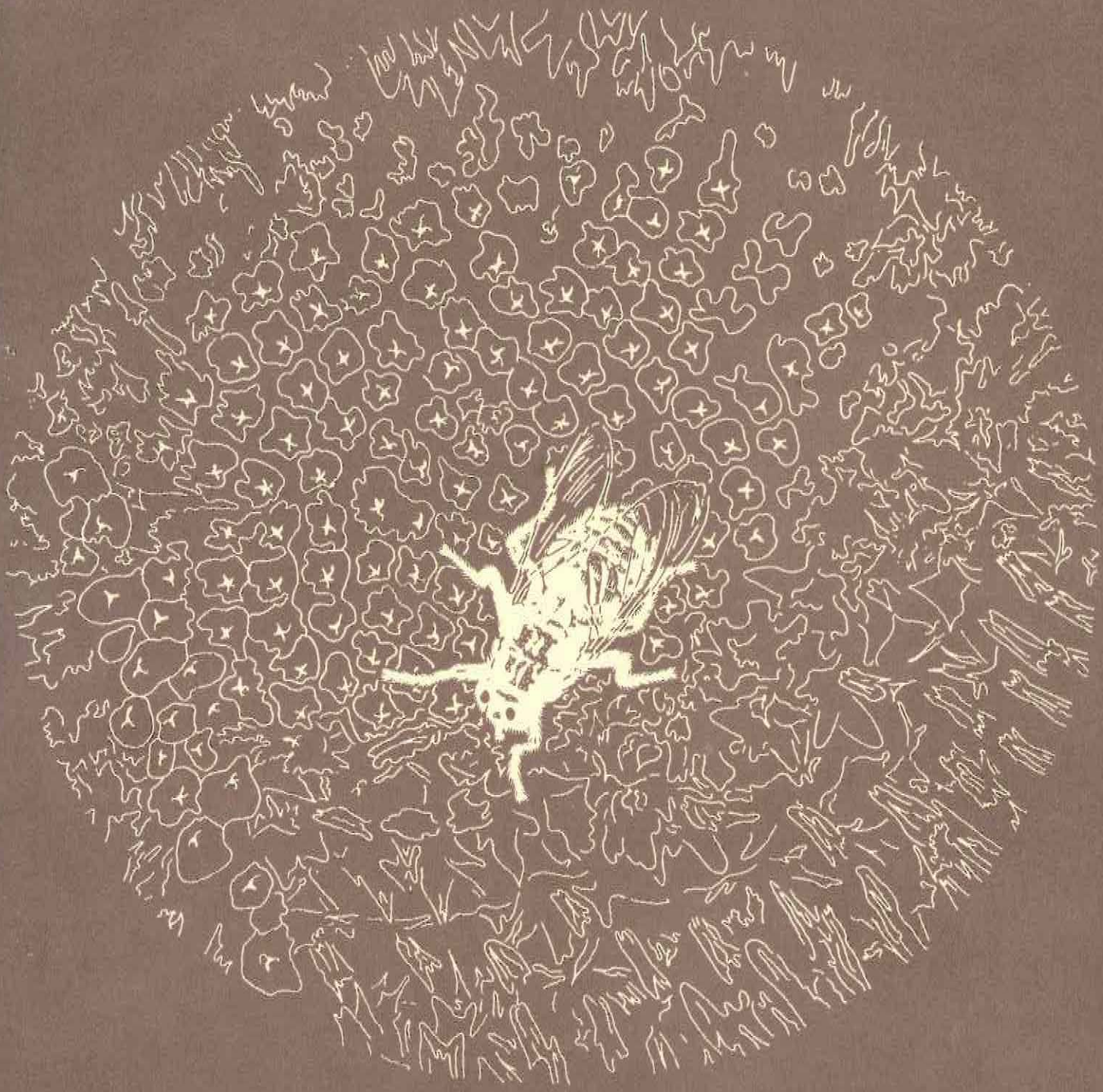
1994
ICIPE
Annual Scientific Report



International Centre of Insect Physiology and Ecology
PO Box 30772, Nairobi, Kenya

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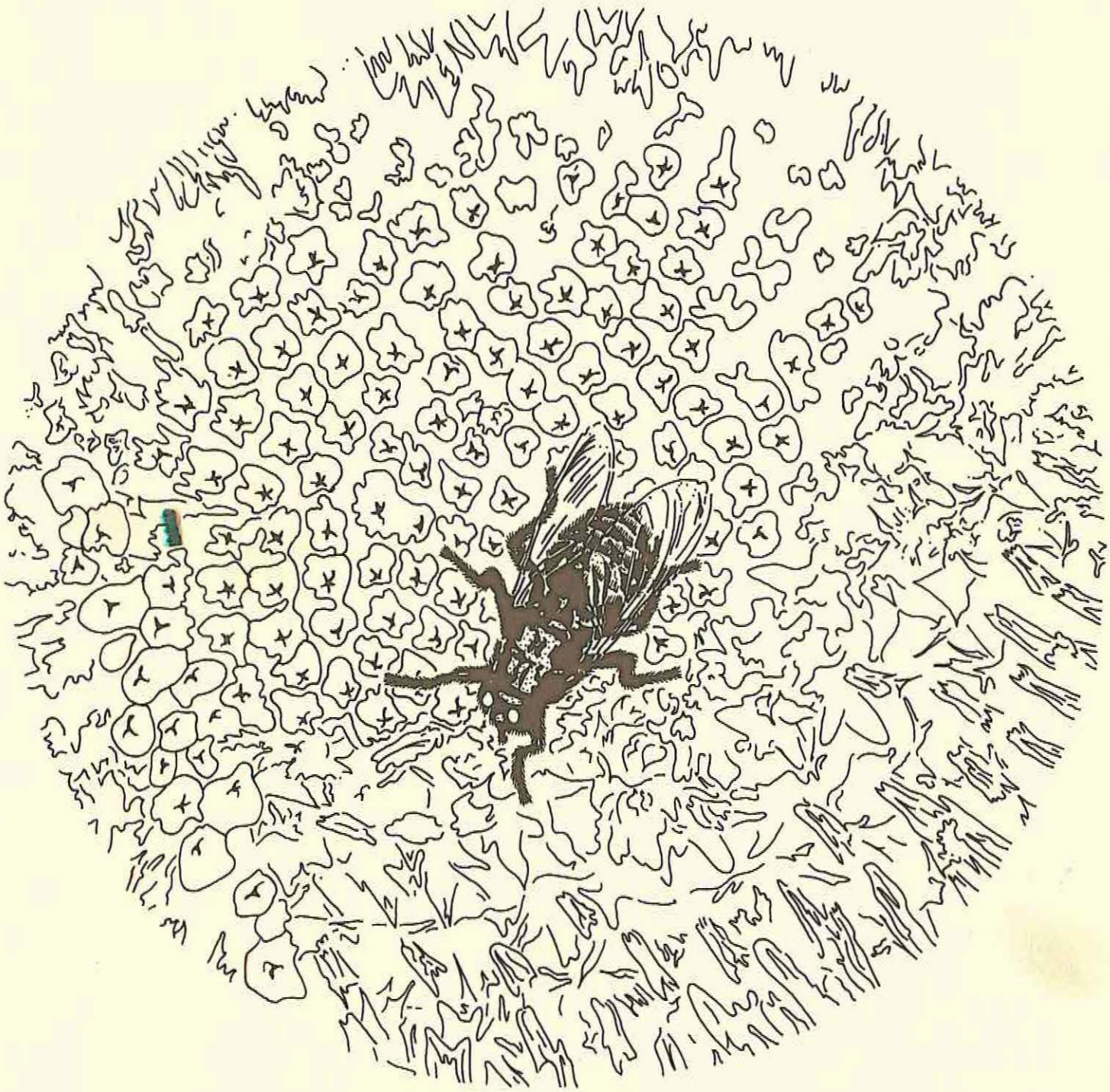

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Foreword

This 1994 ICIPE Annual Scientific Report is the 22nd such volume since the founding of the Centre in 1970 in Nairobi, Kenya 25 years ago. Over the past quarter-century, the names and activities of ICIPE programmes have modified and evolved to reflect and adjust to new priorities in agricultural and human and animal health research.

