and posted messages. It was re-built and is fully functioning again.

2. AFRICA REMOTE SENSING DATA BANK

The Africa Remote Sensing Data Bank (**http://informatics.icipe.org/databank/**) has been developed. The 20 years of World Meteorological Organisation (WMO) ground observation data for more than 1000 stations in Africa, the 40 years average of climatic data from Australian National University, together with many other data sets, are available free to users. More data are under preparation and will be added into the data bank continuously.

3. ICIPE INSECT INFORMATICS HOME PAGE

The ICIPE Insect Informatics Initiative home page (**http://informatics.icipe.org**) has been constructed to provide news and information to end-users. The web-based intelligent insect management information system is under development and is our priority R&D area for the post-PC era.

4. OTHER TOOLS AND TRAINING

The web-based ICIPE Central Management Information System (WICMIS) is under development as a cross-platform tool for managing all ICIPE in-house data via a browser from anywhere in the world. This will facilitate the tele-working and closer links with the GC and donor community.

The web-based virtual training technology has been applied to IPM training in Africa. A project with IITA and other partners funded by USAID KELP is under preparation.

Output

Informatics products

- Web-based Africa Remote Sensing Data Bank (http://informatics.icipe.org/databank/ or http://pestdata.ncsu.edu/informatics/databank.htm)

- Web-based Africa IPM Forum (http://informatics.icipe.org/IPMAfrica)
- Insect Informatics Initiative home page (http://informatics.icipe.org)
- Insect Informatics Unit assisted the ICIPE African Fruit Fly Initiative in the development of a CD-ROM product titled 'Courtship Behaviour of the Mediterranean Fruitfly (Medfly): Worldwide Comparisons'. Both IBM and Macintosh-compatible versions of the CD-ROM are available.

Publications

Xia Y. (1998) PESTNET at ICIPE and Insect Informatics, pp. 133–137. In *Proceedings of the Integrated Pest Management Communications and Information Workshop for Eastern and Southern Africa (ICWESA)*, Nairobi, Kenya, 1–6 March 1998.

Xia Y. and Baumgärtner J. (1999) ICIPE Insect Informatics Initiative: An integrated approach for insect information generation, processing and dissemination, pp. 31–39. In *Role and Potential of IT Systems and Communication Networks for International Development* (Edited by A. Loeper et al.). Universität Bonn-ILB, Germany.

Conferences attended

Xia Y. (1999) Second Multi-Objective Decision Support System (MODSS'99) conference, 1 to 6 August 1999, Brisbane, Australia. Paper presented by Xia Y. and Baumgärtner J. 'Web-based intelligent insect management information system'.

Xia Y. (1999) USAID KELP (Knowledge, Exchange and Learning Partnership) Task Team Meeting, 20–22 September 1999, Washington DC, USA.

Xia Y. (1999) Second European Conference of the European Federation for Information Technology in Agriculture, Food and the Environment (EFITA/99), 27–30 September 1999, Bonn, Germany.

(See also the reports on the Population Ecology and Ecosystems Science Department, Information Services Unit, Biodiversity and Conservation programme and African Fruit Fly Initiative.)

Information Services

Background, approach and objectives

The Information Services Unit was created in September 1997 and consists of 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 and Printshop—a cost-recovery unit
- The Information Resources Centre (Library)

The objective is to consolidate and coordinate the Centre's current information activities and to expand the range of activities and services provided. These are expected to eventually include multi-media productions such as videos, CDs, mobile displays; preparation of materials for electronic information dissemination via the Internet; and improved digitally produced graphic displays, posters and slide presentations. Photographic services for PR events and publishing purposes were also incorporated in the new division, but scientific photography remains a service of the Molecular Biology and Biochemistry Unit. A further down-sizing of staff in mid-1999 has meant that the Science Press is not currently able to publish work for third party clients, although the ICIPE Printshop still handles smaller jobs.

Participating staff: *A. Ng'eny-Mengech*, D.Ouya (*Head of Information Services)*

Assistants: *I. Ogendo, N. M. Komeri, D. Osogo, J. Malombe, J. Kamau (until June 1999), R. Musyoka (until Nov. 1998), M. Kageche, J. Kisini, E. Wasike, J. Lago, W. Ambaka*

Donors: *ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark), Electronic Publishing Trust and Bioline Publications, UK* (for Insect Science and Its Application); *Swiss Academy of Sciences* (for the Information Resources Centre). *Co-publishing agreements are also in force.*

Work in progress

1. EDITING/EDITORIAL SERVICES

The editorial services provided by this office include writing and compiling information about ICIPE and its projects and activities, and providing advice to staff about publishing. The editors also ensure that the scientific manuscripts of ICIPE researchers undergo preliminary editing and peer review before they are submitted to international journals, and frequently edit ICIPE project proposals and donor reports. Shortage of editorial staff continues to limit the range and amounts of information being produced and disseminated.

Among the ICIPE documents originated and produced over this reporting period were the *Annual Report Highlights* for 1997; the consolidated *1995–1997 ICIPE Scientific Report*; a series of nine full-colour brochures about selected ICIPE programmes; poster displays for international fora such as the 50th anniversary of IFAD; a brochure on *ICIPE's Milestones—Steps on the Way to Sustainable Development*; and a list of ICIPE publications for the past 5 years. Also edited and produced were *A Guide to Growing Bananas in the Eastern African Highlands;* the *Business Plan and Research and Capacity Building Outlook 2000–2003: With Major Accomplishments for the Three Previous Years 1997–1999*; and a colour brochure on *Fighting Africa's Deadly Fly—New Ecofriendly Solutions for Tsetse Management: Accomplishments of the European Commission-Funded Project 'Interactive Development and Application of Sustainable Tsetse Management Technologies for Agropastoral Communities in Africa'.* The layout, design, graphics and DTP of the foregoing ICIPE documents were also done in the Science Editing Section. The Section provides scientific illustrations, posters, Powerpoint presentations and other artwork for ICIPE staff and external clients.

Training of ICIPE's ARPPIS PhD students (*See under Capacity Building*) in science reporting and writing was achieved through a series of lectures and seminars given by the Principal Science Editor. Around eight information specialists and students from Kenyan universities and polytechnics and from other countries in Africa were trained in the department throughout this reporting period in science editing and information science.

2. ICIPE SCIENCE PRESS (ISP) AND PRINTSHOP

ICIPE Science Press (ISP) started in 1988 as a service unit for the Centre, and was operated on a cost-recovery basis until June 1999, when the activities were curtailed due to staff down-sizing. The Press published work for the Centre's core departments, project-related activities and third party clients. Since mid-1999, work for external clients has been limited to printing only (i.e. no editorial and DTP services are provided). The printshop was relocated to the main ICIPE campus at Duduville in early 1999 from its previous site on the former ICIPE headquarters at the University of Nairobi Chiromo campus.

During 1998 and the first half of 1999, ISP completed jobs from many other agencies and organisations in Kenya and in other countries. The Press edited and published 4 books in a series for the United Nations University, Institute for Natural Resources in Africa (UNU/INRA). Other examples are the publication of *IPM in Vegetables,Wheat and Cotton in the Sudan: A Participatory Approach* for FAO; *Tropical Entomology:Proceedings of the 3rd International Conference on Tropical Entomology (ICTE)*; the second printing of a two-volume set of essays on *The Political Economy of Development—An African Perspective* (Edited by S. Rasheed and S. Tomori); and a *Directory of Neem Workers in East Africa*, among others (*See the list of publications for the complete output*).

ICIPE itself, however, continues to be the major customer, and the printshop routinely manufactures numerous ICIPE brochures, programmes, institutional stationery, name cards, etc. About to go to press is the handbook on identification of African ticks, and several pest management manuals and guidelines for using neem.

Out 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 fraternity in East Africa. ICIPE Science Press has an important role to play in this region by serving as a medium for publishing manuscripts from African scholars and researchers. Over the years, ISP helped publish the maiden issues of two African journals, namely the *African Crop Science Journal* and *Horizon DAT: Towards a Developed Architectural Tradition*. Activities such as presenting book displays at conferences, participation in international bookfairs, and participating in meetings and seminars of the Kenya Publishers Association and the International Federation of Science Editors (Africa branch), all help to publicise ISP and were useful in acquainting others with the Press' work.

3. *INSECT SCIENCE AND ITS APPLICATION*: THE INTERNATIONAL JOURNAL OF TROPICAL INSECT SCIENCE (ISA)

The year 1998 marked 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 technically by ICIPE, with intellectual 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. The journal has been printed in the ICIPE Printshop (*see the previous section*) for the past several issues, in order to reduce printing costs. Volumes 18 and 19 were edited and produced in 1998 and 1999, including a special issue of Vol. 19 on locust and grasshopper research commissioned by the International Red Locust Control Organisation for Central and Southern Africa (IRLCO-CSA) to mark its 50th Anniversary. Volume 20 of 2000 is in press.

Over the review period, ISA has continued to undergo amendments in its editorial organisation and approach in order to centralise, streamline and modernise operations. Dr Hans Herren was appointed to the position of Editor-in-Chief in 1995. Professor Richard Mwangi, currently the Deputy Vice-Chancellor (Research and Extension) of Egerton University in Kenya, continues to assist on an honorary basis as the Associate Editor, in helping set policy, assigning reviewers, and secretariat decision-making. In order to improve the statistical presentation of the papers, Dr A. Odulaja of the Biostatistics Unit at ICIPE was appointed a member of the International Editorial Advisory Board with Volume 17 and now regularly provides valuable review of manuscripts. Other secretariat staff include an editorial assistant/proofreader, and a DTP designer/imagesetter.

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. ICIPE staff enjoy free on-line access to the full text and graphics of ISA. A profile of the journal and its Tables of Contents are also available on the ICIPE website, at **http://www.icipe.org/isa** and the African Journals Online (AJOL) website of the International Network for the Availability of Scientific Publications (INASP). The secretariat staff are now fully trained in electronic publishing language, thanks to the generous technical assistance of the Electronic Publishing Trust and Bioline, UK. All graphics are digitised and the text is converted to html in Nairobi before being sent electronically to Bioline, UK. There has been a steady, but significant increase in the number of unique sites accessing the journal on-line, which currently stands at about 100 per month (Figure 3a).The recent special

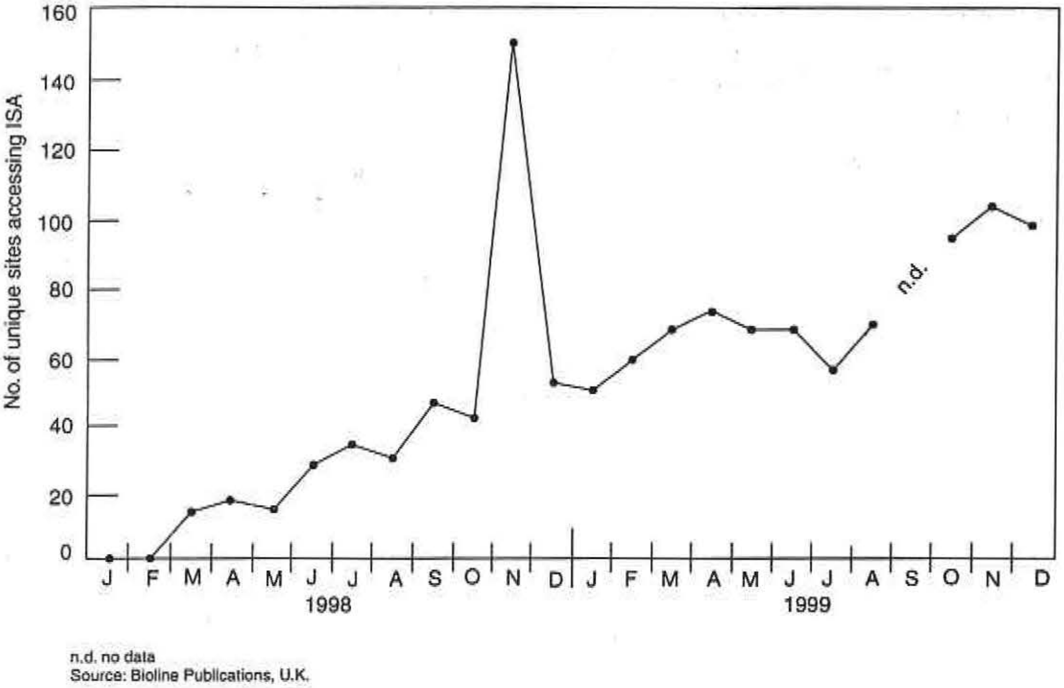

Figure 3a *Insect Science and Its Application* on-line usage

reduction in on-line subscription fees for individuals (to only US$ 30 per volume) is intended to help African scientists gain better access to the South's research information. More funding is being sought to increase the journal's impact within the tropical developing countries.

This move into electronic publishing notwithstanding, ISA will continue to publish a printed version in the foreseeable future, until the journal sponsors are certain that most users, especially those in the Third World, have access to the electronic media. In this regard, a 'Millennium Survey' was conducted towards the end of 1999 with the aim of assessing the 'e-readiness' of ISA's stakeholders, viz. contributors, reviewers and subscribers. The results of this survey are being compiled and analysed and will appear in an issue of Volume 20. Considerable debate still exists internationally about issues such as copyright, duplication of articles, interlibrary loans, and methods of payment for electronically produced publications. The issues are especially pertinent to users in developing countries, who often have no credit cards and only limited access to computers. It

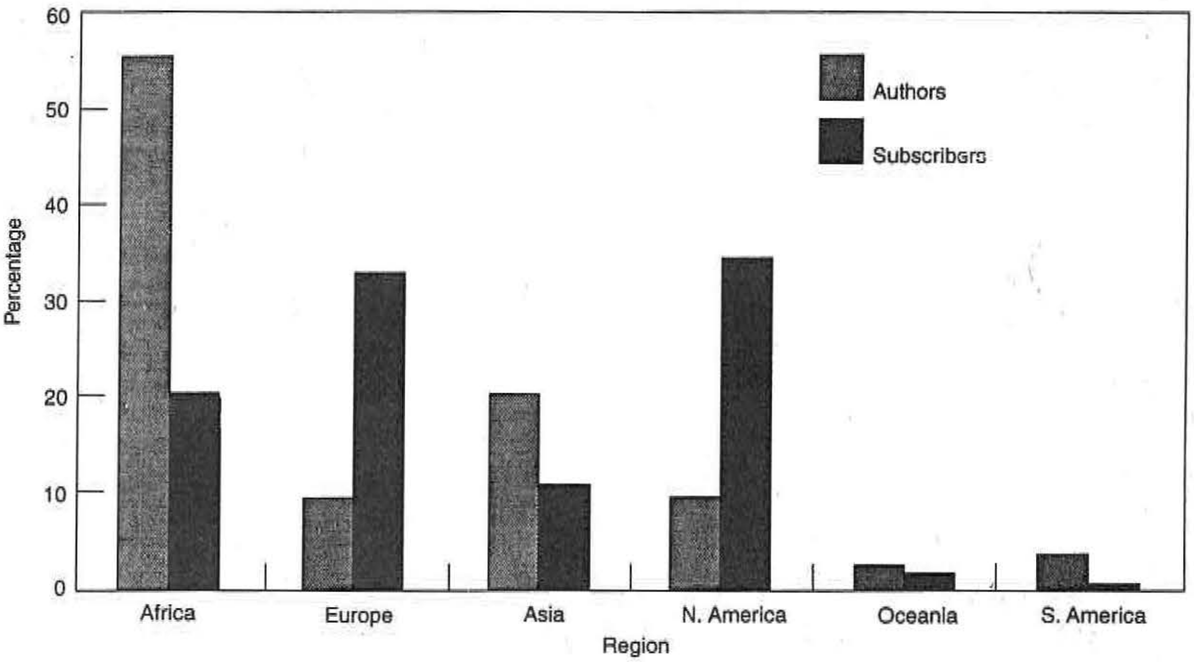

Figure 3b. Regional disparity of authors and subscribers to *Insect Science and Its Application* (1998–1999)

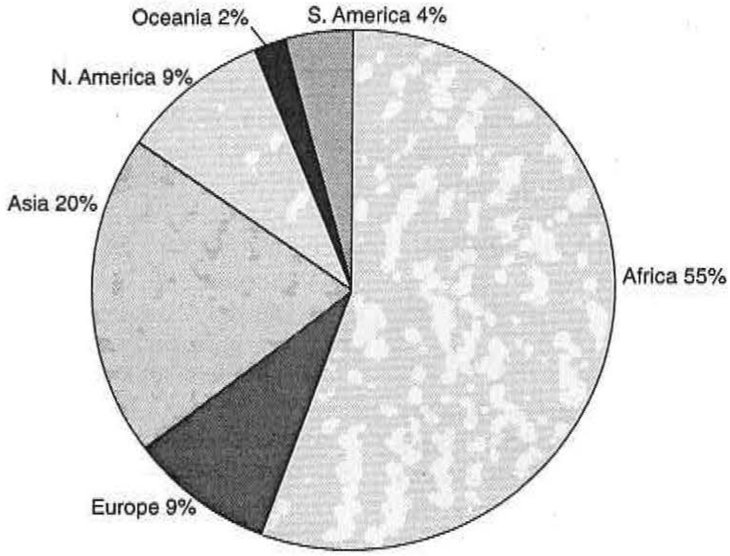

Figure 3c. Profile of *Insect Science and Its Application* authors, by region

is proposed to seek funding for a project to present the journal's research papers in a more understandable and usable style to farmers and other Third World audiences.

The turnover time has been reduced to 6–8 months for papers in a good editorial state, and ISA still believes that 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 3b and 3c. 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. A small UNESCO grant received in 1998 was used to sponsor gratis subscriptions to 8 African universities. 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.

4. INFORMATION RESOURCES CENTRE (IRC)

The IRC (library) was brought into the Information Services Division in September 1997. The IRC is located on the Duduville campus with a small informal branch at the Mbita Point Field Station. It serves not only ICIPE staff, but users from research centres, universities, NARS, and other organisations in the eastern and southern Africa region.

The IRC houses about 10,500 books, and over 150 journals, of which about 130 titles are current subscriptions. Many are specialised publications not found in any other library in the region. Several databases on CD-ROM (e.g AGRIS, CABCD, Current Contents) make up part of the collection. Some journals and reference materials are currently being received in both print and on-line versions; the latter are expected to increase as these become more available and affordable. As well as handling about 8500 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 photocopying service; perform about 120 literature searches yearly for clients; and organise for interlibrary loans. The library is now on-line and searches can be done on the Internet.

Part of the library catalogue has been published on the ICIPE website (*http://www.icipe.org*) and may be accessed by both internal and external users. 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 and 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; PMD 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 journal *Insect Science and Its Application*.

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 interest. The CDS-ISIS software used in the library is the gift of UNESCO. Other gifts during the review period were received from the Bishops Museum in Hawaii through the assistance of Dr Scott Miller (Head of ICIPE's Biodiversity Programme), who also donated old issues of some journals. Several other personal gifts of books and journals were received.

Output

Publications

ICIPE Science Press has had co-publishing agreements with United Nations University, FAO, UNEP, Jomo Kenyaatta University of Agriculture and Technology, AAPAM, AAU, etc. during the period under review.

(For publications of ICIPE Science Press for ICIPE clients— see the 'ICIPE Publications' under the consolidated list of publications at the end of this report.)

- 1995–1997 *ICIPE Annual Scientific Report.* Edited by A. Ngeny-Mengech and S. W. Mwanycky. ISBN 92 9064 121 5. 332 pp. 1998.
- 1997 *ICIPE Annual Report Highlights.* Compiled and edited by A. Ng'eny-Mengech. ISBN 92 9064 115 X. 40 pp. 1998.
- *A Guide to Growing Bananas in the Eastern African Highlands.* A. S. S. Mbwana, L. Ngode, K.V. Seshu Reddy and R. A. Sikora. ISBN 92 9064 120 7. 40 pp. 1998.
- *Business Plan and Research and Capacity Building Outlook 2000–2003: With Major Accomplishments for the Three Previous Years 1997–1999.* Temporary binding. 45 pp. December 1999.
- *Fighting Africa's Deadly Fly—New Ecofriendly Solutions for Tsetse Management: Accomplishments of the European Commission-Funded Project 'Interactive Development and Application of Sustainable Tsetse Management Technologies for Agropastoral Communities in Africa'.* R. Saini. ISBN 92 9064 126 6. 12 pp. 1999.
- *ICIPE. Milestones...:Steps on the Road to Sustainable Development: Recent Accomplishments in Promoting Better Food Security, Health, Welfare and a Wholesome Environment for Peoples of the Tropics.* Compiled and edited by A. Ng'eny-Mengech. ISBN 92 9064 117 7. 12 pp. May 1998.
- *ICIPE Publications List 1995–1998.* ISBN 92 9064 124 X. 14 pp. April 1999.
- *Insect Functional Morphology: A Laboratory Manual.* K. J. Mbata. ISBN 92 9064 093 6. 192 pp. June 1997.
- *Insect Science and Its Application* (The International Journal of Tropical Insect Science). Editor-in-Chief, H. R. Herren. ISSN 0191-9040
  (a) Volume 18 Nos 1–4 (1998)
  (b) Volume 19 Nos 1–4 (1999)
  (Also available as electronic version.)
- *Integrated Pest and Vector Management and Sustainable Development in Africa: Abstracts.* Joint Congress of the African Association of Insect Scientists (13th Congress) and the Entomological Society of Burkina Faso, Ouagadougou, Burkina Faso, 19–23 July 1999. Edited by Denash Giga and M. Ali Bob. ISBN 92 9064 125 8. 58 pp. July 1999.
- *Integrated Pest Management in Vegetables, Wheat and Cotton in the Sudan: A Participatory Approach.* Edited by Z. T. Dabrowski. ISBN 92 9064 100 2. 250 pp. October 1997.*
- *Proceedings of the First ARPPIS Symposium: Abstracts of Papers Presented and Appendixes.* Edited by C. B. Maranga. ISBN 92 9064 128 2. 16 pp + appendixes. November 1999.
- *Proceedings of the First International Workshop on the Conservation and Utilization of Commercial Insects.* Nairobi, 18–21 August 1997. Edited by S. K. Raina, E. N. Kioko and S. W. Mwanycky. ISBN 92 9064 12 3. 252 pp. 1999.
- *The 21st-Century Woman Scientist: From Girl-Student to Woman-Scientist.* E. G. Mwangi. 96 pp. ISBN 92 9064 118 5. 1998.
- *The Horizon-DAT: Towards a Developed Architectural Tradition (DAT) for Africa.* (Journal of the Department of Architecture, JKUAT). ISSN 1026-0552. Volume 2 No.1: The Quest for a Green Architecture. July 1998.
- *The Political Economy of Development: An African Perspective.* Vols I and II. Edited by S. Rasheed and S. Tomori. ISBN 92 9064 095 1. Vol. I, 486 pp.; Vol. II, 339 pp. 2nd printing 1999.
- *Tropical Entomology: Proceedings of the 3rd International Conference on Tropical Entomology.* Edited by R. K. Saini. ISBN 92 9064 108 8. 409 pp. 1998.
- United Nations University, Institute for Natural Resources in Africa. UNU/INRA Assessments Series (Series Editor—Bede Okigbo):
  (a) *Indigenous African Food Crops and Useful Plants. Survey of Indigenous Food Crops, Their Preparations, and Home Gardens in Ethiopia.* Z. Asfaw. ISBN 92 9064 109 6. 65 pp. September 1997.*
  (b) *Mineral Resources of Africa. Field Survey on African Mineral Resources: Status and Management for Sustainable Development in Lesotho, Swaziland and Zimbabwe.* H. Munyanyiwa and M. S. Lipalile. ISBN 92 9064 105 3. 60 pp. November 1997.*
  (c) *Use of African and Foreign Food Preparations in Commercial Eating Places. Indigenous African Food Crop Preparations as Compared to Those Introduced Foods Produced in Africa and Imported Foods in Southwestern Nigeria.* S. H. Abiose and T. O. Omobuwajo. ISBN 92 9064 101 X. 52 pp. January 1997.*
  (d) *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. Miriam J. F. Isoun. 125 pp. ISBN 92 9064 102 9. 119 pp. July 1997.*

**Not listed in previous ICIPE Publications List*

Conferences attended

Mengech A. and Ouya D. (1998) 7th International Federation of Science Editors Conference, Sharm-el-Sheik, Egypt. June 1998.

Proposals written

Support for *Insect Science and Its Application*—To UNESCO (1998)

Promoting Third World Science. Saving One of Africa's Reputable Journals—To TWAS (1998)

Support for putting *Insect Science and Its Application* on-line—To Electronic Publishing Trust and Bioline Publications, UK. Funding for Volume 17 and Volume 18 (1997 and 1998), and nominal cost for subsequent volumes.

Bringing the Benefits of Modern Agriculture to Africa's Farmers (1999): DUDUNET, An Interactive Web Site.

Capacity building

ARPPIS PhD students were 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 communication, science editing and library science programmes from the University of Nairobi, Moi University, Kenyatta University and Kenya Polytechnic, were offered short-term practical training and/or an internship period (av. 8 per year).

Training visits organised for professionals in information science and publishing from the OAU and AAU.

Seminars on various issues of academic publishing offered to members of the Nairobi publishing community during professional meetings.

Animal Rearing and Quarantine Unit

Background, approach and objectives

Development of strategic arthropod management techniques requires vigorous research in both basic ecology and biology of the target arthropod species. The research objectives of most projects are achieved when there is a dependable supply of quality arthropods. Some research protocols (such as bioassays and maintenance of selected pathogens of the target arthropods) also require a dependable supply of certain laboratory or livestock animals. Laboratory-reared arthropods and laboratory/livestock animals cannot be purchased locally at an economical cost. The Animal Rearing and Quarantine Unit (ARQU) meets these essential requirements of ICIPE's research and development (R&D).

In order to meet these objectives, ARQU carries out R&D on new techniques of arthropod rearing, mass production and breeding and handling of small laboratory mammals. An important attribute of this work is to ensure that biological performance and fitness is as close to that of the original populations as possible. The Animal Rearing and Quarantine Unit also carries out capacity building programmes for a variety of R&D practitioners, such as scientists, technologists and technicians from national programmes on techniques of insect rearing. The Unit provides these services at the main activity station of ICIPE's Duduville headquarters, the Mbita Point Field Station and in Ethiopia.

The Animal Rearing and Quarantine Unit provides three key services to ICIPE's R&D, namely Insectary Services, Animal Breeding Services and Quarantine Services. The Insectary Services rear most of the target arthropod species; the Animal Breeding Services breeds small mammals and has a facility for large animals holding. The rearing of commercial insects (honey bees and silkmoths) is currently being undertaken within the Commercial Insects Project.

Participating scientists: *J.P.R. Ochieng'-Odero*, D.J. Nadel (*Unit Head)*

Assistants: *F. O. Onyango, E. M. Ngo'ng'o, J. H. Ongudha, J. M. Kagoiya, F. M. Thuo, J. O. Kokungu, S. A. Patya, J. O. Wabwire, M.G. Kimondo, M. M. Miti, J.M. Onyango, P. S. Muchisu, A. Majanje, A. G. Nyangwara, P. O. Wagara, R. O. Agan, J. Ojude, N. M. Mwikya*

Donors: *ICIPE Core Fund donors (Development agencies of Switzerland, Sweden, Norway and Denmark), Netherlands Government, IFAD, Gatsby Charitable Trust, Austrian Development Cooperation (ADC)*

Collaborators: *• Kenya Agricultural Research Institute (KARI) • Kenya Medical Research Institute (KEMRI) • Kenya Trypanosomiasis Research Institute (KETRI) • National Museums of Kenya (NMK) • International Livestock Research Institute (ILRI) • University of Nairobi • Desert Locust Control Organisation for Eastern Africa • International Red Locust Control Organisation for Central and Southern Africa (IRLCO-CSA) • International Maize and Wheat Improvement Centre (CIMMYT) • National Beekeeping Station, Ministry of Agriculture, Kenya*

Work in progress

1. INSECTARY SERVICES

1.1 CEREAL STEMBORERS

During the review period, ARQU continued to produce and supply five species of stemborers, namely *Chilo partellus, Busseola fusca, Eldana saccharina, Sesamia calamistis* and *Chilo orichalcociliellus* at its Duduville Insectaries. Only *C. partellus* and *B. fusca* were maintained at Mbita Point Field Station (MPFS).

A major user of the borers produced was the Stemborer Biological Control Project for the production of *Cotesia flavipes*. In 1998, for instance, some 19,000 pupae and adults of the stemborers were produced at Duduville and some 23,000 borers were supplied to users at various developmental stages. *Chilo partellus* was the most frequently used stemborer (92%). The borers produced were: *S. calamistis* (5.8%), *B. fusca* (1.5%), *E. saccharina* (0.5%) and *C. orichalcociliellus* (0.3%). The most frequently used stemborer stages were eggs and neonates (69.6%), larval instars L2–L6 (28.9%) and pupae and adults (1.5%). KARI (Embu) was the largest external consumer of the borers, using eggs for the African

Maize Stress Project carried out in collaboration with CIMMYT.

A total of 81, 348 pupae of *B. fusca* and *C. partellus* of different stages were supplied from the MPFS insectaries for research needs, with *B. fusca* accounting for 84% of the supplied quantity. The Gatsby Project used adults for oviposition preference studies.

In the period under report, contamination of the semi-synthetic media continued to be a major obstacle. Incorporation of the fungicide Benlate and the broad-spectrum antibiotic powder Grabacin were evaluated for their efficacy against commonly encountered laboratory contaminants. The fungicide and antibiotic powders are now incorporated as routine dietary supplements.

1.2 LOCUSTS

Rearing of both solitaria and gregaria phases of the desert locust, *Schistocerca gregaria* continued throughout the year in support of the Locusts and Migrant Pests Programme activities. The solitary locust culture was kept at a level of 600 individually reared insects at any one time. The monthly production of the gregarious locust averaged about 2000–3000 insects, rising to meet user needs. The solitary culture is now in its 37th laboratory generation and that of the gregarious is in its 45th. Infections by the parasitic *Malamoeba* have been a major hindrance in producing quality insects. Regular treatment to 3rd instar nymphs with the antibiotic Septrin was the only control measure used during the year.

During the 2-year period, the migratory locust, *Locusta migratoria* was introduced. Currently, three different sub-species are maintained: *L. m. migratoria*, *L. m. capito* and *L. m. manilensis*. Future efforts are aimed at boosting these colonies to levels where supplies to interested users can be provided. Attempts to initiate a culture of the red locust, *Nomadacris septemfasciata* were unsuccessful, as the egg pods received from the International Red Locust Control Organisation for Central and Southern Africa did not hatch.

1.3 TSETSE

A major preoccupation of the Unit in 1998 and 1999 was the development of an improved and cost-effective tsetse mass rearing system. It was in line with the objectives of the project on sustainable management of trypanosomosis and tsetse flies through a new concept: the lethal insect technique (LIT). The improvement aimed at developing a set of techniques associated with tsetse rearing, handling, synchronisation and automated self-sexing of emerging females and males. Consequently, a simple, inexpensive and secure system was under development during the year with funds from the Austrian Development Cooperation (ADC); this 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 has begun producing *Glossina austeni* and *G. fuscipes* for use in the tsetse research and LIT-related activities.