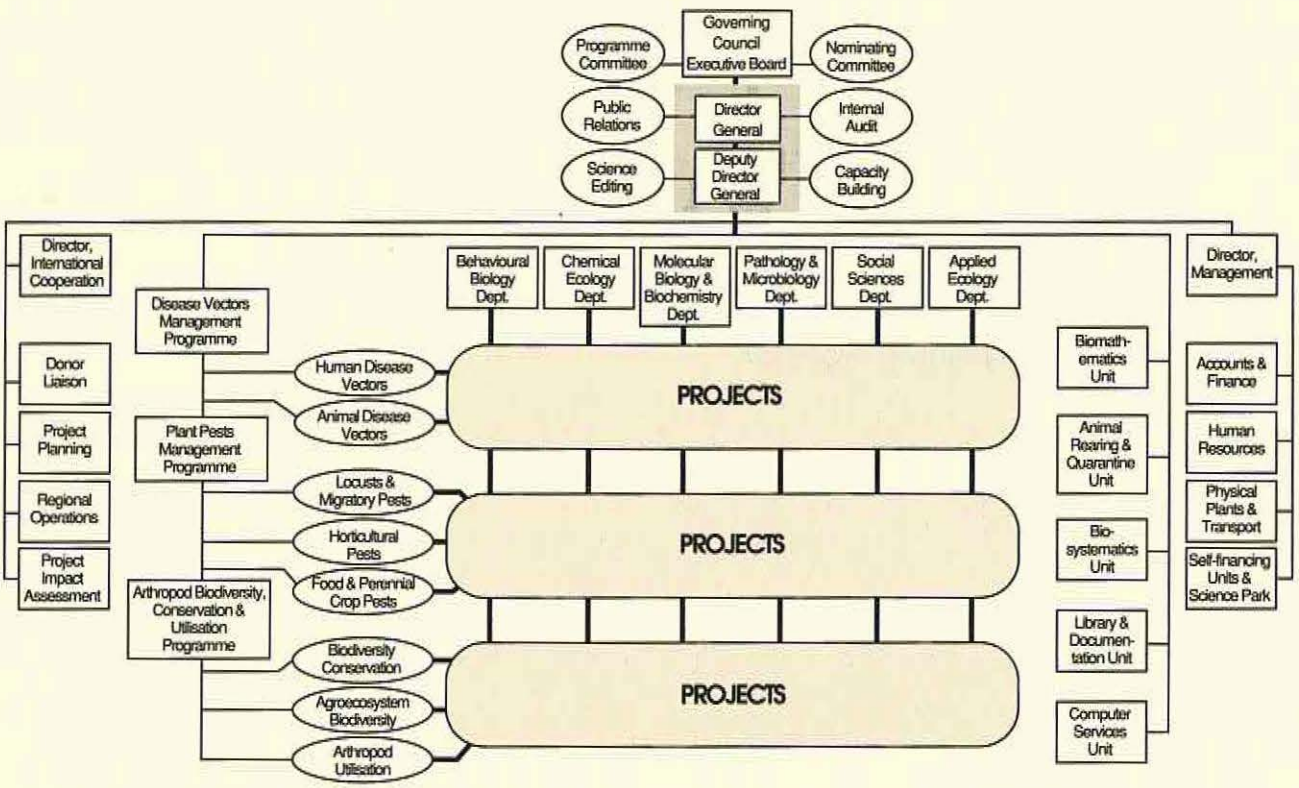
The year 1994 was a year of transition and change at ICIPE, with the Centre undergoing major restructuring and renewal, as reflected in the 'organogram' on the following page. Among the major changes are the creation of a new programme on Arthropod Biodiversity, Conservation and Utilisation and the mobilising of the staff into six new scientific departments and five research support units.

This Report attempts to bridge the gap between the past and present by describing the Centre's research activities for 1994 within the current institutional structure. The content of the Report is organised by projects within each programme, and the present project coordinators identified, so that interested readers can contact these scientists directly for more information about their projects. Alternatively, readers can refer to the publications listed herein for details of experimental methodology and results, as this Report, by necessity, cannot include fully comprehensive descriptions of the hundreds of R&D activities performed.

We welcome your comments and suggestions.

The Editors

Morphogenesis: ICIPE's New Organisational Structure



ICIPE's new organisational structure is designed to ensure that the Centre's outputs in basic insect science and the resulting IPM strategies and technologies are most effectively delivered from the three programmes that define the research agenda. The six departments will provide and guarantee the requisite scientific expertise, supplemented by expert assistance from the research support units. A fourth programme on capacity building embraces all activities of the Centre.

Contents

Message from the Director General

The year 1994 marked two milestones for the ICIPE, one being the 25th anniversary of its foundation and the other its complete restructuring to address the new needs of a rapidly changing world. In the past 25 years, ICIPE has successfully carried out research and capacity building in insect science in Africa. From a mainly basic research centre at its launching in 1970, ICIPE has been increasingly tackling arthropod-induced problems in food crops, animal husbandry and human health, driven by the mission-oriented approach of its founder, Professor Thomas R. Odhiambo.

One of the most significant recent breakthroughs relates to the uncovering of the chemical basis of locust communication and behaviour, thus paving the way to an environmentally sound and economical approach for locust control. Other major achievements include the development of effective and environmentally safe and insecticide-free tsetse traps, utilising cow urine as attractant; the successful establishment of natural enemies against cereal stemborers; and formulating of IPM (integrated pest management) strategies for banana and cereals using agronomic practices and habitat management complemented with biological control.

Major advances have also been made in the control and management of disease vectors such as ticks, mosquitoes and sandflies. More recent projects deal with the promotion of neem and other botanicals as cost-effective and environmentally friendly alternatives to synthetic pesticides. These technologies are being applied in partnership with national institutions and rural communities; for the management of crop borers and tsetse in Kenya and Zambia, and for the management of disease vectors in refugee camps in Ethiopia and northern Kenya. The most important aspect of ICIPE's activities, although not always so obvious since it is embedded within overall strategies, is the Centre's research into the basic understanding of the arthropods' biology and ecology which underpins sustainable solutions to pest problems.

The challenge, however, remains daunting. Pests still destroy an average of 40% of world food production, and this despite an ever larger amount of global pesticide use. Human and animal vector-transmitted diseases are on the rise too, despite the use of pesticides, therapeutic drugs and vaccines. Arthropods have demonstrated a relentless ability to develop resistance to almost any form of synthetic pesticide, thanks to their huge reproduction potential and due to the static nature of non-biological control agents.

With the increasing need for food over the next 25 years for a steadily growing population, and the difficulties in achieving new and substantial yield increases through breeding and agronomic practices, it is becoming even more important to reduce both pre- and post-harvest losses. While food quantity is important, quality should remain the second most important objective. In particular, the production of nutritious, pesticide residue-free food is needed so as not to endanger the health of the consumer nor the agricultural production base through indiscriminate use of chemicals.

ICIPE has recognised that many of its activities in pest control in the past were overlapping with those of the Centres of the Consultative Group on International Agricultural Research (CGIAR). Consequently, ICIPE has now re-oriented its research agenda toward areas long neglected in Africa and to a lesser degree in the tropics as a whole. For example, one new focus is on horticultural crops (vegetables, fruits and ornamentals). Because these plants are the target of so many arthropod pests, they are subject to the largest abuse of pesticides, the latter being enhanced by their high market value and the demand for 'cosmetic' produce. The pesticide abuse on vegetables in particular poses a great risk to consumer health and requires urgent attention.

The ban in the North and the progressive phasing out in the South of methylbromide used in fumigation of horticultural products is opening new opportunities for the use of biological and behavioural management tools for arthropod control. ICIPE, with its experience in relevant research areas, is well placed to tackle this challenge on a global scale. The adoption of the IPM approach in horticultural crops is expected to increase the income of the producers of 'green label products', at the same time possibly advancing the phasing-out time in the South of the ozone-depleting methylbromide.

Pests management in food crops mandated by the CGIAR remains on ICIPE's agenda only as topics for joint projects, where ICIPE will provide components for IPM based on its comparative advantage in the area of

semiochemicals, behaviour, ecology, biological control, biochemistry, biotechnology and social sciences. A further activity to be revamped under a collaborative agreement with the CGIAR, and with other international agricultural research centres (IARCs), national research centres (NRCs) and NGOs is PESTNET, a collaborative network for the implementation of pest and disease vector management strategies, now operating in ten African countries.

ICIPE is opening up to the world and to its constituency in the tropics, in particular. Developing South-South partnership, for example through PESTNET, is one of the major goals for the next five years. The Centre also has a major role to play in becoming the gateway for North-South partnership in arthropod sciences. The foundation for this has been laid by the PhD degree training programme started jointly at ICIPE in 1983, initially with a consortium of African universities, but soon to be extended beyond Africa.

Arthropods make up some 75 percent of the world's biodiversity and most of them play a key role in sustaining life on earth. Only a few, however, are pests or disease vectors, and the time has come now to seriously look at the other side of the coin, i.e. at the positive contributions of arthropods, and how to conserve them through better understanding and utilisation, key words of the United Nations Conference on Environment and Development (UNCED) 1992 Rio Conference. ICIPE is therefore investigating the usefulness of arthropods in the agroecosystem and their potential for income generation in Africa, in particular.

Two insects are especially important in this context: honeybees and silkworms. Both have been providing man with food, drugs and renewable fibres since early civilisation. Africa, with few exceptions, has not benefited from these ancient arts; although beekeeping is carried out, it is mostly done with inefficient and environmentally unfriendly methods. It is now time to tackle both topics and provide willing farmers and entrepreneurs with the necessary scientific basis for bee- and silkworm-based industries to take off. ICIPE is committed to developing the appropriate know-how, from insect rearing to product marketing, with selected partners. Activities such as apiculture and sericulture can become income generating options in a larger strategy for poverty alleviation, particularly for women and rural communities.

Another example of the usefulness of arthropods is demonstrated in the many highly successful biological control programmes which use one organism to control another. Within the framework of the IARCs' IPM Working Group, ICIPE has been assigned the role of lead institution in coordinating research on functional agrobiodiversity. Arthropods also play an important, but neglected, role in soil fertility maintenance and regeneration. ICIPE is proposing research in this area in collaboration with other IARCs to address the sustainability issue of production systems. Arthropods are also potentially useful tools for monitoring of overall biodiversity and as early and very sensitive indicators of changes in the environment. The latter is a promising and primordial field of research in the global undertaking on environmental protection and conservation of the natural resource base.

Consistent with its mission, ICIPE will not only develop new technologies but will also provide the enabling environment to get them off the ground. A science park is being planned, where the research outputs from ICIPE, NRCs and other IARCs will be transformed into innovative arthropod management products in partnership with the private sector. The arrangement, with its potential for income generation in an era of dwindling funding, is also designed to benefit ICIPE.

All of the above-mentioned activities require an institution with the appropriate structure and a strong set of collaborators and partners from the international, regional, national and non-governmental sectors. The restructuring exercises which the new ICIPE is still undergoing have been specifically designed to prepare the Centre for the new tasks ahead. Administration and management have been trimmed and the research and capacity building programmes reorganised and strengthened into an interactive matrix with six scientific departments and three research programmes. In this matrix, the projects are the actual working entity, with specific objectives, activities, output and lifetime.

ICIPE's plans for the future are realistic and address the real problems of the real world; and, they have been developed in consultation with the potential users. Contrary to the much-heralded opinion of many donors, the shelves of the technology stores are *not* full with products gathering dust. Even if they were, there would still be a need for research today, since the needs of tomorrow are addressed by the research of today. With its emphasis on capacity building and end-user participatory research, ICIPE is mindful that research is a means to an end, a means to improving the lives of millions of inhabitants of the tropics who suffer from food shortages, poverty and disease, all areas where well targeted and relevant research will bring the much needed relief.

I am therefore appealing to all concerned parties, the donors and their constituencies in the North, as well as the political leaders of the South, to react now with vigour and generosity and to support the activities of scientists in institutions such as ICIPE concerned with the most basic of human needs: food, health and education.

Hans R. Herren

(This Message was first published in the 1994 ICIPE Annual Report *of October, 1995.)*

Plant Pests Management Programme

Plant Pests Management Programme

PROGRAMME OVERVIEW

by S. Sithanantham, Programme Leader, 1995*

Food security in the generally fragile ecosystems of the tropical world is becoming increasingly linked to the adoption of appropriate interventions to enhance productivity as well as to ensure crop protection. There is also an emerging realisation by researchers and donors alike that, while it is of importance to identify or develop effective interventions through strategic and applied research, it is equally important that their appropriateness and adaptability is also taken into account during technology development if these research recommendations are to find adoption by the multitude of resource-poor farmers.

ICIPE's Plant Pests Research Programme has responded effectively to these emerging concerns through a balanced and integrated approach of linking its upstream research specialities with 'problem solving' multi-disciplinary research themes. At the same time, the programme is involved in adaptive research and social science interfacing focused on refining, adapting and disseminating the technologies.

External collaboration, both nationally and internationally, has been reinforced this year in capacity building and networking activities, involving linkages with the NARS.

ICIPE's focus in 1994 continued to be the development and application of environment-friendly as well as socioeconomically appropriate strategies, so as to culminate in biointensive and sustainable insect pest management on tropical food crops, especially maize, sorghum, banana and cowpeas. The emphasis once again in 1994 was on the appropriate and effective use of pest-resistant crop cultivars, biological control, cultural practices and botanicals. In addition, habitat management and other supplementary insect behaviour manipulation tactics are being investigated. Applied ecology, behavioural biology, chemical ecology and social sciences interfacing were the major disciplines involved in developing and improving the components.

Crop loss assessment and pest monitoring

In a further step towards developing simple-to-follow action thresholds for the spotted stemborer, *Chilo partellus*, validation experiments were conducted at the Mbita Point Field Station (MPFS) in western Kenya and the Muhaka Field Station in coastal Kenya which enabled evolving a 'rule of thumb' threshold of about 15 plants per 100 (15 percent) as the level of pest infestation justifying control action. The refinement of this threshold on the basis of input/output costs will have to be undertaken locally by periodical updating of prices. This rapid sampling technique will allow farmers to make their own decisions on interventions without external guidance, by periodical scouting of a small proportion of plants in their fields.

In addition, behavioural biology studies in coastal Kenya on pheromone trapping of two locally common stalkborer species, *Chilo partellus* and *C. orichalcociliellus*, showed that it should be possible to effectively catch both species in traps baited with a blend of the two major pheromones. The assessment of population patterns by such trapping was shown to be adequately accurate and realistic in western Kenya. Comparative studies on two types of pseudostem traps for the banana rhizome weevil, *Cosmopolites sordidus* also led to standardising a circular disc trap.

Exploiting natural resistance of crops to insects

Over the last decade, ICIPE has been collaborating with CIMMYT (maize), ICRISAT (sorghum), and IITA (cowpeas), on a range of areas directed at understanding and exploiting the naturally occurring resistance/tolerance to insect pests in crop cultivars and genotypes. This year, further selection among several genotypes of

sorghum which had showed combined resistance to *Chilo partellus* and the shootfly was completed and the promising genotypes advanced for yield testing in large plots.

Adaptive testing of the pest resistant/tolerant genotypes of maize, sorghum and cowpea which had been identified or developed at ICIPE in recent years was intensified in coastal Kenya in close collaboration with Kenyan NARS. Farmer-participatory on-farm trials have clarified the potential acceptability of a few genotypes of maize (IC92M4, IC92M5, ICZ5), sorghum (Gaddam, ICS3, Driv 1) and cowpeas (ICV2, ICV3, ICV11 and ICV12). Most of these were also verified for their nutritional quality and consumer acceptability. The Kenyan NARS have incorporated many of the improved varieties into their national testing programmes for further evaluation and appropriate utilisation.

The banana cultivars which showed acceptable levels of resistance to the rhizome weevil, *Cosmopolites sordidus* along with satisfactory yield potential, have been re-tested and planting materials provided to farmers through the NARS in Kenya, Uganda and Tanzania. In addition, several genotypes with combined resistance/tolerance to the rhizome weevil and the banana nematode, *Pratylenchus goodeyi* have been identified among the major classes of highland banana germplasm. In its further research, ICIPE will seek to tie in more closely with other IARCs such as in the partnership in the recently launched regional IITA initiative on IPM of bananas. By this process, ICIPE's facilitation role in adapting the available sources of natural resistance to the needs of national ecologies and circumstances of the target-farmers of the African region through collaboration with regional NARS and IARC programmes in the region, would be effectively fulfilled. In this endeavour, the interfacing of social science aspects has been reckoned as a vital and valuable component.

Biological control

An important milestone in biological control of cereal stemborers was reached when it became evident that the exotic Asian stemborer parasitoid, *Cotesia flavipes* had been established in two ecological zones in Kenya. On the Kenya coast, *C. flavipes* could be recovered from three stemborer species feeding in maize and in wild grasses, while in eastern Kenya it was recovered from the exotic stemborer, *Chilo partellus*. The parasitoid was recovered as far as 20 km from the release sites. Comparative life table studies with the native stemborer parasitoid *Cotesia sesamiae* showed that the exotic parasitoid species *C. flavipes* had a higher intrinsic rate of population increase, which suggests the greater potential of the latter to respond to increases in the pest (stemborer) populations. Biosystematic studies have shown that *C. flavipes* may not be monophyletic; this biological diversity could open up opportunities for its exploitation in other regions of Africa and elsewhere. Several sources of attractants for adult *C. flavipes* have been isolated and identified; these may be useful in developing trap monitoring systems for the parasitoid.

On-farm evaluation of spray formulations of an efficient indigenous strain of *Bacillus thuringiensis (Bt)* in coastal Kenya was undertaken on maize and sorghum which led to validation of its usefulness in reducing the damage by the stalkborers.

Modifying farming practices

ICIPE's agroecologists and IPM specialists continued their search for newer options in cultural practices and adjustments in present practices that can provide an effective reduction in pest severity and contribute to minimising the crop losses caused by insect pests.

Strategic research was focused on the potential for utilising crop diversity as well as for non-traditional cropping system alternatives. Exploratory field experiments at Mbita showed that stalkborer infestation in sorghum was significantly reduced when it is grown as a companion crop with cowpea and cassava, as compared to other crop combinations or sole cropping. Verification trials confirmed that cassava can effectively divert oviposition by *Chilo partellus*, leading to reduction in the pest severity in adjacent strips for sorghum. The scope for the common bean as a replacement for cowpea in strip cropping system was also verified.

In coastal Kenya, on-farm verification of 'strip-relay cropping' for pest management as well as yield benefits was completed. This new cultural practice developed by ICIPE scientists was shown to significantly reduce the stemborer density on sorghum/maize, with a concurrent enhancement of land use intensity and multiple cropping index. Refinement of this model by farmers so as to suit their particular needs for food and income is being undertaken in the next phase.

Botanical control

The usefulness of simple neem derivatives in reducing pest infestation and enhancing the crop yields or biomass was demonstrated in a range of target crops and areas. The target pests included stalkborers on cereals (maize, sorghum) and thrips on cowpea. Neem cake applied at 3 g/plant was found to effectively control maize stalkborers leading to significant increases in grain yields. Another important finding was that the efficacy of neem

cake, stored for one or two years was comparable to that of freshly prepared material for control of stalkborers. Farmers can therefore now be encouraged to store neem seeds and use them as required, without fear of loss of efficacy. In cowpeas, spraying neem seed extract (NSE) at a range of concentrations (5%, 10% and 20%) showed that thrips infestation was significantly reduced; grain yields also increased significantly. Initiatives for popularisation and demonstration of the usefulness of neem were intensified.

Towards better understanding of pest behaviour

Ethological studies on cross attraction between adults of the two stalkborer species occurring in coastal Kenya, *Chilo partellus* and *C. orichalcociliellus*, showed remarkable differences in the response of males of one species to the females of the other species. While males of *C. partellus* responded positively to females of *C. orichalcociliellus*, males of the latter nearly ignored the females of the former. Complementary cross mating studies among the two species showed corresponding responses. These studies have clearly shown that there is considerable but non-symmetrical overlap in communication systems between the two species. The ecological and practical consequences of these responses are to be studied further. The age-dependant mating performance of *C. partellus* adults was also investigated, and it was evident that younger males tended to prefer older females while older males seemed to seek younger females. This behavioural attribute will be taken into account in reproduction-related manipulations.

Habitat dynamics of stemborers among wild hosts and cultivated cereals

ICIPE launched another ecologically strategic and multifaceted project on the role of wild habitats in the invasion of cereal crops by stemborers in Africa, with special reference to *Chilo partellus* and *Busseola fusca*. The major goal of the project is to develop a sustainable integrated pest management approach through enhanced understanding of the multiple interactions among cultivated crops, wild hosts, various stemborer species and natural enemies affecting the dynamics of pest populations. It may be possible to identify wild grasses which could be selectively utilised by farmers as trap crops for stemborers and also as reservoirs and shelter for the natural enemies of the borers.