Hitherto, the ICIPE tsetse rearing system was based on *in vivo* blood feeding on the ears of lop-eared rabbits, the flies being caged in groups of 20 to 30. Starting in late 1997, the practice was gradually replaced by the *in vitro* membrane technique developed and refined by successive IAEA tsetse rearing teams in IAEA, Siebersdorf, Austria. Major modification and improvements that were completed in 1999 are in respect of handling blood and development of new equipment. (*See report under the Tsetse Programme.*)

The main colonies maintained were *G. austeni*, *G. m. centralis* and *G. f. fuscipes* at the Duduville Insectary. The MPFS Insectary is dedicated to colonising and building a laboratory colony from wild *G. f. fuscipes*. The average female mortality over the year has ranged between 0.5 to 1.0%. The colonies have been producing about eight puparia per female. By early 1999, the Addis Ababa Insectary held 2200 adults and some 1800 puparia of *G. pallidipes*; 2600 adults and 2200 puparia of *G. m. morsitans* and 600 adults and 850 puparia of *G. tachinoides*.

1.4 MOSQUITOES

Following completion of the new insectary at Duduville dedicated to the rearing of various species of mosquitoes, further improvements were undertaken to ensure adequate environmental regulation for breeding purposes. Heaters and humidifiers were fitted in and regulated to provide temperatures of 32–34 °C and 26–28 °C for larval and adult rearing, respectively. Relative humidity was regulated at 70–80% and a reverse photoperiod was provided for adult handling and feeding.

Limited colonies of *Aedes aegyti* and *Culex quinquefasciatus* were maintained to meet specific requirements of the Molecular Biology and Biotechnology Department (MBBD) and to support a number of ARPPIS postgraduate scholars. Major activities in 1998 and 1999 involved the colonisation of *Anopheles gambiae*. Eggs and adults of *An. gambiae* were obtained from the Ifakara Health Research and Development Centre based in Tanzania in March 1998. The colony had a previous laboratory history of being reared for some 21 months. Due to the nature of the bioassay studies to be carried out, adult mosquitoes are fed on human blood meals provided by volunteers. A parallel colony of *An. gambiae* is maintained on rat-blood meals.

1.5 TICKS

A limited supply of three essential tick species were produced and supplied from colonies by the Unit for use by members of the Ticks Programme and ARPPIS scholars. Ticks were also supplied for demonstration and practicals during group training courses held in the year. The principal species maintained were *Rhipicephalus appendiculatus, R. variegatum and Amblyomma variegatum.* Limited quantities of *A. gemma, R. pulchellus, R. evertsi evertsi* and *Boophilus decoloratus* were also maintained.

2. REARING OF NATURAL ENEMIES OF THE WATER HYACINTH

Following negotiations with KARI to initiate a water hyacinth bio-control project at ICIPE in January 1998, rearing of natural enemies began at MPFS. Initially, rearing efforts were targeted at the multiplication of the naturally occurring grasshopper *Eichhornia crassipes* (Mart.) Solms. Production of the weevil *Neochetina bruchi* Hustache started in February 1998 when 500 weevils were introduced from the KARI Regional Research Centre in Kibos. A further supply of 500 weevils was obtained from Kibos in April to boost the basin production.

Large PVC Kenpoly basins (100) were purchased locally for use at MPFS. Water hyacinth plants were harvested from a site close to the station (Luanda) and used for the initial production of the weevils. Fifty weevils were introduced per basin. Subsequently, steps were taken to boost the production of the weevils in giant tanks purchased from South Africa. The first 10 tanks arrived and were installed at MPFS in late May 1998. By mid-June, the tanks were infested with the beetles, and more weevils were acquired from KARI to boost the production.

In order to strengthen the biological control approach for the water hyacinth, it will be necessary to introduce other natural enemies. Hence, negotiations were initiated during the year for the importation of further natural enemies of the water hyacinth, which include *Acigona infusella, Sameodes albiguttalis* and *Orthogalumna terebrantis.*

3. ANIMAL BREEDING SERVICES

3.1 SMALL MAMMALS BREEDING

Over the years, ARQU has bred and maintained small mammals (rabbits, rats, hamsters and mice) 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. The levels of the small mammals produced has steadily declined as demands fell due to changing research priorities and following the introduction of tsetse feeding by the membrane technique. Therefore, various consultations were held throughout 1998/1999 within the Nairobi-based R&D institutions to agree on the most cost-effective way of maintaining small animals. It was agreed that a single institution would maintain animals as a service, at cost to the others.

3.2 LARGE ANIMAL HANDLING

The large animal handling facility keep livestock (cattle and goats), used principally for feeding tsetse fly and tick colonies. Some 22 head of cattle, consisting of 16 Boran (Sahiwal), 4 Friesians and 2 Zebu were maintained. Twenty of these were used as blood sources for tsetse and two were used for various experimental protocols, mainly involving tick research. A total of 17 goats were maintained for use in experimental work involving ticks.

The cattle were maintained on a zero grazing regimen, with enough feed and water provided within the pens. The animals were fed on high-quality Rhodes grass, ranch cubes, and salt licks. Due to the management regimen, the animals were normally very healthy and required treatment only in rare cases. Bleeding of the animals was carried out during the 5-day working week, each animal being bled once a month. At any bleeding, no more than 1% of the total body weight was taken. Records of live weight, quantity of blood and PCV levels were made at each blood collection. Collection of blood was later replaced in 1999 with an arrangement to obtain fresh slaughter blood from ILRI.

4. QUARANTINE SERVICES

In order to participate effectively in the classical biological control of cereal stemborers, a need was identified to establish a laboratory facility at ICIPE where studies could be conducted on exotic organisms in a secured environment. Funding was obtained from the Government of the Netherlands to build the facility. The facility, located at the extreme eastern end of the Animal Rearing Building, was constructed on two floors, the top being for expanded mosquito rearing and the bottom as the Biologically Secure Laboratory Facility (BSLF). The BSLF has the following security measures:

- Extra thick and permanently sealed windows
- Double, well-sealed doors enclosing antechambers at the entrance and emergency exit
- Negative pressure to assure airflow into the laboratory when doors are opened
- Ventilation air from outside filtered through fine mesh filters
- UV light traps in both antechambers and in several locations in the interior of the building.
- All electrical connections to the outside sealed with silicone.

Additionally, the laboratory has a computerised temperature control system that will allow four of the rooms to be individually maintained at temperatures between 16 and 32 °C.

The completion of the BSLF in 1998 was a major achievement for ICIPE. The facility was inspected and approved for use by the Kenya Standing Technical Committee on Imports and Exports (KSTCIE) in mid-April 1998 and again in July 1999. This facility enables

ICIPE to continue its activities uninterrupted as importation of various materials can be safely handled within it. Since obtaining approval for the facility, a number of shipments have been received into the quarantine section. These include the fruit fly larval parasitoid, *Psyttalia concolar*, cocoon masses of *Cotesia flavipes* and pupae of the tachnid fly, *Sturmiopsis inferens*; a parasitoid of the stemborer, *Sesamia*.

Output

Workshops attended

Ochieng'-Odero J.P.R. and Onyango F. O. (1998) Invited to attend and present Group Training Course on 'Cereal Stemborers Management in Eastern and Southern Africa', 12–23 October 1998, ICIPE, Nairobi.

Ochieng'-Odero J.P.R., Onyango F. O. , Agan R. O. and Kimondo M.G. (1998) Invited to attend and present, during a one-day workshop organised by the Nairobi Cluster on Wednesday 18 November 1998 at ILRI. Paper presented, 'Insect and animal breeding activities at ICIPE'.

Ochieng'-Odero J.P.R. (1999) The Second International Conference on Crop Protection Chemicals, 11–13 May, 1999, Nantong City, Jiangsu Province, Peoples Republic of China. Paper presented, 'A toolbox of biological agents for pest and vector management in developing countries of Africa: Success and impediments'.

Consultancies undertaken

Under the sponsorship of the CIMMYT's African Maize Stress (AMS) Project, a Consultancy visit to the Namulonge Agriculture and Animal Research Institute (NAARI), Uganda was undertaken by J.P.R. Ochieng'-Odero between 3–5 December 1998. The Consultancy was aimed at evaluating the existing infrastructure, equipment and personnel for stemborer rearing; discussing the needs for developing the stemborer rearing facility *vis a vis* obtaining infesting material from elsewhere in the region; making recommendations on how to get the rearing unit functional by the next growing season (starting March 1999); and discussion of other issues that affect the performance of the Unit, such as funding.

Capacity building

1998 trainees

During 1998, numerous training assignments were held for various categories of trainees. ARPPIS and DRIP scholars continued to extensively rely on ARQU expertise to develop breeding methodologies that are in line with their individual projects. The Unit has continued to receive staff and students for in-house attachments from polytechnics and universities. The following spent time within the ARQU facilities on training assignments:

- Hilda Muchai from Eldoret Polytechnic, Kenya, 1 May – 31 July, 1998
- Everlyne K. Nyachae from Gusii Institute of Technology, Kenya, 15 August – 18 December, 1998
- Aymekulu Yemane from Desert Locust Control Organisation for Eastern Africa, Dire Dawa, Ethiopia 10 August–9 September, 1998
- Zaf G. Tsadik from Desert Locust Control Organisation for Eastern Africa, Addis Ababa, Ethiopia, 23 November – 12 December, 1998
- Amare Beiene from Desert Locust Control Organisation for Eastern Africa, Asmara, Eritrea, 23 November – 12 December, 1998
- Kemo Badji from DPV-Locustox, 23 November – 12 December, 1998.

1999 trainees

- Walter Omondi Odipo, from Kenya Polytechnic 1 March–30 June, 1999.
- Daniel Mutisya, from National Dryland Farming Research Centre, Katumani, 16–31 March, 1999.

Impact

Since insect rearing for the development of IPM and IVM strategies is a specialised support activity in R&D institutions, ARQU continues to receive numerous requests for training and technology transfer, especially to strengthen national agricultural research systems (NARS). The Unit is currently developing approaches aimed at consolidating best practices in animal handling, health and quality issues. It is focusing on developing updated standard rearing procedures (SRP) for all experimental arthropods and animals. Issues regarding animal health, ethical handling and human safety, especially as regards zoonosis and allergic reactions, will be clearly addressed in these procedures. Development of sound quality control regimen will also be addressed. This technological package will be a major resource in regulating R&D quality in NARS.

(See also reports on Tsetse, African Fruit Fly Initiative and the Population Ecology and Ecosystems Science Department.)

The Laboratory Management Unit (LMU)

Background, approach and objectives

The Laboratory Management Unit (LMU) was created in August 1999 to initiate and coordinate the improvement of laboratory practices at ICIPE. The overall objective of the Unit is to work with heads and leaders of departments, projects and units, staff, students and management, to improve standards of laboratory practice. The Laboratory Management Unit, based under the Behavioural and Chemical Ecology Department, sources for relevant information related to good laboratory practice, seeks for appropriate expert advice in the area and coordinates the implementation of relevant and appropriate principles of good laboratory practice at ICIPE. It is working closely with ICIPE's Physical Plants and Services (PPS) and the Health and Safety Committee.

The newly created Unit seeks to ensure that:

(a) An organisational structure exists for laboratories at ICIPE and is maintained.

(b) Quality Assurance Programmes are established and documented by LMU and all laboratories at ICIPE.

(c) Laboratories document and apply health and safety precautions according to national and international regulations.

(d) Laboratory facilities are of suitable size, construction, location, design and with proper storage space and laboratory waste disposal facilities.

(e) Laboratory apparatus/equipment is suitably located, of appropriate design and capacity and is maintained.

(f) Laboratory reagents and experimental sample materials in the laboratories are properly stored and labelled.

(g) Proper conditions are maintained for the housing, handling, care, collection and importation/exportation of animals, plants, microbial, cellular and sub-cellular systems.

(h) Each laboratory has immediately available standard operating procedures (SOPs) relevant to the activities being performed therein.

To achieve the above goals, LMU is undertaking the following activities:

- Documenting, making available assignments of responsibilities for individual laboratories at ICIPE.
- Initiating preparation and compilation of SOPs by all staff and students at the ICIPE laboratories.
- Sourcing for, compiling and making available useful information on better laboratory practices.
- Initiating the implementation of some aspects of good laboratory practices that are currently lacking in ICIPE laboratories.

The LMU will also undertake the following:

- Organise seminars, training and demonstration programmes on good laboratory practices for staff and students.
- Initiate the setting up of quality assurance programmes by ICIPE laboratories.
- Work with the PPS to re-examine the status of laboratory facilities and equipment at ICIPE.
- Establish an information centre on laboratory organisation, inventory of laboratory equipment and SOPs, including those on health, safety and precautions.

Participating scientist: *W. Lwande (Unit head)*

Assistants: *M. M. Chimtawi, L. Moreka*

Work in progress

The Laboratory Management Unit initiated the establishment of an organisational structure for laboratories at ICIPE. Several departmental and project heads and leaders have already assigned laboratory responsibilities to specific personnel.

The Laboratory Management Unit has also initiated the preparation and compilation of standard operating procedures (SOPs). The approved SOPs will be compiled into manuals that will be made available to ICIPE staff and students.

The inventory of laboratory equipment is being redone in collaboration with the Finance section. This inventory will be made available through the local area network (LAN) and will provide an opportunity for LMU to identify equipment that is no longer in use and that can be phased out.

ICIPE Publications for 1998/1999

A. ARTICLES PUBLISHED IN REFEREED JOURNALS

(The list does not include manuscripts in press and those submitted)

Basset Y., Novotny V., Miller S.E. and Springate N.D. (1998) Assessing the impact of forest disturbance on tropical invertebrates: Some comments. *Journal of Applied Ecology* 35, 461–466. 98-1439

Beier J.C., Killeen G.F. and Githure J.I. (1999) Short report: Entomologic inoculation rates and *Plasmodium falciparum* malaria prevalence in Africa. *American Journal of Tropical Medicine & Hygiene* 61, 109–113. 99-1522

Braks M. A. H., Anderson R. and Knols B. G. J. (1999) Infochemicals in mosquito host selection: Human skin microflora and *Plasmodium* parasites. *Parasitology Today* 15, 409–413.

Calgano G. E., Vera M. T., Manso F., Lux S. A., Norry F. M., Vilardi J. C. and Munyiri F. N. (1999) Courtship behaviour of wild and mass-reared Mediterranean fruit fly males (Diptera: Tephritidae) from Argentina. *Journal of Economic Entomology* 92, 373–379.

Dossa S. C., Essuman S. and Kaaya G. P. (1998) Characterization of *Amblyomma variegatum* tick saliva and salivary gland antigens inducing anti-tick immunity in Boran cattle. *International Journal of Acarology* 24, 149–157. 98-1454

Ekesi S., Maniania N.K. and Onu I. (1998) Antibiosis and antixenosis of two cowpea varieties to the legume flower thrips. *African Crop Science Journal* 6, 49–59. 98-1422

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Finance and Administration

The Finance and Administration departments include Finance, Procurement, Human Resources, Physical Plant and Services and Guest Centres. The following is principally a report of 1999 activities, with projections to 2000.

1. FINANCE DEPARTMENT

Participating staff: *C. Hill (Financial Controller, 1999 and Director, Finance & Administration from 2000), D. Njoroge*

Assistants: *A. Akumu, G. Kiondo, H. Ligedere, P. Ndiangui, E. Mbuthia, S. Mungai, N. Mwangi, P. Ngugi, C. Watuku, A. Bubusi*

Background, approach and objectives

The main functions of this department are as follows:

- Preparation of annual accounts for audit by external auditors.
- Issuing of guidelines for and preparation of annual budgets for core and restricted projects.
- Preparation of monthly management accounts for voteholders.
- Cash management and treasury issues.
- Control of petty cash imprests at Nairobi and field stations.
- Preparation and issue of cheques.
- Control of cash flow.
- Control of staff advances.
- Processing of requisitions and payment of suppliers.
- Maintenance of fixed asset registers.
- Preparation and payment of monthly payroll.
- Payment of monthly liabilities such as PAYE/NSSF/pensions/DUSCO collections.
- Preparation of financial statements to donors.
- Assistance to voteholders in controlling project funding.

1.1 ACHIEVEMENTS IN 1999

1.1.1 *Budget 1999*

A zero deficit budget for 1999 was approved by the Governing Council in June and audited by Price Waterhouse Coopers, ICIPE's external auditors. Spending for 1999 remained within budgeted limits.

1.1.2 *Review of budget and expenditure performance for 1999*

In August 1999, the ICIPE management reported in detail on the performance of actual expenditure against budget for the 7 months to July 1999 to a Special Committee of the Governing Council. Cash flows and revised estimates of the operating income and expenditure for the rest of the year were prepared. The Special Committee approved the report.

1.1.3 *Budget for 2000*

A zero-deficit budget for the fiscal year 2000 was prepared and the Executive Board approved this in October. The report on the 'Review of budget and cash flow forecast for 2000' by the external auditors was reviewed by the Governing Council Audit Committee on 9 October 1999.

1.1.4 *Implementation of the Financial Information System (FIS)*

The Finance Systems Analyst received training on Sun Systems in UK in August 1999 and has trained both finance staff and voteholders. During 2000 we intend to have installed the modules for procurement, fixed assets and automatic cheque writing and to have networked the management accounts for access by voteholders. A consultant (funded from a GBP 20,000 grant from DFID) provided further training in November.

1.1.5 *Banks*

Standard Chartered Bank confirmed the renewal of the overdraft facilities for a further 12 months to July 2000, with the eventual phasing out of the overdraft by September 2000.

1.1.6 *Cash flow*

As a result of having accurate budgets and timely management accounts, we were able to control expenditure within the budgeted limits and manage the cash flow to meet the liabilities of the Institute.

1.1.7 *Annual Accounts 1999*

Timely preparation of Annual Accounts to CGIAR standards was accomplished.

1.2 OBJECTIVES/GOALS FOR 2000

1.2.1 *Financial Accounts*

- Prepare annual accounts as soon as possible after year end.
- Maintain or reduce external audit fee.
- Ensure that accounts are CGIAR-compliant.

1.2.2 *Management Accounts*

- Ensure accounts are distributed to voteholders no later than 10th of following month.
- Improve accuracy of posting.
- Network the accounts within ICIPE.
- Ensure all postings are done daily so that accounts are updated for access by voteholders.

1.2.3 *Systems/Procedures*

- Update Financial Rules and Regulations.
- Review systems and procedures for requisitions/approval of invoices/petty cash requests, etc.
- Review all internal controls.

1.2.4 *Sun Systems*

- Review payroll module.
- Implement procurement, cheque writing and fixed assets modules.
- Review possibility for online payments to suppliers.

1.2.5 *Payroll*

- Review alternative systems.
- Electronic transfer of salaries at month end.

1.2.6 *Banking*

- Liaise regularly with Standard Chartered Bank over fees and charges.
- Expand use of facilities with on-campus bankers. (Commercial Bank of Africa)

1.3 RESOURCES REQUIRED

1.3.1 *Staff training*

- Computer skills—Excel, Word, Access, PowerPoint and E-mail.
- Maximising use of Sun Systems facilities.
- Personal development.
- Report writing.
- Professional updates.
- CGIAR report compliance.

1.3.2 *Personnel*

- Experienced trainees to cover for annual leave, sickness, etc.

1.3.3 *Software*

- Payroll system compatible with Sun Systems.

2. PROCUREMENT UNIT

Participating staff: *P. Ndirangu*

Assistants: *D. O. Owino-Olalo, P. M. Matheri, E. M. Aosa, T. O. Oloo*

Background, approach and objectives

The main functions of this Unit are as follows:

- Source and procure demanded materials and services of the right quality, quantity, delivery time and price and from right suppliers.
- Select, negotiate and evaluate quotations and place orders with competitive and reputable suppliers, while adhering to existing regulations, rules and procedures as contained in the existing Financial Regulations and Rules.
- Process orders on daily basis to ensure timely provision of goods and services to the users.
- Regularly advise end-users on status of their outstanding orders and most importantly, inform them in good time on any unavoidable delays so that they are able to adjust to planned operations accordingly.
- Liaise with the clearing and forwarding agents and the customs on imports clearing and exports forwarding at the Jomo Kenyatta International Airport (JKIA), Embakasi Inland Container Depot (ICD), General Post Office and Mombasa Port.
- Process and forward insurance claims for goods lost or damaged while in transit.
- Prepare/process both the duty and value added tax (VAT) exemptions through the Ministry of Foreign Affairs (MFA) and the Kenya Revenue Authority.
- Process exemptions on rates and rents and provision of special permits and licences through MFA and relevant ministries and departments of the Kenya Government.
- Receive and inspect ordered goods and issue them to users and to stock at central stores, satellite stores in the workshops and outside stations.
- Raise Goods Received Notes (GRNs) and issue notes and forward them to the accounts to support payments of suppliers' accounts and charges to the expense accounts.
- Prepare, marshall, package and organise dispatch of goods from the headquarters to outside stations, satellite stores and the suppliers' returns.
- Maintain stocks at established and approved levels on the agreed common user items within

the Centre and also input data of orders received, stockholding and materials movement in and out of the stores.

- Organise, prepare and coordinate tendering for the Central Tender Committee (CTC) deliberations. Also coordinate disposal of scrap, obsolete, redundant materials and equipment available at the Centre.
- Process and progress notification of arrival and departure, visas, work permits and other registration for non-Kenyan employees and visitors, through the MFA and Immigration Department.

2.1 ACHIEVEMENTS IN 1999

2.1.1 *Ordered supplies*

Despite the cashflow constraints existing, orders supposed to go through were processed and delivered in good time.

2.1.2 *Expedited duty/VAT exemptions*

Improved understanding and relationship with the MFA, expedited the flow and applied exemptions. As a result, deterioration of perishables and warehousing charges at ports of entry were considerably reduced.

2.1.3 *Item codes*

Established common user item stocks and codes ready for use during the implementation of the procurement and inventory modules. (Over the years, the Centre operated without codes for the purchased items.)

2.1.4 *Training*

Most Procurement Staff underwent computer training in the Sun System procument and inventory modules and also Excel.

2.1.5 *Immigration affairs*

Undertook immigration affairs responsibility and processing of visas, work permits and other alien registration requirements for non-Kenyan employees and visitors.

2.2 OBJECTIVES/GOALS FOR 2000

2.2.1 *Vendor rating*

Reduce to the minimum, prepayments and COD orders and enlist competent, reliable and reputable suppliers that agree with the Centre's recommended credit period and terms of payment.

2.2.2 *Relationship with key players*

Maintain and strive to improve better understanding and relationship with key players (suppliers, end-users, buying and clearing agents, MFA, immigration, customs, etc.), to expedite delivery of ordered goods and services for the Centre.

2.2.3 *Stockholding*

Review stock levels of the approved common user items and ensure that stocks held and operating stock levels are those dictated by demand and lead time. Review the existing materials manual and make necessary recommendations compatible with changes that occurred in the structured reporting lines within the Centre's management.

2.2.4 *Sun-Systems*

Implement Sun System procurement and inventory modules in the order of processing and matching goods received.

2.2.5 *Staff training*

Liaise with the Kenya Government Ministries and Departments for procurement staff to attend some of the organised training seminars and programmes in the new and upcoming procedures and requirements for the imports/exports customs clearing and forwarding.

3. HUMAN RESOURCES DEPARTMENT

Participating staff: *W. Awori (Human Resources Manager)*

Assistants: *L. Macharia, T. Kaviti, P. Kaweru*

Background, approach and objectives

The main functions are as follows:

- Carrying out all recruitment and placement formalities including advertising, interviewing, medical examinations, issuance of contracts and terminations for lawful cause, poor performance, etc.
- Documentation, dissemination, maintenance and interpretation of human resources/ administration policies and procedures with regular revisions and updates.
- Provision of staff benefits such as medical, educational allowances, pension, leave and transport allowances as stipulated in employment contracts and maintenance of records of such benefits.
- Maintenance and regular updating of all personnel records of staff, including files, databases, annual leave, home leave and travel, in line with the Centre's policies.
- Promotion and maintenance of harmonious industrial relations at the Centre through correct interpretation and implementation of sound labour practices, legislation and Centre policies.
- Ensuring that performance at all levels is regularly evaluated as a tool of fostering and reinforcing good communication and understanding between employees and their supervisors, in order to identify strengths and

weakness towards improving the Centre's standard of excellence.

- Identification of areas of development through individual training, personnel sponsorship to courses, training needs and appraisals and to advise as appropriate.

3.1 ACHIEVEMENTS IN 1999

3.1.1 *Personnel policies and procedures*

A new Personnel Manual with policies and procedures was approved by the Governing Council and effected.

3.1.2 *Performance evaluation*

New performance evaluation forms were approved and introduced and the evaluation carried out for all staff.

3.1.3 *Medical facilities*

A new provider of health services was contracted following the collapse of Medivac and the Centre's expenditure on medical benefits reduced substantially and prompt refunds to staff achieved.

3.1.4 *Insurance matters*

- More favourable and cost effective GPA cover was negotiated for all professional staff and ARPPIS.
- All outstanding GPA issues were resolved, accounts reconciled and 90% of all GPA and general insurance claims settled.
- GLA and Director's Liability Insurance cover were resolved, policy renewed and new Brokers appointed.

3.1.5 *Grading structure*

Job descriptions were introduced, concluded and a grading structure put in place for application with minor amendments to be resolved.

3.2 OBJECTIVES /GOALS FOR 2000

3.2.1 *Staff Associations*

Facilitation of the election of office bearers for the staff associations—a media for initiating communication, discussions and consultations between staff and the management.

3.2.2 *Performance evaluation*

Finalise all outstanding issues on evaluation by implementing promotions, merit awards and annual increments as soon as possible. Improve on mechanism (forms) for future regular evaluations.

3.2.3 *Personnel database*

Improve, broaden and update personnel database by inclusion of organograms with a view to making them more comprehensive and accessible to voteholders/end users.

3.2.4 *Personnel policies and procedures*

Collate views on personnel policies and procedures, initiate discussion on any proposed changes, revisions, updates and inclusions and obtain approval from the appropriate organs for application.

3.2.5 *Payroll management*

Finalise a timetable for the takeover of the payroll management and some of the related personnel functions.

3.2.6 *Staff training and development*

Identify the Centre's training needs and ways and means of funding appropriate courses, attachments, and study tours, geared towards improvement of staff development.

3.2.7 *Insurance and pension matters*

Initiate discussions, consultations with insurance providers, pension managers/administrators (Brokers, ICEA and Zurich), regarding the proposed changes in the RBA legislation in order to secure improvements in the existing GPA, GLA cover and pension schemes.

3.2.8 *Medical facilities*

Initiate improvements in the current medical service provided to staff at Mbita and Duduville, Kasarani with a view to opening up the two clinics.

3.2.9 *Secretarial functions*

Re-engineer the secretarial functions at the Centre so that there is optimum utilisation of this resource for the good of the majority.

3.2.10 *Resources*

Ensure the Department has all the resources it requires in terms of office space, personnel and equipment as soon as possible.

3.3 RESOURCES REQUIRED

3.3.1 *Personnel*

- An experienced Human Resources Training Specialist to handle the training, staff development and succession planning, to be recruited.
- Alternatively, an experienced Secretary with institutional knowledge of the Centre to handle training functions and succession planning as an assistant.
- Accept trainees on attachment for 1–3 months to assist in filing.

3.3.2 *Staff training*

Computer skills to be improved, i.e. Excel, Word and PowerPoint. Courses geared at personal improvement, such as presentation skills, etc.

3.3.3 *Computer software*

To shop around for suitable HR software such as Peodesy, Payroll or any that is compatible with Sun Systems.

3.3.4 *Office space*

Ensure office location is organised for easy flow of work, accessibility, and record keeping.

4. PHYSICAL PLANT AND SERVICES (PPS)

Participating staff: *F. Lustenberger, A. Razak*

Assistants: *N. Patroba, D. Mutua, C. Muthoni, J. Mutua, J. Nyongesa, D. Kakuku, A. Wanyama, J. Waweru, S. Khaemba, W. Omino, P. Otieno, R. Mutunga, D. Wanjara, T. Ngutu, S. Karanja, E. Oguok, J. Oluk, D. Maranga, R. Muiruri, E. Umar, D. Mwachoni, A. Macharia, W. Warui, H. Njachi, A. Kirimba, J. Warania, J. Mweu, J. Makumi, E. Otieno, D. Mulwa, P. Apodo, G. Omondi, L. Nzomo, N. Njuguna*

The main functions are:

(a) Operation and maintenance of a fleet of 80 motor vehicles, consisting of: 38 units of saloon cars for IPS staff and restricted projects; 35 units of 4WD field vehicles such as Land Rovers, Isuzu Troopers and pick up trucks; 10 units of motorcycles; 1 unit of 5-tonne lorry; 1 unit of a 20 seater bus.

(b) Building maintenance
- Electrical (appliances and installations)
- Plumbing
- Carpentry
- Masonry.

(c) Maintenance and repairs of existing laboratory and office equipment.

(d) Production and fabrication of new traps for scientific fieldwork, etc. made of wood, metal and Perspex and office equipment, such as furniture and shelves, made of wood and metal.

(e) Physical and administrative maintenance of institute-owned land, residential and commercial properties, in addition to Duduville Headquarters, Mbita Point, Muhaka and Nguruman:
- ICIPE House, Arboretum Drive
- ICIPE House, Riverside Drive
- Various parcels of land without permanent structures and buildings.

(a) Providing adequate security to institute properties and staff.

(b) Responsible for institutional safety of workplaces and infrastructures.

(c) Supervision of day-to-day activities of contracted security force.

(d) Supervision of outsourced work of landscaping and grounds maintenance at Duduville Headquarters.

(e) Liaison office for administrative and technical cooperation between ICIPE and USAID as interim tenant.

4.1 ACHIEVEMENTS IN 1999

4.1.1 *Transport*

- Disposed of old and obsolete vehicles. The following were advertised and sold: 11 units of Hyundai saloon cars were disposed. 14 units of 4-WD field vehicles were disposed.
- Abolished airport transfers by contracting Express Travel. Positions of 2 pool drivers retrenched.
- Night driver duties outsourced to contract security company. Position of 1 pool driver retrenched.
- Advanced stage of agreement with USAID for joint collaboration of vehicle workshop and fuel station facilities. Expected income for service rendered approx. US$ 10, 000 p.a.
- Established a working relationship with ICRAF for common services: Negotiating on vehicle workshop joint operation.

4.1.2 *Workshop*

- Re-allocation of ICIPE administrative offices from former administration building into R&D building. Workshop was actively involved in re-designing and converting of labour space into office space.
- Fabricating of partitioning screens and subdividing of large offices into smaller units.
- Switching locations of library and conference facility. Renovating and improving of former library building into conference facility.

4.2 OBJECTIVES/GOALS FOR 2000

The overall goal is to perform better as a unit and stay within the budgetary limits.

Specific objectives are as follows:

4.2.1 *General*

To implement a schedule for general staff training in the relevant areas and personal development within PPS. We are operating with absolute minimum staff and a better understanding of principal management of time and resources, will improve the overall output of all sections within the department.