Several wild host plants for the various stemborer species *(Chilo partellus, Busseola fusca, Sesamia inferens* and *Eldana saccharina)* have already been identified. Among six host plants tested against *Chilo partellus*, cultivated sorghum followed by wild sorghum were found to be preferred for oviposition and more suitable for larval development than maize, *Hyparrhenia rufa, Panicum maximum* and *Pennisetum purpureum*. Periodical monitoring of the parasitoids occurring on stemborers across host habitats has been initiated and the information gleaned will be used for possible manipulations towards enhancing biocontrol effectiveness. Studies have also been initiated towards identification and evaluation of behaviour-modifying chemicals from cultivated and wild hosts and non-host plants for stemborers and their natural enemies.

Locusts: preventing the plagues

ICIPE's approach to desert locust (*Schistocerca gregaria*) control over the past few years has concentrated on developing methods for physiological, behavioural and ecological disruption of the swarming process and on methods for biological control using locust pathogens. Once again this year, chemical ecology studies of the desert locust provided several new pieces in the puzzle of locust behaviour. From previous work, it is now known that the pheromone system of the gregarious desert locust is a complex mixture of volatiles emitted by different developmental stages of the insect and their waste products. The pheromone system of mature adults was characterised by chromatographic, electroantennographic, spectroscopic and behavioural assays as a blend of four aromatic compounds. One of these compounds which disrupts aggregation in the nymphal stages is now the subject of intensive field studies.

Recent investigations of the volatiles produced by the fifth-instars has revealed 18 electrophysiologically-active compounds which have been isolated and characterised as linear aliphatic compounds. These are now the subject of detailed behavioural assays. Wind-tunnel studies on the sex attraction in solitarious locusts have demonstrated that adult male solitarious desert locust are attracted to volatiles emanating from females of the same species. Out of three electrophysiologically active components isolated from female volatiles, one has been fully characterised and is currently the subject of detailed behavioural assays.

Other studies are looking at the chemicals produced by the locusts themselves or by their environment that influence maturation, simultaneous egg-laying and mating behaviour. Some of these may find use in preventing swarm formation by causing confusion or preventing aggregation.

The egg froth of the locust egg pods has been shown by ICIPE scientists to contain a pheromone that stimulates aggregation of the females and oviposition at a common site. This year, two major GC-electrophysiologically active peaks from froth volatiles were identified as acetophenone and veratrole. These compounds may find use in attracting the locusts to a fairly small egg-laying site where they can be controlled through localised application of pesticides or by one of the biological control agents such as those under test, as described below.

Several biological control agents have been considered for use in regulating locust populations and preventing swarm formation. Results from ICIPE's three-year project on the use of pathogens for desert locust management came to an end in 1994, but several notable results have been obtained that now require field testing.

The protozoan *Malamoeba locustae* caused a gradual decline in desert locust populations, as well as lowering the fertility of females through delaying oviposition or disrupting the reproductive system. The pathogen, which is transmitted from one generation to the next through trans-ovarian infection, also causes a decrease in fecundity and longevity. The mortality life table analysis suggests that a chronic infection with the protozoan would eventually retard the locust population, even under conditions otherwise favourable for reproduction.

The fungal pathogen, *Beauveria bassiana* was also found to be an efficient biocide, being pathogenic to all stages. The LT_{50} of the fungus was shortened from 15 to 10 days by formulating it with UV protectants in corn oil. Mortalities of up to 85% were recorded with the formulated product.

The efficacy of the individual pathogens as biocontrol agents was improved by combining them. A broad-range biocide of protozoal origin has been developed by criss-crossing it between two hosts: *Locusta migratoria* and *Schistocerca gregaria*.

Working with social scientists for improving the appropriateness and sustainability of technologies

Plant pests research scientists worked in close collaboration with ICIPE's social scientists this year in two adaptive research projects in coastal Kenya. In the Kwale-Kilifi Adaptive Research Project, jointly implemented by ICIPE and the Kenya Agricultural Research Institute (KARI), the focus was on assisting the reduction in yield loss as well as the yield benefits of using pest-resistant genotypes of maize and sorghum under farmers' own management. Under the Interactive Socioeconomic Research for Biointensive Pest Management (ISERIPM) project, the biological scientists assisted in implementing researcher-managed on-farm evaluations of pest resistant genotypes of maize and sorghum, strip-relay intercropping and the use of the insect pathogen, *Bacillus thuringiensis*.

Network linkages and capacity building

In addition to the PESTNET linkages with KARI, the ICIPE resident scientist based in Zambia under PESTNET (Pest Management Research and Development Network) completed a significant research and training contribution to the Zambian host NARS in applied pest management research, particularly on stemborers.

Plant Pests Research scientists actively participated in both in-country and international short training courses organised by ICIPE and other institutions in the region. In addition, they supervised doctoral and postdoctoral trainees in various topics related to ICIPE's mission.

*(*1994 Programme Leaders were K. V. Seshu Reddy, Crop Pests Research Programme and S. El Bashir Mohamed, Locusts Research Programme.)*

CROP PESTS RESEARCH

I. IPM Strategies for Crop Pests

The biointensive integrated pest management (BIPM) approach includes an integrative application of host plant resistance, habitat management strategies, biological control, botanical control and supportive tactics such as the application of pheromonal biology and crop loss assessment. In 1994 ICIPE's Plant Pests Management Programme concentrated on the major food crops maize, sorghum, cowpea, banana and their insect pests.

1. HABITAT MANAGEMENT TECHNOLOGIES FOR INSECT PESTS

Participating scientists: *K. Ampong-Nyarko*, K. V. Seshu Reddy (*Project Coordinator)*

Assisted by: *S. O. Paye, D. O. Nyagol, I. O. Odhul*

Donor: *ICIPE Core Funds*

Background

Research on habitat manipulation approaches to insect pest management aims at improving crop health by reducing insect pest density and damage through a better understanding and management of the agroecosystem and integrating the various insect management technologies. Research in this area started with intercropping but over the last year has evolved to provide the ecological understanding required to manage the agroecosystem for suppressing insect pests.

Work in progress

1. Functional mechanisms in agroecosystems

The objective of this activity is to determine the mechanisms and interrelationships between the crop, the pests, natural enemies and the environment.

Agroecosystem characterisation: Effect of crop diversity

The effect of crop diversity on stemborer population dynamics was studied in the short rains of 1994. Treatments consisted of monocultures of maize, sorghum, cowpea, cassava; dicultures (maize + sorghum, maize + cowpea, maize + cassava, sorghum + cowpea, sorghum + cassava); tricultures (maize + sorghum + cowpea, maize + sorghum + cassava, maize + cowpea + cassava, sorghum + cowpea + cassava); four crop cultures (maize + sorghum + cowpea + cassava). Increasing complexity in crop diversity did not necessarily lead to increased pest suppression. There was, however, the indication that certain combinations were more effective than others. Sorghum + cowpea + cassava gave a 12.5% incidence of stemborers compared to sorghum + maize + cassava (36.3%). Parasitism of *Chilo partellus* was low (3%) and also did not increase with increasing complexity of diversity.

Agroecosystem characterisation: Crop characteristics

Several crop characteristics such as permanence of vegetation, crop duration, susceptibility/resistance, and long/short duration affect the regulation of insect pests in agroecosystems. The objective of this exploratory study was to establish some crop characteristics that regulate pests. An experiment initiated in the 1994 short rains consisted of a factorial combination of two maize cultivars (long duration, H-511; short duration Katumani Composite) intercropped with cassava of two different growth stages (5 months old standing cassava crop and cassava planted simultaneously as maize) with maize monocrops as control in single alternate row arrangements. At 6 weeks after emergence, significantly less stemborer damage was observed in maize intercropped in the five-month-old cassava (4%) compared with the maize and cassava simultaneous planting (22%). However, excessive shading occurred which reduced maize yields when intercropped in the 5-month-old cassava.

Further studies will be initiated to unravel the underlying ecological principles and the manipulation of cropping arrangement to improve maize yields.

Tritrophic interactions in intercropping systems

The effect of cropping patterns on natural enemies of stemborers was monitored weekly in the crop diversity experiment. Parasitoids were observed by rearing all larvae from third instar and pupae in the laboratory

until adult emergence. Various trapping techniques were used to evaluate natural enemies. The level of parasitism was generally low in both intercrops and monocrops. The parasitoids recovered from stemborers were predominantly *Cotesia sesamiae* and a few *Dentichasmias busseolae*.

2. *Design of novel insect-suppressing cropping system alternatives*

The objectives of this activity are to design cropping pattern alternatives which increase productivity and cropping system intensification and suppress insect pests.

Improvement in design of strip cropping

The influence of row-ratios in strip cropping as a means of controlling insect pests and increasing grain yields have been established for sorghum-cowpea cropping systems. The concept of strip relay cropping is also being investigated in the ISERIPM Project at the Kenya coast with cowpea. Experiments were conducted in the long rains of 1994 to examine the use of early maturing legumes such as beans in maize/beans strip relay cropping. The treatments consisted of strips of maize + beans followed by beans in the long rains, strips of maize + beans and single alternate row arrangement of these with monocrops of maize and beans. Insect pressure was low during the season but the indication is that beans will be a much better alternative to cowpea in areas where beans are adapted.

Non-traditional cropping system alternatives for the management of insect pests

The use of leguminous cover crops was examined as a possible cropping system for management of stemborers of maize. This study was conducted in the long and short rains of 1994. Treatments consisted of intercropping of maize ICZ3 with low and high densities of silver leaf (*Desmodium* spp.), groundnuts, bambarra (*Voandzeia subterranae*), maize mono crop with weeds background, strip cropping of maize and cowpea and monocrops of maize and cowpea. The silver leaf, groundnut and bambarra were planted one week before planting of maize. During the short rains maize was planted into silver leaf cover crop established in the long rains. In the long rains, at five weeks after plant emergence (5 WAE) all intercrops except bambarra gave significantly lower stemborer incidence than the maize monocrop. Bambarra had a high incidence of *C. partellus* due to its initial slow growth. Planting maize in already established *Desmodium* cover in the second cropping season gave a dramatic reduction in stemborer incidence and damage. At harvest the percent damaged plants was 18% for the *Desmodium* whilst the average for the other treatments was 70%.