4.2.2 *Transport*

- To implement a new policy for assigned vehicles (service cars)

- To finalise a vehicle replacement policy and make recommendations to the management for 2001 budget
- To adopt a computerised system for all transport related expenses and part movements (procurement module of Sun System?).

4.2.3 *Workshop*

- A new generator unit will be installed and we need to redesign some consumer circuits. The new unit will be capable of supporting the ICIPE operation at Duduville.
- The existing generator will be re-allocated to the guest centre and an upgrading of existing wiring is necessary to accommodate a stand-by generator.
- To implement a strict maintenance schedule for the whole infrastructure at Duduville.
- To update all available information on change of designs and layouts after the re-allocation exercise.
- To keep all infrastructure in all locations up-to-date. Mbita and Nguruman are on minimum budget and we cannot implement major changes or incur heavy expenses.

4.2.4 *Security*

- To implement a security communication network with all strategic position within and from outside Duduville. This will include some two way radio sets for the pool vehicles.

4.3 RESOURCES REQUIRED

4.3.1 *Personnel*

- Fleet Manager (already advertised).
- Security Supervisor (already advertised).
- Attachment students and trainees.

4.3.2 *Staff training*

- Computer skills in Excel/Word and e-mail.
- Personal development.
- Reporting.
- Professional updates.

4.3.3 *Equipment/software*

- 2–3 additional computer stations.
- Two-way radios for the security and transport pool network.
- Maintenance Management Software.
- Fleet Management Software.

5. ICIPE'S INTERNATIONAL GUEST CENTRE SYSTEM (IGCS)

Participating staff: *K. Iten*

Assistants: *S. M. Aritho, G. M. Ongoncho, S. O. Ojwang', N. Mwendwa, P. Mungithya, D. O. Otieng, P. A. Omollo, P. A. Ocholla, T. A. Ogongo, J. A. Awich, N. Ifire, J. N. Kipserem, C. O. Nyagaya, L. M. Mulae, A. Lweya, J. K. Kayaa, G. Gichuru, M. K. Wepukhulu, B. M. Lihanda, K. O. Kwemoi, M. Etuku, M. M. Wanjala, R. M. Wekesa, D. Nyaribo, S. Mutta, M. Nalo, R. K. Manyara, F. N. Omutsembi, W. M. Serenyi, J. O. Mukubi, H. A. Ouma, J. Adisa, E. Ondeyo, R. M. Masaka, A. W. Karanja, E. J. Tirop, S. A. Abongo, P. Siva, L. W. Mwaura, G. S. K. Kariuki*

Funding: *The IGCS has moved from being a donor-supported field accommodation to a financially independent guest house operation.*

The Nairobi and Mbita Guest Centres provide quality services at competitive prices to local and international guests of ICIPE and other organisations. The Centres will operate independently without ICIPE's financial support.

5.1 DUDUVILLE INTERNATIONAL GUEST CENTRE, NAIROBI (DIGC)

The following is a summary of achievements covering the period 1 January 1999 to 31 December 1999.

5.1.1 *Staff*

- All staff members have changed in a positive way (attitude and commitment towards ICIPE/DIGC).
- Quality of service and meals has improved tremendously through an improved performance by our staff.
- The staff undertakes additional work without hesitation.
- All departments within DIGC practise Teamwork/team spirit.
- The staff is interested in the performance of DIGC.
- The daily short meetings in the morning among the supervisors (kitchen/service/housekeeping, accounting/front desk) have assisted in raising the team spirit to an excellent level.
- The staff adapted well to the higher demands with regard to quality standards and guest relations.

5.1.2 *Training*

- DIGC received some 25 students on attachment during 1999. They were sent by various training institutions, mainly from Nairobi.
- The feedback from the students is very positive. They often come back after their examinations to express their positive attitude for the time they spent here.
- Staff are trained by the DIGC Manager on a daily basis.

5.1.3 *Staff performance and workload*

The staff at DIGC is basically the same in number as in 1996. However, their output over the past years has increased by at least fourfold.

5.1.4 *Staff performance and revenue*

The input of our staff has contributed dramatically to the improved quality service of our Guest Centre. The feedback from our customers is very positive and consequently reflects in our improved financial performance in the Guest Centre.

5.1.5 *Meal quality and variety*

- The meal quality in the restaurant has improved and can be compared with first class hotels in Kenya. Only specialised restaurants (Indian, Thai and Japanese) have an advantage with their specialised varieties over DIGC.
- Variety of meals has improved (from 1 to 4 choices on the daily buffet for hot meals, salads from 1 to 4 choices and desserts from 1 to 2 choices).
- Our strawberry tartlets are definitely still the best in town, and doughnuts are also very popular. A variety of 4 different types of sweet snacks and cakes, sandwiches and samosas are offered on a daily basis.
- DIGC staff can now handle cocktails and special buffet functions for up to 600 guests.

5.1.6 *Coffee shop*

The coffee shop revenues have increased from approximately Kshs 55,000 to Kshs 110,000 per month. The upward trend points to an even better performance during the course of the year 2000/2001.

5.1.7 *Financial performance*

- Compared to 1998 we were again able to increase the sales considerably during 1999 from Kshs 20,212,000 to a new record of Kshs 22,741,000, an increase of Kshs 2,500,000.
- The operational cost in 1999 was underestimated due to the dramatic devaluation of the Kenya shilling. The shilling lost more than 20% at times with an exchange rate varying from Kshs 59–75 to the US Dollar. Consequently, our operational costs increased by approximately 20%.
- The electricity costs increased by 25%.
- DIGC has paid for the renovation of the Mwanzo House which in 1998 was US$ 3600 and in 1999 US$ 10,800.
- Seminars were lost to the amount of US$ 17,000 due to circumstances beyond our immediate control (loss of seminar facility). Another US$ 16,000 was relinquished to other hotels because of lack of accomodation at DIGC with 30 bedrooms only.

5.1.8 *USAID—A new partner and customer*

USAID:

- Moved into ICIPE on 1 September 1999.
- Invested in the Guest Centre approximately US$ 135,000 for the enlargement of the kitchen, restaurant and food display area.
- Also provided some new equipment like tables, shelves and refrigerators for the cold kitchen.
- As a new customer, started to frequent our Restaurant on a regular basis. The feedback regarding our services is positive.
- Brings us an additional cash revenue of around US$ 200 per working day.

5.1.9 *Opening of the new facilities and introduction of new meals*

- The kitchen will start to implement new varieties of food as soon as the construction work is finished. The emphasis will be on light and healthy meals (salads, cold meals). Freshly grilled T-bone steaks, hamburgers, seafood and Italian pasta dishes will be gradually introduced on an 'A la carte' basis. The salad bar will offer a wider choice.

5.2 MBITA GUEST HOUSE

The following is a summary of achievements covering the period 1 January 1999 to 31 December 1999.

5.2.1 *Staff*

- In November 1999, we implemented a staff restructuring programme which is generating excellent results.
- The introduction of a new Guesthouse Manager has had a positive effect on the overall quality of services provided at Mbita.
- The quality of our meals has improved tremendously with the new Chef.
- The new Housekeeper also assists at the reception.
- The new Receptionist with accounting and computer background will be an asset for operation in Mbita.
- The staff has adapted well to the new leadership and the higher demands with regards to quality standards and guest relations.

5.2.2 *Training*

- Mbita received a request from Kisumu to train 2 students on attachment.
- Our regular staff is trained on the job, but also with visits to DIGC, Nairobi.

5.2.3 *Performance and revenues*

The input of our staff has contributed dramatically to the improved quality service of our Guest Centre. The feedback from our customers is very positive and consequently reflects in our improved financial performance at the Guesthouse.

5.2.4 *Financial performance*

Compared to 1998 we were able to increase the profit considerably during 1999 from US$ 3000 to US$ 10,000.

5.3 NGURUMAN—ICIPE'S FIELD STATION NEAR MAGADI

- The field station is located some 170 km from Nairobi.
- The station is presently underutilised and also understaffed.
- Middle- to long-term planning is difficult due to lack of early bookings.
- Nguruman station has tourist potential and could be operated without loss, provided a minimum maintenance and guesthouse service is provided.

5.4 RESOURCES

To serve well at DIGC, Mbita Guesthouse and Nguruman the following are needed:

- A 9-seater air-conditioned minibus with easy removable passenger seats (for transport of goods to/from Nairobi to Mbita/Nguruman–Nairobi/ staff/guests).
- A Hyundai Accent GLS for daily shopping
- A pick-up in Mbita, which can reach Ungoya, and for daily shopping in Mbita

Financial Report—1999

1999 SCHEDULE OF GRANTS (US$ '000)

DONOR	Unrestricted	Restricted	Total 1999 Income
African Development Bank (ADB)		236	236
Australia Centre for International Agricultural Research (ACIAR)		4	4
Austria, Government of		914	914
CIAT		90	90
Danish International Development Agency (DANIDA)	712	51	763
Department for International Development (DFID), UK		25	25
Directorate for NGO, International Education and Research Programme (DPO) of the Netherlands Government		1481	1481
Dupont		2	2
European Union		40	40
FPEAK/Vitaress/Kenya Flower Council		7	7
Finland, Government of		177	177
Gatsby Charitable Foundation		247	247
German Academic Exchange Service (DAAD)		174	174
German Federal Ministry of Economic Co-operation (BMZ)		232	232
Global Biodiversity Institute		19	19
ICIPE/IFAD/ILRI Collaborative Project		131	131
ICRISAT		4	4
ICSC—World Laboratory		22	22
Institute of Arable Crops Research		1	1
International Development Research Centre (IDRC)		5	5
International Fund for Agricultural Development (IFAD)		1299	1299
International Institute of Tropical Agriculture (IITA)		2	2
International Potato Centre		1	1
International Water Management Institute		11	11
Japan International Research Centre for Agricultural Sciences (JIRCAS)		19	19
Kenya, Government of	7		7
NIH, USA		108	108
Norway, Government of	513		513
OPEC Fund for International Development		6	6
Packard Foundation		19	19
Rockefeller Foundation		128	128
Swedish International Development Agency (SIDA)	986		986
Swedish University		39	39
Switzerland, Govt. of (Special Grant)	800	105	905
Texas A&M Research Foundation		19	19
UNDP		1	1
UNEP		19	19
United States Agency for International Development (USAID)		156	156
University of Hawaii/Florida, USA		30	30
World Health Organisation (WHO)		105	105
Other donors		1	1
Total operating grants	**3019**	**5930**	**8949**

STATEMENT OF FINANCIAL POSITION AT 31 DECEMBER, 1999

	1999 US$ '000	1998 US$ '000
FIXED ASSETS		
Property	236	245
Plant and Equipment	167	222
Total Fixed Assets	**403**	**467**
CURRENT ASSETS		
Consumable Stores	66	61
Grants Receivable	935	837
Debtors and Prepayments	237	490
Bank Balances and Cash	352	567
Total Current Assets	**1590**	**1955**
CURRENT LIABILITIES		
Bank Overdraft (Secured)	125	1339
Loan Payable within 1 year		42
Creditors and Accruals	1169	1694
Unexpended Operating Grants	2940	2055
Total Current Liabilities	**4234**	**5130**
NET CURRENT LIABILITIES	**-2644**	**-3175**
TOTAL ASSETS LESS CURRENT LIABILITIES	**-2241**	**-2708**
FINANCED BY:		
Reserves	-2923	-3400
Provision of Staff Separation	652	652
Deferred Financing	30	40
	-2241	**-2708**

STATEMENT OF ACTIVITIES FOR THE YEAR ENDED 31 DECEMBER, 1999

	1999 US$ '000	1998 US$ '000
INCOME		
Unrestricted core grants	3019	3144
Restricted project grants	5930	6489
Other income	439	184
Total Income	**9388**	**9817**
EXPENDITURE		
Centre Management	772	925
Research and NRES Strengthening	6814	7724
International Cooperation	179	344
Administration and Finance	901	950
Other Support Units	633	703
Utilities	514	665
Separation and Retrenchment		704
Overhead Recovery	-793	-779
Write off Donor funds not received		679
Total Project and Support Costs	**9020**	**11,915**
Purchase of fixed assets	137	578
Total Expenditure	**9157**	**12,493**
Surplus/(deficit) before extraodinary item	231	-2676
Extraordinary item		-330
SURPLUS/(DEFICIT) FOR THE YEAR	**231**	**-3006**

ICIPE Governing Council (1998–1999)

1. 1998 ICIPE GOVERNING COUNCIL

Prof. Norman Lindsay Innes
Chairman GC/Chairman, Executive Board
Agricultural Research Consultant and formerly, Deputy Director, Scottish Crop Protection Institute (UK)

Prof. Dr Christopher Chetsanga
Vice Chairman GC
Director General, Scientific and Industrial Research and Development Centre (SIRDC) (Zimbabwe)

Dr Barbara Ekbom
Chairperson, Programme Committee
Swedish University of Agricultural Sciences (Sweden)

Dr Deborah Merrill-Sands
Chairperson, Nominating Committee
Visiting Fellow
Simmons Institute for Leadership and Change, Simmons College (USA)

Prof. Dr Niklaus A. Weiss
Chairman, Audit Committee
Swiss Tropical Institute (Switzerland)

Dr Walter Masiga
Director, InterAfrican Bureau for Animal Resources
Organisation of African Unity (OAU) (Kenya)

Prof. Hans Wilps
Gesellshaft für Technische Zusammenarbeit (GTZ) (Federal Republic of Germany)

Dr Paul K. arap Konuche
Director, Kenya Forestry Research Institute (KEFRI) (Kenya)

Dr Dely Gapasin
The World Bank (Philippines)

Dr Jorge Soberon
Secreatrio Ejectivo
CONABIO (Mexico)

Dr Gabrielle Persley
Ausbiotech Alliance (Australia)

Dr Hans Herren
Ex Officio/Director General, ICIPE (Switzerland)

2. 1999 ICIPE GOVERNING COUNCIL

Prof. Norman Lindsay Innes
Chairman GC/Chairman, Executive Board
Agricultural Research Consultant and formerly, Deputy Director, Scottish Crop Protection Institute (UK)

Dr Dunstan Spencer
Vice Chairman GC
Dunstan Spencer and Associates (Sierra Leone)

Dr Barbara Ekbom
Chairperson, Programme Committee
Swedish University of Agricultural Sciences (Sweden)

Dr Deborah Merrill-Sands
Chairperson, Nominating Committee
Visiting Fellow
Simmons Institute for Leadership and Change, Simmons College (USA)

Prof. Dr Niklaus A. Weiss
Chairman, Audit Committee
Swiss Tropical Institute (Switzerland)

Prof. Dr Christopher Chetsanga
Director General
Scientific & Industrial Research & Development Centre (SIRDC), (Zimbabwe)

Dr Walter Masiga
Director, InterAfrican Bureau for Animal Resources
Organisation of African Unity (OAU) (Kenya)

Prof. Hans Wilps
Gesellshaft für Technische Zusammenarbeit (GTZ) (Federal Republic of Germany)

Dr Paul K. arap Konuche
Director, Kenya Forestry Research Institute (KEFRI) (Kenya)

Dr Nancy Andrews
President, Low Income Housing Fund (USA)

Dr Dely Gapasin
The World Bank (Philippines)

Dr Jorge Soberon
Secreatrio Ejectivo
CONABIO (Mexico)

Dr Gabrielle Persley
Ausbiotech Alliance (Australia)

Dr Hans Herren
Ex Officio/Director General, ICIPE (Switzerland)

Seminars at ICIPE

1. 1998 SEMINARS

Prof. Harold Wilson
Ohio State University, USA
Topic: First year corn rootworm in Ohio—A case of resistance to a cultural pest management practice

Dr Ron Stinner
North Carolina State University, USA
Topic: Entomology and electronic information sharing

Dr Thomas Randolph
WARDA
Topic: The role of social science in IARCs: Policy research in WARDA

Dr Melaku Girma
ICIPE
Topic: Odour-baited development for riverine tsetse

Dr Barbara Frei
ICIPE
Topic: A search for drugs from plants used in traditional medicine

Dr Lisbeth Riis
ICIPE
Topic: Quantification of whitefly immigration and emigration in field crops

Dr Jocelyn Meyerink
Wageningen Agricultural University,
The Netherlands
Topic: Olfactory sensitivities of malaria mosquitoes to human sweat and other host-odour related compounds

Mr Jason Kap-Kirwok
ICIPE
Topic: Readership analysis in proposal writing

Dr Ana Milena Varela
ICIPE
Topic: Environmental-friendly production of flowers: The prospects for 'green flowers'

Dr Adedapo Odulaja
ICIPE
Topic: The trap-elusive tsetse: How many are they?