More studies will be required on the management of the cover crop in the second cropping before the full pest suppressing potential can be realised.

Relative contribution of different IPM components to insect pest reduction and yield increase

As a follow-up of 1993 study an experiment was conducted at Ogutu's field, MPFS to determine the relative effectiveness of strip cropping, resistant maize cultivars, *Bacillus thuringiensis* (*Bt*) and neem to insect suppression and increased yield. Due to very low incidence of stemborers, no differences could be observed among treatments.

Completed studies

Ampong-Nyarko K., Seshu Reddy K. V. and Saxena K. N. *Chilo partellus* (Swinhoe) (Lep., Pyralidae) oviposition on non-hosts: A mechanism for reduced pest incidence in intercropping. *Acta Oecologica*, 15(4), 469–475.

Field and screenhouse experiments are employed to study the ovipositional behaviour of *C. partellus* in maize-sorghum-cowpea, sorghum-cowpea and maize-cassava intercropping systems. *Chilo partellus* gravid moths oviposited about a third of the total eggs on the non-host crop cowpea or cassava. The oviposition on non-host crop was dependent on intercropping with host crops. The eggs were able to hatch on cowpea but the number of neonate larvae that arrived on the sorghum host diminished with distance. There was no difference between the number of eggs laid on cowpea plants at 22 cm and at about 315 cm away from sorghum. *Chilo partellus* oviposition on non-host crops is one of the mechanisms for its reduced abundance in intercropping.

Ampong-Nyarko K., Seshu Reddy K. V., Nyang'or R. A. and Saxena K. N. Reduction of insect pest attack on sorghum and cowpea by intercropping. *Entomologia experimentalis et applicata* 70, 179–184.

Two experiments to establish the relationship between insect suppression by intercropping and grain yield in sorghum and cowpea were conducted under field conditions. Treatments consisted of monocrops and intercrops of sorghum and cowpea and an additional pair of monocultures and mixtures protected by insecticides. Intercropping reduced the number of stemborer, *Chilo partellus* in sorghum and thrips, *Megalurothrips sjostedti* in cowpea. The monocropped, unprotected sorghum yield was reduced by 28% compared to the protected monocrop, while reduction in the unprotected intercropped sorghum was 15% compared to the protected intercrop. Similarly, in the unprotected cowpea, monocrop yield was reduced by 94% and intercrop yield was reduced by 51%. Thus, there is reduction in yield loss under conditions where intercropping reduces insect pest density. Intercropping can form a component of an integrated pest management programme.

Ampong-Nyarko K., Nyang'or R. A., Saxena K. N. and Seshu Reddy K. V. Compatibility of intercropping stemborer resistant sorghum, *Sorghum bicolor* Moench genotypes with cowpea *Vigna unguiculata* (L) Walp and its effect on flower thrips. *Tropicultura* 12(1), 10–14.

The compatibility of sorghum, *Sorghum bicolor* Moench genotypes with varying levels of resistance to stemborers for intercropping was studied in field experiments for two cropping seasons at the ICIPE in Kenya. Sorghum genotypes IS-1820, IS-1044, IS-22069, ICS-3, ICS-4, LRB-6, 2Kx17 and Gaddam El Hamam were grown both as monocrops and as intercrops with cowpea. Intercropping reduced the *Chilo partellus* population density but there was no significant

genotype x intercropping interaction. Intercropping significantly reduced the number of flower thrips *Megalurothrips sjostedti* in cowpea *Vigna unguiculata* (L) Walp. The stemborer resistance level of sorghum genotypes tested was not affected by intercropping. There were, however, differences in agronomic productivity. Grain yield of intercropped sorghum was positively correlated with the number of tillers per harvestable head. Sorghum genotypes with high tillering capacity, of intermediate plant height and intermediate leaf area were considered compatible for intercropping with cowpea.

Harahap Z., Ampong-Nyarko K. and Olela J. C. *Striga, hermonthica* resistance in upland rice. *Crop Protection* 12, 229–231.

Upland rice breeding lines were evaluated in field trials for resistance to the obligate hemi-root parasite *Striga hermonthica* at two sites in Kenya in 1990 and 1991. The lines differed in their reaction to *S. hermonthica* ranging from highly resistant to extremely susceptible. IR 49255-B-B-5-2, IR 38547-B-B-B7-2-2, IR 47255-B-B-5-4 and Ble Chai were confirmed resistant to *S. hermonthica*. The indication is that the gene for resistance to *S. hermonthica* is widespread in rice.

Other publications

Ampong-Nyarko K. Weed management in tropical cereals: maize, sorghum amd millet. In *Weed Management for Developing Countries* (Edited by Labrada R., Caseley J. C. and Parker C.), pp. 264–270. FAO Plant Production and Protection Paper No. 120.

Ampong-Nyarko K. Weed management in cowpea. *Ibid.* pp. 277–281. FAO Plant Production and Protection Paper No. 120.

Ampong-Nyarko K. Weed management in tropical roots and tubers: yam, cocoyam, cassava and sweet potato. *Ibid.* pp. 301–308. FAO Plant Production and Protection Paper No. 120.

Pathak M. D. and Khan Z. R. *Insect Pests of Rice*. International Rice Research Institute, Manila, Philippines and International Centre of Insect Physiology and Ecology, Nairobi, Kenya, 89 pp.

The world rice crop is attacked by more than 100 species of insects; 20 of them can cause economic damage. Insect pests that can cause significant yield losses are stemborers, leafhoppers and planthoppers, gall midges etc. The book includes updated information on biology, damage, seasonal history and factors of abundance, and control measures of the major insect pests of rice. The book is published jointly by IRRI and ICIPE.

Smith C. M., Khan Z. R. and Pathak M. D. *Techniques for Evaluating Insect Resistance in Crop Plants*. CRC-Lewis Press, USA, 320 pp.

Growing of insect-resistant crop varieties has led to major increases in food production in many tropical developing countries of the world. The varieties have played an important role in the 'Green Revolution' in south and Southeast Asia. During the development of these and many other varieties, several entomological techniques and methods were developed for evaluating insect resistance. These techniques were developed to measure the levels of insect resistance, as well as to elucidate the morphological and chemical bases of insect resistance in crop plants. Many of these techniques made use of existing technologies, but in several instances, new technologies have been developed to help identify and quantify insect resistance to crop plants. As plant breeding programmes involving insect resistance have expanded, all of these techniques have been invaluable in detecting insect resistance in crop plants. Unfortunately, published and unpublished records on these techniques are scattered and are often not easily available to scientists working in developing countries. The purpose of this book is to serve as a comprehensive overview of the entomological techniques and to demonstrate how each has been utilised to evaluate insect resistance in plants. This book is the first effort in over 40 years to catalogue the variety of techniques on plant resistance to insects.

Demayo C. G., Barrion A. A., Saxena R. C.* and Domingo I. T. Cytological and allozyme variation in the green leafhopper, *Nephotettix virescens* (Distant) populations adapted to rice with different *Glh* genes for resistance. *Philippine Entomologist* 9(3), 302–312.

Demayo C. G., Barrion A. A., Saxena R. C.* and Domingo I. T. Genetic differentiation in local populations of the rice green leafhopper, *Nephotettix virescens* (Distant). *Philippine Entomologist* 9(3), 313–323.

Demayo C. G., Barrion A. A., Caoile A. G., Tudor V. A., Khan Z. R., Saxena R. C.* and Angeles A. T. Variability in two species of rice leaffolders from the Philippines. *Philippine Entomologist* 9(3), 324–349.

Liu G., Saxena R. C.* and Wilkins R. M. Behavioural responses of the whitebacked planthopper, *Sogatella furcifera* (Homoptera: Delphacidae) on rice plants whose odors have been masked. *Journal of Insect Behaviour* 7(3), 343–353.

*(*ICIPE authors are starred)*

2. ASSESSING CROP LOSSES

Participating scientists: *K. V. Seshu Reddy, K. Ampong-Nyarko*

Assisted by: *D. O. Nyagol*

Donor: *ICIPE Core Funds*

Background

The objective of crop loss assessment is to improve BIPM by enhancing decision support systems. In 1993, a mathematical model was developed that quantitatively relates the proportion of plants infested with larval population density and grain yield. This formed the basis for a rapid sampling technique initiated in 1994. A validation experiment was carried out at Muhaka field site in the long rains and at Mbita Point Field Station (MPFS) in both the long and the short rains. Treatments consisted of a factorial combination of proportion of plants infested (10, 20, 30, 40, 70, 100%) and time of infestation (2, 4, 6 weeks after plant emergence) plus uninfested control. The plants were artificially infested with 10 *C. partellus* larvae at the appropriate time. Earlier infestation or reinfestation was avoided by growing plants under screens at MPFS or the use of insecticide

under farmers field. Based on the price of the produce, the point when 15% of plants show damage symptoms appears to be a good time to take control measures. This rapid sampling technique will allow farmers to decide if the economic threshold has been reached by sampling only a few plants in each field.

3. IMPROVEMENT AND DEVELOPMENT OF MAIZE FOR RESISTANCE TO STEMBORERS

Participating scientist: *S. O. Ajala*

Assisted by: *P. M. Chiliswa, P. O. Omolo*

Donor: *ICIPE Core Funds*

Background

A complex interaction of several factors determines resistance/susceptibility of maize to stemborer attack. These factors vary from morphological and biophysical to biochemical in nature and result in varying levels of colonisation/damage by the insect and grain yield loss.

Selection for reduced level of grain yield loss would have been a desirable approach to breeding for resistance to stemborers, but grain yield itself is a complex character, being the end product of several intermediate events. Therefore, ability of the host plant to withstand or tolerate a stress factor at the appropriate phenological stage of development would affect grain yield loss. For the stemborer *Chilo partellus*, damage occurs to the plant when the early instar larvae commence feeding upon hatching within the leaf whorls, causing foliar lesions or deadheart if the feeding extends to the meristematic region. Extensive stem tunnelling occurs when the larvae feed within the stem as the plant grows older and the leaves unfurl.

Consequently, it is desirable to determine appropriate stages of growth to evaluate for different types of resistance and/or the different resistance parameters to select for upon the application of appropriate weighting factors. Our efforts in the year under review were thus directed towards a basic understanding of the phenomena mentioned above for their practical utility.

Work in progress

Mode and time of infestation for discriminating amongst genotypes

Earlier studies had concluded on the use of about 30 first instar larvae (30 L1) of *Chilo partellus* introduced into the leaf whorl at about three weeks after plant emergence (3 WAE) to effectively discriminate between resistant and susceptible genotypes. However, such efforts were based on the use of egg masses approximated to the number of desired larvae or actual counting of the number of required larvae. Apparently, the former approach is fraught with errors, while the latter would be very tedious to use for screening a large number of genotypes. An experiment was therefore designed to determine the best time and method of larval infestation for large-scale screening purposes. The times considered were 2, 3 and 4 WAE while the mode of infestation was the use of eggs at the blackhead stage of development, to give approximately 30 L1s, physical counting of 30 L1 larvae into the leaf whorl and a standardised mechanical larval dispensing device 'Bazooka' using maize cob grit as carrier.

Initial results obtained from trials across two locations on four differently maturing maize genotypes indicated that infesting at 2 WAE was less reliable for distinguishing genotypes as it tends to cause more of deadheart, especially among the early maturing genotypes. Infesting at 4 WAE however, was rather too late as it tends to discriminate more for leaf feeding than for stem tunnelling. It seems, therefore, that infesting at 3 WAE as earlier observed would be more appropriate for distinguishing between resistant and susceptible genotypes. Also, the use of 'Bazooka' gave comparable results with physical counting of 30 L1s at 3 WAE and thus suggests that mass screening for *Chilo partellus* is feasible using 'Bazooka'.

Selection for tolerance

An attempt at selecting for reduced levels of damage, especially foliar damage and stem tunnelling and reduced yield loss due to these damages, was continued in two maize progeny types. The rank mean index (RMI) obtained from a multivariate statistical approach-cluster analysis was compared with the performance index (PI) combining damage parameters and grain yield, that is

$$PI = a\,[Yu]\,[Damage] - 1$$

which represents grain yield weighted by the damage levels. The value of 'a' is determined by the level of damage the plant can tolerate with no significant yield loss and/or loss in aesthetic value.

The 27 and 13 selections identified by PI from the two progeny types were also a major part of those selected by RMI. In effect, PI as a measure of our type II tolerance, which is reduced grain yield loss despite damage, would be adequate for selection purposes. However, to improve on the practical utility of the index for rapid screening, PI as proposed would still have to be correlated with a morphological or biochemical parameter that can be determined readily early in the life of the plant. Therefore, the use of relative levels of a chemical compound or marker-assisted selection if linked to PI needs to be considered.

Progress from recurrent (mass) selection

The original (C0) and improved cycles (C1 to C3) of selection from two maize populations of Poza Rica 7832 and MMV 400 were evaluated under artificial infestations to estimate progress from selection to reduced leaf and stalk feeding by larvae of *C. partellus*. Results obtained from an earlier evaluation of C0 to C2 from the two populations suggested that progress due to mass selection

was slow and may require an additional phase of S1 testing before recombination. However, evaluation of an additional cycle (C3) in this study reveals that changes in gene frequencies are indeed occurring in the desired direction and that selection for reduced damage levels only required more cycles to reach significant levels. Thus, mass selection that utilises two seasons per cycle as opposed to S1 testing that would require three seasons/cycle may still be desirable in the long run by having net gain especially in a situation of two natural seasons per year.

Line extraction

Extraction of resistant lines of different generations of inbreeding continued in pedigree nursery. Three hundred and forty (340) lines at the S3–S6 stage are currently being screened. Although our interest is not in a hybrid programme *per se*, we intend to make sure that our lines have good combining abilities and that they could find immediate usefulness in some national programmes. Testcross tests of the desirable and selected lines will continue to be carried out.

Completed work

Ajala S. O. Maize (*Zea mays* L.) stem borer (*Chilo partellus* Swinhoe) infestation/damage and plant resistance. *Maydica* 39, 203–205.

Ajala S. O., Saxena K. N. and Chiliswa P. Selection in maize (*Zea mays* L.) for resistance to the spotted stem borer (*Chilo partellus* Swinhoe) attack. *Maydica* (in press).

4. DEVELOPMENT OF SORGHUM CULTIVARS FOR RESISTANCE TO STEMBORERS AND SORGHUM SHOOTFLY

Participating scientist: *A. M. Nour*

Assisted by: *P. O. Ollimo, R. O. Oluoch*

Donor: *ICIPE Core Funds*

Background

Multiple resistance can gradually build up into high yielding well adapted backgrounds. This depends on the presence of suitable parents, screening methodology and selection procedure. In view of this, the present study aiming at combining the existing sources of resistance into good agronomic backgrounds was initiated in 1990. Two sources of stemborer resistance, namely IS-1044 and N-13 and two sources of shootfly resistance, IS-2269 and IS-5469, were crossed to three adapted varieties, namely LRB-5, LRB-6 and LRB-8, yielding 14 F_1 crosses.

In the 1991 season, 208 F_3 progenies were selected as having various combinations of resistance to stemborer and shootfly. These selections (208 F_3) were further evaluated during the 1992 crop season as F_4 families. The results indicated that out of 208 progeny, 36 F_4 multiple resistant (MR) families were identified as promising families which combined a high level of resistance (<10% deadheart) for both stemborer and shootfly.

Work in progress

These selected families were further evaluated during the 1993 and 1994 seasons in a replicated yield trial at MPFS. The shootfly incidence was recorded as percent deadheart on the 21st day after plant emergence. The stemborer incidence was recorded as percent deadheart as well as stem tunnelling on the 5th week after plant emergence.

Among the 36 tested entries, seven families, namely MR-11, MR-12, MR-15, MR-25, MR-26, MR-29 and MR-32 recorded 0% deadheart for both stemborer and shootfly. However, for shootfly deadheart alone, 17 entries scored 0% deadheart while for stemborer deadheart alone 13 entries scored 0%.

The promising selections will be advanced for further evaluation.

5. STATISTICAL PROCEDURES FOR CLASSIFYING CROP VARIETIES

Participating scientist: *M. Nabasirye*

Donor: *DSO*

Collaborators: *A. Odulaja, L. S. Luboobi (Makerere University, Kampala, Uganda), and S. O. Ajala (Supervisors)*

Background

Utilisation of plant resistance for insect pest management requires identification of resistant genotypes and development of cultivars combining high levels of resistance with other desirable characteristics. Consequently, a large number of genotypes are usually screened under suitable conditions to identify those with resistance to the insect pest in question using appropriate measures.

A basic limitation to conventional selection methods is the choice of cut-off point(s) for efficient partitioning of genotypes into resistant/susceptible groups and the assumption that resistance traits contribute equally and independently to yield loss. This makes it difficult to effectively distinguish and/or delineate genotypes into resistant/susceptible groups and may thus hinder selection and consequently delay or derail the development of resistant genotypes.

Work in progress

This study considered objective statistical approaches to the classification and selection problems. The aim was to optimise the average level of resistance in the selected group, by maximising the differences between the selected group and the other group(s) while minimising the differences within the selected group. Procedures for partitioning crop genotypes into resistance classes, based on observed resistance levels, were proposed and the

potential for their use in selecting genotypes was evaluated.

For the single-trait selection, the three categories of procedures investigated include a graphical method where plots of ordered means against the corresponding normal scores were used to determine the optimum number of groups and their limits. The second is based on cluster analysis techniques. In the third procedure, classification models were formulated and hypothesis testing using some appropriate test statistics (likelihood ratio and the quasi bayesian test statistics) facilitated the identification of the most plausible points to subdivide the entries under study into distinct groups.

Cluster analysis (CA) and likelihood ratio test (LRT) procedures were investigated for multi-trait selection, focusing on interrelationships among the resistance parameters. Use of principal component analysis (PCA) generated indices (principal components (PCs)) was compared with some 3 commonly used indices: rank summation index (RSI), Smith-Hazel index (SHI) and Dobie's index of susceptibility (I).

The practical application of the procedures was investigated using two groups of real field data and the comparison of their relative performance was made through simulation studies. The results show that the hypothesis testing procedure performed best overall. The LRT statistic plots for the 2-group model, in addition to locating the optimum cutpoint for the model, gave a clear picture of the entire structure of the data, especially when distinct groups existed. Its power to detect the 1-group model, as shown from simulation studies, is an added advantage over the others. Use of the quasi bayesian test statistic gave poor results.

Cluster analysis (CA), in general, gave fairly similar results to the LRT procedure. The method was fairly robust to distributional assumptions and perhaps easier to use. Normal score plots were fairly precise at determining the optimum number of groups in the data and, used along with other procedures, the plots gave satisfactory and useful results.

The results further showed that, for multivariate classifications, the appropriate procedure and index to adopt depended heavily on intercorrelations among the variables. Simulation studies indicated that classification was greatly facilitated by the existence of high correlations among variables. In this case, promising results were obtained using PCs as the basic variables for classification, in comparison to RSI, SHI and I. Overall, the optimal conditions for all the classification procedures included equal groups sizes and high intercorrelations among variables.