Dr Christiane Weigner
ICIPE
Topic: Review processes of donors

Dr Adiel Nkonge Mbabu
KARI
Topic: Institutionalising socioeconomics research in the national agricultural research systems (NARS): The case of the Kenya Agricultural Research Institute (KARI)

Dr Hans G. P. Jensen
REPOSA, Costa Rica
Topic: An interdisciplinary methodology for sustainable land use exploration at the regional level: Application to Costa Rica

Prof. Xie Tianjian
Wuhan, China
Topic: *B.t.* commercialisation and application in China

Dr Markus Knapp
ICIPE
Topic: The Red Spider Mite Project at ICIPE

Dr R. C. Saxena
ICIPE
Topic: The incredible neem

Mr Michael Davis
Topic: Recharge systems for international organisations

Mr Christopher Hill
UK
Topic: Identify strengths and weaknesses at ICIPE and how you would manage the process for strengthening the system.

2. 1999 SEMINARS

Dr Matthias Griesbach
Institute of Plant Diseases and Plant Protection, Department of Soil Ecosystems
Topic: Biological control of banana weevil with fungal endophytes

Dr Remy Pasquet
Research Scientist,
MBBD Department, ICIPE
Topic: Wild cowpea gene pool organisation and systematics

Mr Tim Robinson
Head, Information Technology, ICIPE
Topic: An overview of information technology at ICIPE

Dr Slawomir Lux
Senior Research Scientist, ICIPE
Topic: Development and validation of the trap-treat-release (TTR) concept for banana weevil control

Dr Morton Satin
Chief, Agroindustry and Postharvest Management Service, FAO, Rome, Italy
Topic: The new FAO INPho programme

Dr Barbara Frei
Postdoctoral Fellow,
BCED and Malaria, Vectors Programme, ICIPE
Topic: An ethnobotanical-phytochemical search for mosquito repellent African plants to reduce malaria transmission in rural communities

Prof. Uriel Kitron
Division of Epidemiology and Preventive Medicine, University of Illinois, Urbana-Champaign, USA
Topic: Spatial analysis of geo-referenced data for vector-borne diseases+

Prof. Motoyoshi Mogi
Division of Parasitology,
Saga Medical School, Japan
Topic: Mosquito and mosquito-borne disease dynamics in rice agroecosystems: A case of Japanese encephalitis (JE)+

Dr Allan Saul
Queensland Institute of Medical Research,
Brisbane, Australia
Topic: Modelling the role of alternate blood meal sources in vector-borne disease transmission+

Prof. Louise Vet
Laboratory for Entomology,
Wageningen Agricultural University,
Wageningen, The Netherlands
Topic: Do parasitoids please plants? Ecological and evolutionary consequences of plant-carnivore interactions

Dr Richard Stouthamer
Laboratory for Entomology,
Wageningen Agricultural University,
Wageningen, The Netherlands
Topic: Sex ratio distortion in Hymenoptera: Parasitic chromosomes versus manipulating microbes

Dr Billy Annan
Senior Research Biologist,
E. I. Du Pont de Nemours &
Company Agricultural Enterprise,
R&D Newark, Delaware, USA
Topic: Emerging trends in the discovery of crop protection products, and the importance of biodiversity in sustainable agricultural production

Dr Itamar Glazer
The Volcani Centre, Israel
Topic: Entomopathogenic nematodes: Applications and research

Dr Bill Overholt
Principal Scientist, PEESD, ICIPE
Topic: An overview of the introduction and establishment of *Cotesia flavipes* in Africa

Dr Pim Martens
International Centre for Integrative Studies (ICIS), Maastricht University,
The Netherlands
Topic: Global climate change and vector-borne diseases

Dr Willem Takken
Laboratory for Entomology,
Wageningen Agricultural University,
Wageningen, The Netherlands
Topic: Effects of changes in eco-climatic zones on malaria vectors and malaria risk in the Amazon region

Dr Martijn Bezemer
Postdoctoral Fellow, PEESD, ICIPE
Topic: Impacts of global change on model terrestrial ecosystems

Mr Ernst-Jan Scholte
MSc student, Wageningen Agricultural University,
The Netherlands
Topic: Studies on oviposition behaviour, repellents and biological control methods for the African malaria vector *Anopheles gambiae* at Mbita Point

Dr Michael Brownbridge
University of Vermont, USA
Topic: Commercial biopesticides in North America

Dr Martijn Bezemer
Postdoctoral Fellow, PEESD, ICIPE
Topic: Insect–plant interactions in changing environments

Dr Adele Ngi-Song
Postdoctoral Fellow, PEESD, ICIPE
Topic: The African Association of Insect Scientists (AAIS): An overview

Mr Levi Wekesa
ARPPIS student, Biodiversity Programme, ICIPE
Topic: Assessing the impact of fragmentation in coastal forests: Case study on termites

Dr Nikolaus Zenz
Postdoctoral Fellow, PEESD, ICIPE
Topic: Effect of mulch application in combination with NPK fertiliser in cowpea (*Vigna unguiculata* (L.) Walp.; Leguminosae) on two key pests, *Maruca vitrata* F. (Lepidoptera: Pyralidae) and *Megalurothrips sjostedti* Trybom (Thysanoptera: Thripidae), and their respective parasitoids—Overview of PhD thesis

Mr Jason Kap-Kirwok
Chief Strategic Planning,
COMESA, Lusaka, Zambia
Topic: Regional integration within a globalising world economy: Opportunities for ICIPE and COMESA

Dr Johann Baumgärtner
Head, PEESD, ICIPE
Topic: Population models: Bases for the design of control, utilisation and conservation strategies

Prof. John A. Pickett
Head, Biological and Ecological
Chemistry Department
IACR-Rothamsted, UK
Topic: New opportunities for exploiting chemical ecology in biocontrol of insect pests

Mr Willis Awori
National Bank of Kenya
Topic: Processes for implementing an evaluation system while considering the compensation factors for an institution that is facing severe financial problems

Dr Andreas Brune
University of Constanz
Topic: Termite guts: World's smallest bioreactors

Dr Alan Schroeder
USAID/AFR/SD/CMR,
Research, Education
Topic: Strategies and policies for improved emergency pest prevention and management in Africa: Education, research and environmental protection

Prof. Rumei Xu,
College of Biological Science,
Normal University of Beijing
Topic: Let's chat about whiteflies

Dr Kotaro Konno
National Institute of Sericulture and
Entomological Science
(Ministry of Agriculture,
Fishery and Forestry, Tsukuba, Japan),
Laboratory of Silkworm Artificial Diet
Topic: Glycine in digestive juice: A strategy of herbivorous insects against chemical defence of host plants

Mr Sileshi G. Weldesemayat
ARPPIS student
Topic: Some aspects of the biology and ecology of the defoliator beetle *Mesoplatys ochroptera* on *Sesbania sesban* in agroforestry systems in southern Africa

Dr Bart Knols
ICIPE
Topic: Exploiting malaria vector ecology and behaviour in order to optimise integrated vector management for malaria control in Africa

Dr Henry Mwambi
Nairobi University
Topic: Ticks and tick-borne diseases: A vector–host interaction model

Mr Chris Hill
ICIPE
Topic: Budget 2000

Staff List—1998 Personnel

MANAGEMENT AND GENERAL OPERATIONS

OFFICE OF THE DIRECTOR GENERAL

Hans Rudolf Herren, *Director General*
Christiane Dorothea Weigner, *Personal Assistant to DG*
Dinah Wairimu Njoroge, *Internal Auditor*
Remedios Dela Paz Ortega, *Public Relations Officer*
Purity Ngima Kaweru, *Executive Secretary*
Julius Kuria Kamau, *Assistant Internal Auditor*
Titus Musyoki Kaviti, *Clerical Assistant*
Francis Omondi Ujiji, *Driver*

OFFICE OF THE DEPUTY DIRECTOR GENERAL

Akke Jitske Van Der Zijpp, *DDG Research*
Susan Mukami Kagondu, *Executive Assistant*
Susan Kabui Iruku, *Executive Assistant*

ADMINISTRATION

Tina Marie Kuklenski, *Director of Administration*
John Mwaiwe Mwendar, *Personnel Officer (C&B)*
Emily Adhiambo Alwala, *Personnel Officer (R&T)*
Simprose Oyola Oyugi, *Telephonist/Receptionist*
Susan Wanjiku Muna, *Telephonist/Receptionist*
Elijah Asami, *Mail Clerk*
Syprine Amolo Abongo, *Office Assistant*
Fredrick Chichi Makhulo, *Office Assistant*
Simon Mutta Mkamba, *Office Attendant*
Wilfred Omondi Adhiambo, *Office Attendant*
Esinas Jeptum Tirop, *Office Attendant*
George S.K. Kariuki, *Office Attendant*
Benard Mita Okech, *Office Attendant*
Elias Ondeyo, *Office Attendant*
Lucy Wanjiru Mwaura, *Office Attendant*
Phoebe Siva, *Office Attendant*
Margaret Alunga Ochanda, *Office Attendant*
Richard Musyoki Masaka, *Office Attendant*
Fredrick Onyango Athula, *Office Attendant*
Anne Wanjiku Karanja, *Office Attendant*
Edwin Henry Otieno, *Security Guard*
Dickson Mulwa Mwilu, *Security Guard*
Peter Owino Apodo, *Security Guard*
Geoffrey Mureu Kinyuah, *Security Guard*
Gilbert Ouma Omondi, *Security Guard*
Lawrence Masila Nzomo, *Security Guard*
Nelson Njuguna Munyinyi, *Security Guard*

Information Technology Unit

Timothy Brett Robinson, *Information Systems Manager*
Darisi Murali, *Senior EDP Specialist*
Mohammed D. Mungai Gathoga, *Computer Technologist*

Dudu Travel Agency

Fraser Jackson Utanje, *Travel Manager*
Peris Wambui Njenga, *Travel Assistant*

FINANCE

Accounting

Khrisnahsamy Appadu, *Head of Financial Accounting*
Gitonga Jasper Rugendo, *Treasury Accountant*
Dominic Francis Sifuna, *Project Accountant*
Serah Njeri Mungai, *Project Accountant*
Patrick Ngahu Ndiangui, *Project Accountant*
George Muchuku Kiondo, *Assistant Project Accountant*
Cyrus Kimani Watuku, *Systems Analyst*
Peter Ossmy Ngugi, *Assistant Accountant*
Henry Victor Ligedere, *Assistant Accountant*
Eustace Njuma Mbuthia, *Accounts Assistant*
Nancy Wangui Mwangi, *Accounts Assistant*
Agripina Valerie N. Ramoya, *Executive Assistant*
Alphonse Bubusi, *Mail Clerk*
Anthony Akumu Abogi, *Field Station Accountant (MPFS)*
Peter Nyakeri Onsongo, *Accounts Assistant (MPFS)*
John Muhia Kibera, *Accounts Assistant (MPFS)*

Procurement

Peter Dickson Kamau Ndirangu, *Procurement Supervisor*
Elias Maikuri Aosa, *Purchasing Officer*
Tobias Odongo Oloo, *Purchasing Officer*
Daniel Oduor Owino Olalo, *Storekeeper*
Patrick Matheri Munyui, *Procurement Clerk*
John Odongo Gombe, *Purchasing Officer (MPFS)*

PHYSICAL PLANT AND SERVICES UNIT

Administrative Services

Alfred Lustenberger, *Head*
Catherine M. Muthoni Macharia, *Data Input Clerk*
Daudi Mutua Muumbi, *Storekeeper*
Susy Nekesa Khaemba, *Assistant Storekeeper*
Julius Otieno Okeyo, *Electrician*
John Musyoka Mutua, *Electrician*

Donald Mwachoni Nyambu, *Mechanic*
Anastasia Kabura Macharia, *Mechanic*
Walter Kariuki Warui, *Mechanic*
Joseph Raphael Makumi, *Driver/Mechanic*
John Pancras Nyongesa, *Artisan/Carpenter*
Joseph Odondi Oluk, *Electrician (MPFS)*

TRANSPORT SERVICES
David Marangu Mbui Kimotho, *Transport Assistant*
Dick Mutisya Kakuku, *Artisan/Metal Plastic Fabricator*
Richard Muiruri Mugi, *Artisan Assistant*
Umar Ibrahim, *Artisan Assistant*
Peter Njoroge Mahogo, *Driver*
Henry Njoroge Njachi, *Driver*
Alex Owino Kirimba, *Driver*
John Mweu Mutunga, *Driver*
Joseph Mucheru Gachugu, *Driver*
Benard Mulwa Musee, *Driver*
Joseph Mututa Mwarania, *Driver*
Kennedy Otieno Onyango, *Driver (MPFS)*

WORKSHOPS AND LABORATORY SERVICES
Abdul Razaq Shaffy Abdalla, *Workshop Manager*
Patroba Nyachieo, *Senior Artisan*
Jacob Otieno Omondi, *Artisan/Carpentar*
Andrew Makheti Wanyama, *Artisan/Plumber*
Tony Linus Ngutu, *Mechanic (MPFS)*
Patrick Edward Otieno, *Artisan/Panel Beater (MPFS)*
Robert Mutunga Nzioka, *Artisan Assistant (MPFS)*
Dominic Owinyo Wanjara, *Artisan Assistant (MPFS)*
Eliud Oguok Ndiao, *Artisan Assistant (MPFS)*
Samwel Mwaura Karanja, *Generator Operator (MPFS)*

INTERNATIONAL GUEST CENTRE SYSTEM

DUDUVILLE INTERNATIONAL GUEST CENTRE
Kurt Benjamin Iten, *General Manager - Guest Centres*
Simon Maitethia Aritho, *Assistant Accountant*
George Makini Ongoncho, *Accounts Assistant*
Alphonse Lweya, *Head Chef*
George Gichuru, *Chef*
Petronila Achieng Ocholla, *Housekeeper*
Ruth Molly Wekesa, *Telephonist/Receptionist*
Tabitha Akeyo Ogongo, *Room Stewardess*
Lawrence Munyasia Mulae, *Room Steward*
Silas Owiti Ojwang', *Kitchen Assistant*
Joseph Omari Mukhobi, *Kitchen Assistant*
Keneth Kwemoi Omari, *Kitchen Assistant*
Benson Muyonga Lihanda, *Kitchen Assistant*
Moses Kasembeli Wepukhulu, *Kitchen Assistant*
Marystella Mutasta Wanjala, *Kitchen Assistant*
John Nalisi Kipserem, *Laundry Assistant*
Joan Auma Awich, *Laundry Assistant*
Patrick Ajuoga Omollo, *Barman/Waiter*
Patrick Mungithya, *Barman/Waiter*
David Otieno Orinda, *Barman/Waiter*
Naomi Ifire, *Waitress*
David Nyaribo, *Cleaner*
Naomi Mwendwa Stephen, *Cleaner*
Jane Adisa Asaba, *Cleaner*

MBITA POINT INTERNATIONAL GUEST CENTRE
Johnstone Okal Koyaa, *Catering Officer*
Charles Odera Nyagaya, *Room Steward*
Fredrick Okebe Orwa, *Kitchen Assistant*
Wilson Mahindu Esirenyi, *Kitchen Assistant*
Helen Atieno Ouma, *Laundry Assistant*
Francis Namoyo Omutsembi, *Laundry Assistant*

INTERNATIONAL COOPERATION AND CAPACITY BUILDING

Mudiumbula Tshitumbu Futa, *Director*
Vitalis Ogunja Musewe, *Head of Capacity Building*
Lucy Wanjiru Gacheru, *Projects Assistant*
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William Allan Overholt, *Principal Scientist*
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Susan Wangari Kimani-Njogu, *Postdoctoral Fellow*
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Paul Kizito Ogino, *Research Assistant*
Walter Okello Ogutu, *Research Assistant*
Eli Munyoki Ng'ong'o, *Research Assistant*
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Peterson Wachira Nderitu, *Technician*
James Kagoiya Mwangi, *Technician*
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Gerphas Okuku Ogola, *Technical Assistant*
Jonna Okoth O. Ongata, *Technical Assistant*
Tom Mboya Ondiek, *Technical Assistant*
Michael Ouma Majua, *Technical Assistant*
Dickens Aluoch Ogollah, *Technical Assistant*
Julius Ochieng Omondi, *Technical Assistant*
Jael Auma Lumumba, *Technical Assistant*

Nixon Benard Onyimbo, *Technical Assistant*
Faith Wamurango Nyamu, *Technical Assistant*
Hellen Wambui Mburu, *Technical Assistant*
Daniel Kinyanjui Mungai, *Technical Assistant*
Raphael Odhiambo Agan, *Technical Assistant*
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Getachew Tikubet, *Country Coordinator*

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Hayder Hanan Korina, *Technician*
Mohamed Osman Suliman Mohamed, *Technician*
Babiker Gasmalla Mohamed, *Technical Assistant*
Abdel Rahim Wedaatalla Bashir, *Technical Assistant*
Hassan Ismael Ishag, *Driver*
Mohamed Ahmed Ishag El Sheikh, *Driver*

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Zedekia Boaz Ooko, *Technical Assistant*
Patrick Oranga Ochanjo, *Technical Assistant*
Dickens Obondo Nyagol, *Technical Assistant*
Peter William K. Nyongesa, *Farm Supervisor*
Philemon Ondiek Ouma, *Farm Assistant*
Hilda Awiti Abade, *Secretary*

MUHAKA-BASED
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Silas Paul Ojwang', *Technical Assistant*
Moses Kamau Mungai, *Technical Assistant*
Maurice Ochieng Wanga, *Technical Assistant*
Boaz Kimanzi Musyoka, *Technical Assistant*
Peter Omolo Owuor, *Technical Assistant*

MOLECULAR BIOLOGY AND BIOTECHNOLOGY DEPARTMENT

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Nguya Kalemba Maniania, *Scientist*
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Elizabeth Awuor Ouna, *Research Assistant*
James Gitari Kabii, *Research Assistant*
James Oluoch Adino, *Research Assistant*
Pamela Beatrice Anyango Seda, *Research Assistant*
Mathayo Mangwe B. Chimtawi, *Technician*
Mark Gacau Kimondo, *Technician*
Moses Amoke Mbeke, *Technical Assistant*

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Rajinder Saini, *Senior Scientist*
Slawomir Antoni Lux, *Senior Scientist*
Bart Geert Jan Knols, *Scientist*
Baldwyn Torto, *Scientist*
Clifford Maina Mutero, *Scientist*
Peter George Nganga Njagi, *Scientist*
Wilber Lwande, *Scientist*
B. Onesmus Kaye Wanyama, *Senior Research Assistant*
Andrew Mbiru, *Senior Research Assistant*
Florence Njeri Munyiri, *Senior Research Assistant*
Edward Nyandat, *Research Assistant*
John Akiri Andoke, *Research Assistant*
James Owino Mbayi, *Research Assistant*
Enock Mpanga, *Research Assistant*
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Lamberts V. Moreka, *Technician*
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Peter Muriuki Njiru, *Technician*
Timothy Wanyonyi Wanjala Chole, *Technician*
Habert Amiani Chanzu, *Technical Assistant*
David Mbuvi Mbesi, *Technical Assistant*
Peter Nthale Muasa, *Technical Assistant*
Naphtali Ochieng Dibogo, *Technical Assistant*
Samuel Ezekiel Mokaya, *Technical Assistant*

MPFS-BASED
Zeyaur Rahman Khan, *Senior Scientist*
Peter Mwombe Chiliswa, *Research Assistant*
Pascal Agollah Oreng, *Technical Assistant*
Stephen Gwendo Ogechi, *Technical Assistant*

KITALE-BASED
Aloice Ouma Ndiege, *Field Trial Assistant*

SOCIAL SCIENCES DEPARTMENT

MPFS-BASED
Ramesh Chandra Saxena, *Principal Scientist*
Joseph Wokulira Ssennyonga, *Senior Scientist*
Joseph Muthee Muchiri, *Technician*
Evelyn Abigael Odhiambo, *Secretary*
Margaret Agenga Ayugi, *Technical Assistant*
Susan Akinyi Akello, *Technical Assistant*

DUDUVILLE-BASED
Boniface Ajuoga Omolo, *Technician*
Polycap Mbuya Barnabas, *Technical Assistant*

GTZ - RED SPIDER MITE PROJECT
Markus Alois Knapp, *Postdoctoral Fellow*
Miriam Mwarania Kungu, *Technical Assistant*
Benard Musembi Muia, *Technical Assistant*

RESEARCH SUPPORT UNITS AND SERVICES

BIOMATHEMATICS UNIT

Adedapo Odulaja, *Scientist and Head*
Philip Eliveha Ragama, *Senior Research Assistant*
Christopher Nyawalo Olando, *Senior Research Assistant*

ANIMAL REARING AND QUARANTINE UNIT

James Patrick Ochieng'-Odero, *Scientist, Acting Head*
Francis Omeno Onyango, *Senior Research Assistant*
James Henry Ongudha, *Technician*
Saul Ayub Patya, *Technician*
John Wabwire Otsieno, *Technician*
Mathew Mugweru Miti, *Technical Assistant*
Alphonce Majanje, *Technical Assistant*
Joanes Mbala Onyango, *Technical Assistant*

Amos Gadi Nyagwara, *Technical Assistant (MPFS)*

INFORMATION SERVICES UNIT

Annalee Ng'eny Mengech, *Head*
Daisy Wairimu Ouya, *Science Editor, Journal*
Irene Akinyi Ogendo, *Graphics Artist and Imagesetter*
Dolorosa Osogo, *Proofreader*

ICIPE Science Press
Newton Mwanga Komeri, *Scientific Illustrator*
Joseph Mwanthi Malombe, *Printing Technician*
Jemima Wambui Kamau, *Typesetter*
Joshua Mbithi Kisini, *Clerical Assistant*
Gilbert Mwaura Kageche, *Driver*

Library and Documentation Services
Eddah Wasike, *Library Assistant*
Joash Ada Lago, *Library Assistant*
Wellington Ambaka, *Clerical Assistant*

FIELD STATIONS

Mbita Point Field Station
Administrative Services
Kundam Venkata Seshu Reddy, *Scientist-in-Charge*
George Khaemba Khisa, *Telephonist/Receptionist*
Susan Adhiambo Otila, *Cleaner*

Transport Services
William Nagenda Omino, *Transport Assistant*
Eric Omondi Ogutu, *Tractor Operator*
Zablon Owigo Nyandere, *Groundsman*
Johannes Deya Orimbo, *Groundsman*
Alois Aiko Awich, *Groundsman*

Security Services
Peter Otieno Kisaria, *Security Guard*
John Mongare Motari, *Security Guard*
George Okaka Aunga, *Security Guard*
Samuel Ojako Okumu, *Security Guard*

Muhaka Field Station
Douglas Charo Kalume, *Office Attendant*

Marigat Station
Paul Barchebo Chepkoimet, *Security Guard*
Richard Kipkorir Leitich, *Security Guard*
Samuel Kulei Chesang, *Security Guard*

Nguruman Station
Joseph Naata Tanchu, *Security Guard*

Ethiopia Country Office
Getachew Tikubet, *Country Coordinator*
Ato Befekadu Ameya, *Protocol Officer*
Gelila Mengistu, *Administrative Assistant*
G/Ammanuel Samrawit Tadesse, *Assistant Project Accountant*
Tesfaye Alemu, *Mail Clerk*
Assefa Admike Lanteyidru, *Driver*

Port Sudan Field Station
Magzoub Omer Bashir, *Senior Scientist*

Staff List—1999 Personnel

MANAGEMENT AND GENERAL OPERATIONS

OFFICE OF THE DIRECTOR GENERAL

Hans Rudolf Herren, *Director General*
Christiane Dorothea Weigner, *Assistant to Director General*
Dinah Wairimu Njoroge, *Internal Auditor*
Remedios Dela Paz Ortega, *Public Relations Officer*
Purity Ngima Kaweru, *Executive Secretary*
Titus Musyoki Kaviti, *Clerical Assistant*
Francis Omondi Ujiji, *Driver*
Fredrick Chichi Makhulo, *Office Assistant*

OFFICE OF THE DEPUTY DIRECTOR GENERAL

Akke van der Zijpp, *Deputy Director General*
Susan Kabui Iruku, *Executive Assistant*
Peter Njoroge Mahogo, *Driver*

INTERNATIONAL COOPERATION AND CAPACITY BUILDING

Muduimbula T. Futa, *Director, International Cooperation*
Lucy Wanjiru Gacheru, *Projects Assistant*
Marie Louise Mukakalisa, *Executive Assistant*

ADMINISTRATION

Human Resources

Tina Marie Kuklenski, *Director of Administration*
Willis Awori, *Human Resources Manager*
Lucy Wangari Macharia, *Specialist Compensation Benefits*
John Mwaiwe Mwendar, *Personnel Officer C&B*
Emily A. Alwala, *Personnel Officer R&T*
Simprose Oyola Oyugi, *Telephonist/Receptionist*
Susan Wanjiku Muna, *Telephonist/Receptionist*
Elijah Asami, *Mail Clerk*

Dudu Travel Agency

Fraser Jackson Utanje, *Travel Manager*
Peris Wambui Njenga, *Travel Assistant*

Information Technology

Timothy Brett Robinson, *Information Technology Manager*
Darisi Murali, *Senior EDP Specialist*
Mohammed D. Mungai Gathoga, *Computer Technologist*

FINANCE

Accounting

Christopher Geoffrey Hill, *Financial Controller*
Krisnahsammy Appadu, *Head, Financial Accounting*
Antony Akumu Abogi, *Financial Accountant*
Serah Njeri Mungai, *Treasury Accountant*
Jasper Gitonga Rugendo, *Treasury Accountant*
Patrick Ngahu Ndiangui, *Project Accountant*
Dominic Francis Sifuna, *Project Accountant*
George Muchuku Kiondo, *Assistant Project Accountant*
Cyrus Kimani Watuku, *Systems Analyst*
Peter Ossmy Ngugi, *Assistant Accountant*
Henry Victor Ligedere, *Assistant Accountant*
Eustace Njuma Mbuthia, *Accounts Assistant*
Nancy Wangui Mwangi, *Accounts Assistant*
Agripina Valerie Ramoya, *Executive Assistant*
Alphonse Bubusi, *Mail Clerk*
Peter Nyakeri Onsongo, *Accounts Assistant* (MPFS)
John Muhia Kibera, *Accounts Assistant* (MPFS)

Procurement

Peter Dickson Kamau Ndirangu, *Procurement Supervisor*
Elias Maikuri Aosa, *Purchasing Officer*
Tobias Odongo Oloo, *Purchasing Officer*
Patrick Matheri Munyui, *Procurement Clerk*
Daniel Oduor Owino Olalo, *Storekeeper*
John Odongo Gombe, *Purchasing Officer* (MPFS)

PHYSICAL PLANT AND SERVICES UNIT

Alfred Lustenberger, *Head*
Abdul Razaq Shaffy Abdalla, *Workshop Manager*
David Marangu Mbui Kimotho, *Transport Assistant*
Catherine M.Muthoni Macharia, *Data Input Clerk*
Daudi Mutua Muumbi, *Storekeeper*
Susy Nekesa Khaemba, *Assistant Storekeeper*
John Musyoka Mutua, *Electrician*
Julius O. Okeyo, *Electrician*
Donald Mwachoni Nyambu, *Mechanic*
Anastasia Kabura Macharia, *Mechanic*
Walter Kariuki Warui, *Mechanic*
Patroba Nyachieo, *Senior Artisan*
Andrew Makheti Wanyama, *Artisan/Plumber*
John Pancras Nyongesa, *Artisan/Carpenter*
Dick Mutisya Kakuku, *Artisan/Metal Plastic Fabricator*
John Waweru Njeri, *Artisan*
Jacob Otieno Omondi, *Artisan*
Richard Muiruri Mugi, *Artisan Assistant*
Umar Ibrahim, *Artisan Assistant*
Joseph Raphael Makumi, *Driver/Mechanic*
Joseph Mucheru Gachugu, *Driver*
Benard Mulwa Musee, *Driver*
Joseph Mututa Mwarania, *Driver*
Henry Njoroge Njachi, *Driver*

Alex Owino Kirimba, *Driver*
John Mweu Mutunga, *Driver*
Dickson Mulwa Mwilu, *Security Guard*
Peter Owino Apodo, *Security Guard*
Gilbert Ouma Omondi, *Security Guard*
Lawrence Masila Nzomo, *Security Guard*
Nelson Njuguna Munyinyi, *Security Guard*
Edwin Henry Otieno, *Security Guard*
Geoffrey Kinyuah, *Security Guard*
Joseph Odondi Oluk, *Electrician*(MPFS)
Kennedy Otieno Onyango, *Driver* (MPFS)

INTERNATIONAL GUEST CENTRE SYSTEM

DUDUVILLE INTERNATIONAL GUEST CENTRE
Kurt Benjamin Iten, *General Manager - Guest Centres*
Simon Maitethia Aritho, *Assistant Accountant*
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George Gichuru, *Chef*
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Mary Nyeusi Etuku, *Kitchen Assistant*
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Joan Auma Awich, *Laundry Assistant*
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Patrick Mungithya, *Barman/Waiter*
David Orinda Otieno, *Barman/Waiter*
Naomi Ifire, *Waitress*
David Nyaribo, *Cleaner*
Naomi Mwendwa Stephen, *Cleaner*
Jane Adisa Asaba, *Cleaner*

MBITA POINT INTERNATIONAL GUEST CENTRE
Johnstone Okal Koyaa, *Catering Officer*
Wilson Mahindu Esirenyi, *Kitchen Assistant*
Fredrick Okeben Orwa, *Kitchen Assistant*
Charles Odera Nyagaya, *Room Steward*
Helen Atieno Ouma, *Laundry Assistant*
Francis Namoyo Omutsembi, *Laundry Assistant*

NGURUMAN FIELD SITE
Joseph Saningo Ole Soinkei, *Camp Attendant*
Joseph Naata Tanchu, *Security Guard*

JANITORIAL SERVICES/HOUSEKEEPING
Elias Ondeyo, *Office Attendant*
Simon Mutta Mkamba, *Office Attendant*
Esinas Jeptum Tirop, *Office Attendant*
George S. K. Kariuki, *Office Attendant*
Benard Mita Okech, *Office Attendant*
Lucy Wanjiru Mwaura, *Office Attendant*
Phoebe Siva, *Office Attendant*
Richard Musyoki Masaka, *Office Attendant*
Anne Wanjiku Karanja, *Office Attendant*
Syprine Amolo Abongo, *Office Attendant*
Wilfred Omondi Adhiambo, *Office Assistant*
Fredrick Onyango Athula, *Office Assistant*