Application of the proposed procedures to real data demonstrated that the conventional methods of pre-setting selection conditions, in the form of group limits, selection intensity, etc., could lead to enormous loss of useful materials.

It was concluded that, other than being alternatives for solving the classification and subsequent selection problems, the procedures proposed in this study would better serve as complementary solutions. It is therefore recommended that, where possible, more than one technique be applied before deciding on the optimal solution.

6. A MODEL FOR AGRICULTURAL PRODUCTION BY SMALL-SCALE FARMERS IN SUB-SAHARAN AFRICA

Participating scientists: *A. Odulaja, F. G. Kiros*

Donors: *ICIPE Core Funds*

Background

Agricultural production in Africa has been virtually dominated by small-scale farmers who are known to produce 80–90% of food consumed in some countries of the continent. Despite the fact that a high percentage of the population are farmers, demand for food cannot be met. In many developed countries, relatively small numbers of farmers produce adequate food to meet domestic needs as well as for exportation to the developing world.

Farmers in sub-Saharan Africa produce at levels far below the predicted estimates of the new packages released by various national and international agricultural research organisations. The unfortunate consequence is that the farmers, and hence the people, remain in abject poverty and continue to import food, or rely on food aid, from the developed countries.

Inadequate understanding of farmers' goals and resource limitations has been identified as one important factor causing the food shortage problems. The need to study the various factors responsible for the low productivity cannot therefore be over-emphasised. The objective of this work is to develop models relating to production by small-scale farmers to the factors for better understanding of the functional relationships. Such models will assist in leading to relevant national and international policies with respect to small-scale farmers in sub-Saharan Africa and the Third World in general. Such policies are necessary if Africa is to achieve food sufficiency and improve its quality of life.

Work in progress

Models formulation

Categorisation of the factors may not be generalisable. For simplicity, the main parameters of our model are limited to three, each representing land (or herd) size, environmental and management effects.

Consider the production of a smallscale farmer, Y, as a function of the land (or herd) size, L; the environmental effect, E and management effect, M, represented as

$$Y = f(L)g(E)h(M)$$

where f, g and h are some functions relating L, E and M to Y respectively. We propose and develop these functions.

Land area

This is usually measured in hectares. The relationship between crop production and land area, L, has been found to be best described by the power function

$$f(L) = \alpha L^{\beta}$$

where α and β are constants. In the case of dairy production, L could well represent the herd size. Given all other conditions as fixed, Y is expected to increase with increase in L at a power rate of β. Hence, β will necessarily be greater than zero.

Environment

This is constituted by environmental factors such as rainfall, soil type, humidity and temperature. These factors are location-specific. In most socioeconomic surveys, these factors are represented by ordinal scales such as good/bad, high/medium/low, and so on. For more meaningful modelling, our approach will be to transform these to continuous scales using the uniform-rank transform method. This is performed by ranking the data for each variable in ascending order and then dividing by the total sample size. The mean of the uniform-ranks over all the environmental variables is then obtained for each sample to represent the environment as an index. Hence, the environmental index, E, is distributed in the interval [0, 1]. We propose an exponential model of the form

$$g(E) = \gamma e^{\theta E}$$

where γ and θ are constants. Since the data were ranked in ascending order of favourability to production, both γ and θ will be positive.

Management

Various factors regarded as constituting management include both physical properties and personal qualities possessed by the farmers. These include number of work implements, work force, literacy level, external assistance on the production aspects and other resources needed for production. All these variables will also be treated as the environmental variables since many of them are measured on ordinal scales. Given the management index, M, for each farmer, we propose a model similar to the environmental model to relate production to M, as

$$h(M) = \lambda e^{\eta M}$$

where λ and η are positive constants.

General model

The general model relating production, Y, to land size, L, environmental index, E, and management index, M, may be written as

$$Y = aL^{b}\exp(cE + dM) + \varepsilon$$

where a, b, c, and d are positive constants and ε is the residual.

A case study

Data collected in a rural survey undertaken by the Social Sciences Department of ICIPE was used to examine the proposed model. The survey covered the Oyugis and Kendu Bay Divisions in South Nyanza, western Kenya, and took place during the period January to March, 1992. In total, 801 farmers who are homestead heads, consisting of approximately 60% males and 40% females, were interviewed during the survey aimed at identifying 'resource-poor farmers'. Information collected from each interviewed farmer include marital status, age, number of household members and their ages, educational qualification, crops grown, size of land owned, size of land cropped, land fertility level, livestock number, types and number of farm implements, production and income from each crop, proportion of production directly used by the homestead, and assistance from extension services agents.

Only the land fertility level was used to represent the environmental effect, while educational level, age, numbers each of oxploughs, *jembes* (hoes), *pangas* (cutlasses), wheelbarrows, spades, forks, and external assistance and work force constituted the management effect. The crop production was converted to economic values to represent the dependent variables, Y, in the model.

The data fit our model adequately, with all the parameters of the model highly statistically significant.

Sensitivity of model to management index: A simulation

The management level of farmers is probably the most easily controllable out of the three independent variables used in the model. It is therefore necessary to investigate the effect of changing the management level on production. A simulation was carried out using the parameter estimates obtained from the data and varying the management index, M, within the interval [0, 1]. Improving the management level by 0.1 will multiply the production by the factor $e^{0.1d}$ (= 1.39) which represents an increase of 39% in production.

How much effort would be required to achieve an improvement of 0.1 in M is no doubt a subject of interest. A simulation result of how changes in some of the factors and their combinations would affect production given our model was carried out. It was found, among other things, that M will increase by 0.03, yielding an increase of about 10.5% in production if all farmers have 9–12 years of formal education (about secondary school level). If this educational level attainment is combined with access to extension services at least once in every quarter of the year, the increase in M will be about 0.048 resulting in over 17% increase in production. Given the cost per farmer of improving each of these factors,

policies by the governmental and non-governmental organisations can be sharply focused at reduced cost and optimum results.

Further analysis

To further classify the various factors constituting farmers' management level, a factor analysis was carried out using the eleven management variables in the case study data set. Three classes, each consisting of one or more factors, were identified. The first consisted of numbers of *jembes*, hoes, spades, wheelbarrows, *pangas*, oxploughs and forks as well as the work force. These variables can generally be called resource (labour and implements) variables. They explained over 25% of the variation in the management levels of the farmers. The second class, consisting of farmers' age and educational level, explained about 13% of the total variation, while the third class was made up of extension services assistance and contact farmers' privilege, accounting for about 12% of the total variation.

Hence, the differences between the farmers' management level are basically in terms of farm implements and labour sources. It therefore seems that access to farming implements will go a long way to making the farmers produce more. Provision of farm machinery like tractors through cooperatives or other movements may therefore be a good step in the right direction.

(Publications of Biomathematics Unit staff are listed under the report from that Unit.)

II. IPM of Stemborers in Zambia: Outreach *via* PESTNET

Participating scientist: *C. Mugoya (PESTNET Resident Scientist)*

Donors: *ICIPE Core Funds, Government of Zambia, SIDA*

(See also the report on PESTNET on page 169)

Background

The PESTNET Project (Pest Management Research and Development Network) was mooted in June 1986 by representatives from eastern and southern African countries and other institutions in Africa who recognised the mandate of the ICIPE to develop and promote methods of pest and vector control which were appropriate for African ecosystems. ICIPE was chosen as a coordinating centre on behalf of the participating institutions.

In Zambia, the PESTNET Project was started in 1988 with the posting of a resident scientist from ICIPE. The Ministry of Agriculture also seconded several personnel to the project including 3 technical assistants. By the time UNDP support for PESTNET ended in 1991, the project was well established and had made an impact at national level. This prompted ICIPE to continue funding it from its core funds until the end of 1994, when this project ended.

The Zambian national programme has approved substantial assistance amounting to 50% of the ICIPE contribution to the project. Other donors, particularly SIDA through its Plant Protection Programme (PPIP) for southern Africa, have been supporting the project activities in biological control and use of natural pesticides in stemborer control. In the past two years, the following are the major achievements of the project:

- insect mass rearing activities, particularly of *Busseola fusca*, *Cicadulina* leafhoppers, and the indigenous stemborer parasitoid, *Cotesia sesamiae*;
- establishing of clear patterns in the seasonal population build-up of the stemborers *Chilo partellus* and *B. fusca* using pheromones;
- surveying of indigenous stemborer natural enemies in Zambia and recording of several natural enemies;
- screening of a large number of maize genotypes over several years for resistance to stemborers and MSV (maize streak virus);
- investigations into the use of plant-derived pesticides from *Tephrosia vogelii* in stemborer management;
- research on intercropping and its role in suppressing stemborer infestation and damage;
- conducting of two training courses and one symposium.

Work in progress

1. INSECT MASS REARING

The initiation of insect mass rearing activities in Zambia was a direct extension of ICIPE's expertise in this field to the needs of a national programme which required a large number of standardised insects at a given time for studies such as host plant resistance, evaluation of biological control agents and bioassays of natural pesticides.

The project started off by rearing *Chilo partellus* for studies on host plant resistance. This was followed by *Busseola fusca* which initially posed several problems due to its diapausing behaviour. However, by 1993, most of the difficulties had been overcome and thousands of *B. fusca* larvae were being reared. The rearing of leafhoppers (*Cicadulina* spp.) for MSV screening is another contribution which PESTNET Zambia has made to the national programme. The rearing is carried out in a fully automated clear hard plastic greenhouse purchased by FAO and installed by PESTNET.

In 1994, PESTNET Zambia embarked on rearing of the stemborer parasitoid *Cotesia sesamiae*, which is currently being used in augmentative release trials.

2. SCREENING OF SOME MAIZE GENOTYPES FOR RESISTANCE TO THE STEMBORERS *CHILO PARTELLUS* AND *BUSSEOLA FUSCA*

The use of resistant and tolerant crop cultivars forms one of the most important pest control methods. However, for many years, the maize improvement programme in Zambia paid more attention to yield improvement than on breeding for resistance to stemborers.