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Johann Baumgärtner, *Principal Scientist and Head*
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William Allan Overholt, *Principal Scientist*
David Nadel, *Principal Scientist*
Suresh Kumar Raina, *Senior Scientist*
Srinivasan Sithanantham, *Senior Scientist*
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Adele Josee Ngi-Song, *Scientist*
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Esther Ndaisi Kioko, *Postdoctoral Fellow*
Zhou Guofa, *Postdoctoral Fellow*
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Gideon Jira Chigunda, *Technician*
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Benard Musembi Muia, *Technical Assistant*
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Rebecca Kemunto Raini, *Technical Assistant*
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Dickens Obondo Nyagol, *Technical Assistant*
Patrick Oranga Ochanjo, *Technical Assistant*
Maurice Ochieng Wanga, *Technical Assistant*
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Peter Khaemba, *Technical Assistant*
Peter William K. Nyongesa, *Farm Supervisor*
Philemon Ondiek Ouma, *Farm Assistant*

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Rajinder Saini, *Senior Scientist*
Wilber Lwande, *Scientist*
Baldwyn Torto, *Scientist*
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Bart Geert Jan Knols, *Scientist*
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Adati Taro, *Visiting Scientist–JSPS*
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Florence Munyiri, *Senior Research Assistant*
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John Akiri Andoke, *Research Assistant*
James Owino Mbayi, *Research Assistant*
Enock Mpanga, *Research Assistant*
Andrew Mbiru, *Research Assistant*
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Angela Wamuhu Manyeki, *Secretary*
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Dalmas Omondi Otieno, *Technician*
Peter Muriuki Njiru, *Technician*
Timothy Wanyonyi Wanjala Chole, *Technician*
Peterson Wachira Nderitu, *Technician*
Basilio Ngari Njiru, *Technician*
Millicent Akinyi Okumu, *Technician*
Faith Wamurango Nyamu, *Technical Assistant*
Peter Nthale Muasa, *Technical Assistant*
Jeremiah Adoyo Ojude, *Technical Assistant*
Habert Amiani Chanzu, *Technical Assistant*
David Mbuvi Mbesi, *Technical Assistant*
Milcah Wanjiru Gitau, *Technical Assistant*
John Mbatha Kiilu, *Technical Assistant*

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Hayder Hanan Korina, *Technician*
Babiker Gasmalla Mohamed, *Technical Assistant*
Abdel Rahim Wedaatalla Bashir, *Technical Assistant*
Hassan Ismael Ishag, *Driver*

MPFS-BASED
Zeyaur Rahman Khan, *Senior Scientist*
Mutunga Kithokoi, *Technician*
Stephen Gwendo Ogechi, *Technical Assistant*
Dickens Nyagol, *Technical Assistant*
Naphtali Ochieng Dibogo, *Technical Assistant*
Samuel Ezekiel Mokaya, *Technical Assistant*
Pascal Agollah Oreng, *Technical Assistant*
Jacob Otieno Opere, *Technical Assistant*

KITALE-BASED
Peter Mwombe Chiliswa, *Research Assistant*
Aloice Ouma Ndiege, *Field Trial Assistant*

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Acronyms and Abbreviations

AAAP	attraction-aggregation-attachment pheromone
AAIS	African Association of Insect Scientists
ABOS	Belgian Administration for Development Cooperation
ACIAR	Australian Centre for International Agricultural Research
ADB	African Development Bank
ADC	Austrian Development Cooperation
ADO	arbitrary digital object
AFFI	African Fruit Fly Initiative (ICIPE)
AHI	African Highland Initiative
AJOL	African Journals Online website
AOAD	Arab Organisation for Agricultural Development (Saudi Arabia)
ARC	Agricultural Research Corporation (Sudan)
ARP	African Regional Programme (of AVRDC)
ARPPIS	African Regional Postgraduate Programme in Insect Science (ICIPE)
ARQU	Animal Rearing and Quarantine Unit
ASA	ARPPIS Scholars Association
ASARECA	Association for Strengthening Agriculture Research in East and Central Africa
AVIRC	Africa Virtual Insect Resource Centre
AVRDC	Asian Vegetable Research and Development Centre (Taipei, Taiwan, China)
AWF	African Wildlife Foundation
BARNESA	Banana Research Network for Eastern and Southern Africa (Uganda)
BCR	benefit/cost ratios
BMZ	Bundesministerium fur Wirtschaftliche und Entwicklung Zusammenarbeit (Bonn, Federal Republic of Germany)
BSLF	Biologically Safe Laboratory Facility (ICIPE)
BSU	Biosystematics Support Unit (ICIPE)
Bt	*Bacillus thuringiensis*
BtRDC	B.t. Research and Development Centre (China)
CA	corpus allatum
CAAS	Chinese Academy of Agricultural Sciences
CABI	Commonwealth Agricultural Bureau International
CBD	Convention on Biological Diversity
CDS	contaminating device strategy
CGF	catalytic group of farmers
CGIAR	Consultative Group on International Agricultural Research (Washington DC, USA)
CIAT	Centro Internacional de Agricultura Tropical (Colombia)
CIBU	Capacity and Institution Building Unit (ICIPE)
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo (Mexico DF, Mexico)
CIP	Centro Internacional de la Papa (Lima, Peru)
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)
COCTU	Coordinating Office for Control of Trypanosomosis in Uganda
C-PITT	Centre for Pest Information Technology and Transfer (Australia)
CRF	Coffee Research Foundation (Kenya)
CSB	Central Silk Board (India)
CSBR	Centre of Sericulture and Biological Pest Management Research (India)
CUVV	Cucumber Yellow Vein Virus
DAAD	German Academic Exchange Service
DANIDA	Danish International Development Agency (Copenhagen, Denmark)
DBM	diamondback moth
DFID	Department for International Development (UK); formerly ODA
DGIS	Directorate General for International Cooperation (The Netherlands)
DL	desert locust
DLCO-EA	Desert Locust Control Organisation for Eastern Africa
DPV	Déportement de Protection des Végétaux (Senegal)
DRIP	Dissertation Research Internship Programme (ICIPE)
DRSRS	Department of Resource Survey and Remote Sensing (Kenya)
DSO	Direct Support to Training Institutions in Developing Countries Programme
DVBD	Division of Vector-Borne Diseases (Kenya)
EARO	Ethiopian Agriculturaal Research Organisation
ECF	East Coast fever
EHNRI	Ethiopian Health and Nutrition Research Institute
EMPRAPA	Empresa Brasileira de Pesquisa Agropecuãria (Brazilian Agricultrual Research Corporation), Brasilia

EMPRES FAO's Emergency Prevention System (Rome)
ENEA Italian Agency for New Technology, Energy and Environment (Italy)
ESRDF Ethiopian Social Rehabilitation and Development Fund
ESTC Ethiopian Science and Technology Commission
ETH Swiss Federal Institute of Technology
EU European Union
FAO Food and Agriculture Organisation of the United Nations
FBRCAF Federal Biological Research Centre for Agriculture and Forestry (Germany)
FD Forest Department
FFS Farmers' Field School
FITCA Farming in Tsetse Control Areas
FOFIFA Centre national de recherche appliquée au développement rural (Madagascar)
FPEAK Fresh Produce Exporters Association of Kenya
FPIF FITCA project implementers and farmers
GBDI Global Biodiversity Institute
GCI Grain Crops Institute (South Africa)
GEF Global Environment Fund
GIS geographic information systems
GISP Global Invasive Species Programme
GIT geographic information technology
GM genetically modified
GPS global positioning system
GRSS Geoscience & Remote Sensing Society
GTZ Gesellschaft für Technische Zusammenarbeit (Eschborn, Germany)
HMF hydroxymethylfurfural
HORTI Horticultural Research and Training Institute (Tanzania)
HRC Horticultural Research Centre, Marondera
IACR Institute for Arable Crops Research (Rothamstead, UK)
IAEA International Atomic Energy Agency (Vienna)
IARCs international agricultural research centres
IBRA International Bee Research Association (UK)
ICRAF International Centre for Research in Agroforestry (Kenya)
ICRISAT International Crops Research Institute for the Semi-Arid Tropics (Hyderabad)
ICSC International Centre for Scientific Culture—World Laboratory (Lausanne)
ICT information and communication technology
IDRC International Development Research Centre (Canada)
IEEE Institute of Electrical and Electronics Engineers Inc.
IFAD International Fund for Agricultural Development (Rome)
IGAs income generating activities
IGRs insect growth regulators
IITA International Institute of Tropical Agriculture (Ibadan, Nigeria and Cotonou, Benin)
ILO International Labour Organistion
ILRI International Livestock Research Institute (Nairobi, Kenya and Addis Ababa, Ethiopia)
INASP International Network for the Availability of Scientific Publications
INBIO National Biodiversity Institute (Costa Rica)
INERA Institut de l'envirotudes de recherches agricoles, station de recherches agronomique (Bobo Dioulasso)
INIBAP International Network for the Improvement of Banana and Plantain
INRA Institut national de la recherche agronomique (France)
IOCD International Organisation of Chemical Sciences in Development (USA)
IPM integrated pest management
IR&C ICIPE researchers and collaborators
IRC Information Resource Centre (ICIPE)
IRLCO-CSA International Red Locust Control Organisation for Central and Southern Africa (Zambia)
ISAAA International Service for the Acquisition of AgriBiotechnology Application
ISP ICIPE Science Press
ITC International Trypanotolerance Centre (Banjul, The Gambia)
ITDG Intermediate Technology Development Group (UK)
IUCN World Conservation Union
IVRP Indian Vegetable Research Project
IWMI International Water Management Institute (Colombo)
JH juvenile hormone
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
KABICOTOA Kakamega Biodiversity Conservation Tour Operators Association (Kenya)
KARI Kawanda Agricultural Research Institute (Uganda)
KARI Kenya Agricultural Research Institute
KEFRI Kenya Forestry Research Institute
KELP Knowledge, Exchange, Learning and Partnership by USAID
KEMRI Kenya Medical Research Institute
K-REP Kenya Rural Enterprise Programme
KEPHIS Kenya Plant Health Inspectorate Service
KETRI Kenya Trypanosomiasis Research Institute
KFC Kenya Flower Council
KISABE Organisation for Community-Managed Tsetse in Lambwe Valley
KSTCIE Kenya Standing Technical Committee on Imports and Exports
KVI Kimron Veterinary Institute (Israel)
KWS Kenya Wildlife Services
LAN local area network
LIRI Livestock Health Research Institute (Uganda)
LIRS lethal insect release strategy
LIT lethal insect technique
LMU Laboratory Management Unit (ICIPE)
LUBILOSA Lutte Biologique contre les Locustes et les Sauteraiux (IITA/CABI)
LWG liveweight gain
MIM Multilateral Initiative on Malaria Research in Africa
MOALDM Ministry of Agriculture Livestock Development and Marketing (Kenya)
MoH Ministry of Health (Kenya)
MPFS Mbita Point Field Station (ICIPE)
MRLs maximum residue limits
MRS Malkerns Research Station (Swaziland)
MSV Maize Streak Virus
NAARI Namulonge Agriculture and Animal Research Institute (Uganda)

NARES	national agricultural research and extension systems
NARL	National Agricultural Research Laboratories (Kenya)
NARO	National Agricultural Research Organisation (Uganda)
NARS	national agricultural research system
NGOs	nongovernmental organisations
NIB	National Irrigation Board (Kenya)
NIH	National Institutes of Health (USA)
NIMR	National Institute for Medical Research (Tanzania)
NKCP	neem kernel cake powder
NMK	National Museums of Kenya
NPB	nymphal pheromone blend
NPV	nuclear polyhedrosis virus
NRI	Natural Resources Institute (UK)
NSW	New South Wales (Australia)
OAU	Organisation of African Unity (Addis Ababa, Ethiopia)
ODA	Overseas Development Agency (UK)-now DFID
OPEC	Organisation of Petroleum Exporting Countries
OVI	Onderstepoort Veterinary Institute
PAN	phenylacetonitrile
PCV	packed cell volume
PEEM	Panel of Experts on Environmental Management for Vector Control (Switzerland)
PIF	project implementers and farmers
PMD	Pest Management Database(ICIPE)
PPRI	Plant Protection Research Institute (South Africa)
R&CB	Research and Capacity Building projects (ICIPE)
R&D	research and development
REDSO	USAID Regional Economic Development Services Office, East and Southern Africa
RSM	red spider mites
RTTCP	Regional Tsetse and Trypanosomiasis Control Programme (Zimbabwe)
SARDNET	Sericulture Apiculture Research and Development Network
SARI	Selian Agricultural Research Institute (Tanzania)
SDC	Swiss Development Corporation
SI	Smithsonian Institution (USA)
SIDA	Swedish International Development Agency
SPV	Service de la protection des végétaux
SRI	Sericulture Research Institute (China)
SRICAAS	Sericulture Research Institute of Chinese Academy of Agricultural Sciences
SSU	Social Sciences Unit (ICIPE)
SUA	Sokoine University of Agriculture (Tanzania)
SUNY	State University of New York, USA
T&TBDs	ticks and tick-borne diseases
TAG	Technical Assistance Grants
THBP	Taita Hills Biodiversity Project
TOT	Training of Trainers
TTR	trap-treat-release concept
TTRI	Tsetse and Trypanosomiasis Research Institute (Tanzania)
TUP	Trickle-up Programme (UNDP)
TVTV	Tomato Vein Thickening Virus
TYLCV	Tomato Yellow Leaf Curl Virus
UNBRP	Uganda National Banana Research Programme of NARO
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNHCR	United Nations High Commission for Refugees
UNIFEM	United Nations Development Fund for Women
UNU/INRA	United Nations University, Institute for Natural Resources in Africa
USAID	United States Agency for International Development (Washington DC, USA)
USDA	United States Department of Agriculture
UTCC	Uganda Trypanosomiasis Control Council
VT	Virginia Polytechnic Institute and University (Virginia Tech) (USA)
WARDA	West Africa Rice Development Association (Bouake, Côte d'Ivoire)
WAU	Wageningen Agricultural University (The Netherlands)
WCSV	Watermelon Chlorotic Stunt Virus
WFED	World Foundation for Environment and Development (USA)
WHO/TDR	World Health Organisation/Tropical Diseases Research
WIPO	World Intellectual Property Organisation (Switzerland)
WMO	World Meteorological Organisation
WOTRO	Netherlands Foundation for Tropical Science
WTVs	whitefly-transmitted viruses
WWW	World Wide Web
ZADI	German Centre for Documentation and Information in Agriculture

Now in its third decade, the International Centre of Insect Physiology and Ecology (ICIPE) has evolved into an organisation that studies much more than simply the insects (and related arthropods such as ticks and mites) themselves. ICIPE delves into every aspect of the way these creatures—the most varied and numerous of all Earth's life forms—impact on our daily lives. From the means by which arthropods carry some of the world's most serious and debilitating human and animal diseases, to the way they help create (through pollination), protect and destroy our food supply, and to the way their diverse and complicated labours secure the very basis of agricultural and biological productivity, ICIPE tries to find better ways of managing these tiny denizens in the service of peoples of the tropics. New, environmentally benign but effective solutions are being developed that are affordable and appropriate for the smallholder farmers and urban folk in developing countries. Insects are also being exploited as the biogenerators of food, fibre and medicinals in ICIPE's apiculture, sericulture and bioprospecting initiatives, providing much needed supplementary income and employment.

This consolidated Annual Scientific Report for the years 1998 and 1999 outlines the Centre's major activities in research, technology development and capacity building in improving the (4–Hs)—human, animal, plant and environmental health—through "Tropical Insect Science for Development".

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