During the 1992/93 and 1993/94 seasons, the PESTNET project screened selected maize genotypes for stemborer resistance/tolerance to *C. partellus* and *B. fusca* at the Golden Valley Research Centre located 80 km north of Lusaka at an altitude of 1300 m above sea level. The area receives an average annual rainfall of about 800 mm. Open and inbred lines from several stages of improvement in the Zambian breeding programme were artificially infested with stemborer egg masses. Foliar damage and deadhearts were recorded at 3 and 6 weeks after inoculation, while the number of larvae and tunnelling were recorded on 10 plants at harvest.

Results showed that in the *C. partellus* trial, cultivars 660, 400, 574, 26, 289, 449, 7316, MM400, 544 and 512 presented a low percentage of foliar damage. Genotypes 26, 7316, 544, local 2, 857 and 512 showed low foliar damage and stem tunnelling, suggesting tolerance to *C. partellus* damage. Genotypes 363, 400 and local 1 showed significantly fewer exit holes than the rest, while cultivars 289 and 574 had the lowest yield. In the *B. fusca* trial, differences in levels of damage were not significant.

Previous screening for resistance to MSV during the 1992/93 season using the same cultivars tested for stemborer resistance had shown that genotypes 26 and 400 were promising candidates for sources of multiple resistance against stemborers and MSV.

3. SEASONAL POPULATION PATTERNS OF STEMBORERS

Insect pheromones can be used as a pest management tool. Massive adult trapping at specified times of the year followed by spot insecticide killing can serve to disrupt mating in the field. Stemborer adult population monitoring using pheromone traps has been done at ICIPE where an effective dispensing technique was developed for *C. partellus*. In Zambia, the flight phenology of *C. partellus* and *B. fusca* populations was monitored for two years using pheromone traps. The *Busseola* pheromone was obtained from ICIPE while the *Chilo* pheromone was obtained from ICRISAT/SADCC who also supplied modified plastic Omni-traps (Mare-traps). The traps were hung 1.5 m above the ground on a wire fence surrounding sorghum and maize fields. Pheromone capsules were placed through a hole made in the ceiling of the trap.

Results obtained during the season indicated that *B. fusca* moths appeared in two peaks during the rainy season: the first in mid-November and the second between March and June. No moths were caught in June when the weather is cold and dry. On the other hand, high mean trap catches of *C. partellus* were recorded from late December/early January rising gradually to October (Figure 1). Similar results have been recorded by Leuschner in Zimbabwe (personal communication). These results demonstrated the potential of pheromone trapping as a forecasting tool as well as a control strategy.

4. ROLE AND PREFERENCE OF HOST PLANTS MAIZE, SORGHUM AND WILD HOSTS ON STEMBORER COMPLEX IN RELATION TO THE INDIGENOUS PARASITOID *COTESIA SESAMIAE*

This activity was carried out during the 1992/93 and 1993/94 seasons at Golden Valley Research Centre. Maize and sorghum were planted in opposite plots measuring 20 x 10 m. Plots were buffered from wild grasses and field edges by four rows of maize or sorghum. Popular maize and sorghum hybrids MM752 and WS287, respectively, were planted in rows at the recommended spacing. Transects of wild full-grown but green

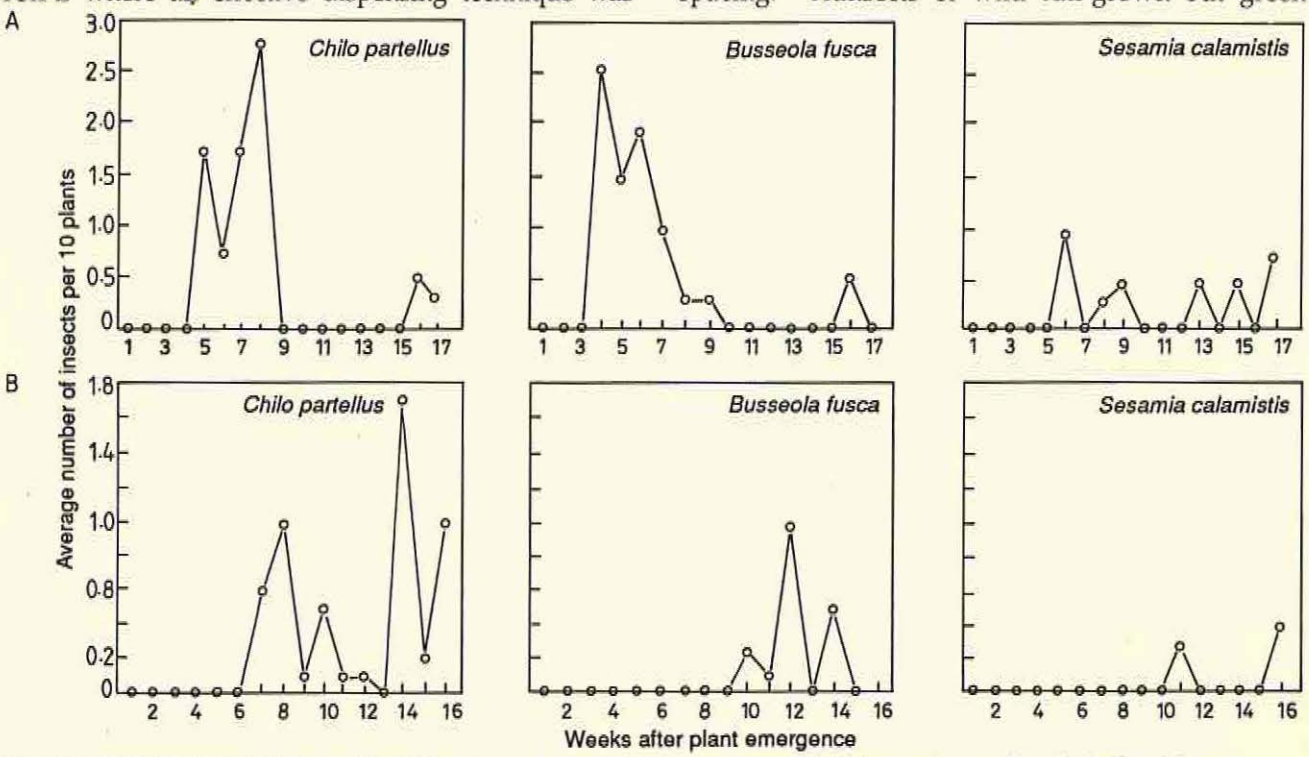


Figure 1. Seasonal distribution of stemborers: (A) in maize at Chipapa and (B) in sorghum at Lusitu in Zambia.

Hyparrhenia variabilis and *Sorghum verticiflorum* verging on maize/sorghum fields were demarcated.

At each site, simple random sampling for stemborers was conducted weekly from 3–18 weeks after crop emergence. Sampling was imposed on populations of maize, sorghum and the wild graminaceous hosts, *H. variabilis* at Mt. Makulu and *S. verticiflorum* at Golden Valley. The number of stemborer larvae, species and stadia obtained were recorded. Live insects were maintained on their host plants for possible emergence of parasitoids. The results obtained revealed the presence of several stemborer biocontrol agents, including the following:

(i) *Cotesia sesamiae* Cameron (Hymenoptera: Braconidae), a gregarious larval parasitoid;
(ii) *Dentichasmias busseolae* Heinrich (Hymenoptera: Ichneumonidae), a solitary pupal endoparasitoid;
(iii) *Pediobius busseolae* (Gahan) (Hymenoptera: Eulophidae) a gregarious pupal endoparasitoid;
(iv) *Chelonus* sp. (Hymenoptera : Braconidae), a solitary egg-larval endoparasitoid attacking the host egg but utilising the larval stage;
(v) *Diaperaticus erythrocephala* Oliver (Dermaptera: Forficulidae) or earwigs, general predators on *C. partellus* eggs;
(vi) *Cheilomenes* spp. (Coccinellidae: Coleoptera) or ladybird beetles, predators of stemborer larvae.

Among these natural enemies, *Cotesia sesamiae* was the most prevalent, attacking mainly third and fourth instar larvae. *Busseola fusca* and *Chilo partellus* were the preferred hosts for *C. sesamiae* on maize and sorghum crops in both locations. No *C. sesamiae* or *B. fusca* was recovered from *H. variabilis* at Mt. Makulu. On the other hand, *S. verticiflorum* sustained stemborers with levels of parasitism comparable to those of cultivated hosts. Stemborer infestation in wild hosts was generally lower than in cultivated hosts. Such low levels of infestation are nevertheless significant considering that only a small reservoir of borer and parasitoid population surviving the long dry season is necessary to form a source of infestation during the growing season. All *S. calamistis* larvae recovered in maize and in the wild host were parasitised, while none were parasitised in sorghum.

Results from the 1993/94 season on sorghum and maize showed that in sorghum, the percentage of borer species parasitised were 33% in *B. fusca*, 10% in *C. partellus* and 9% in *S. calamistis*; in maize, they were 25% in *B. fusca* and 20% in *C. partellus*. Clearly, sorghum favours a higher parasitism than maize. We also observed that parasitism rarely occurred before the 9th week after plant emergence. Therefore, a large proportion of the first generation population completed its life cycle without any parasitism. This probably explains why the parasitoid is ineffectual.

Current attempts are being made to quantify its contribution to stemborer mortality through an augmentative release programme. It is only when this has failed that a recourse to exotic introductions will be justified. Other areas of research that demand urgent attention are

(i) the role of wild hosts in relation of stemborers,
(ii) susceptibility of different stages of stemborers to natural enemies, and
(iii) effect of agronomic and cultural practices on performance of natural enemies.

5. EFFECT OF INTERCROPPING ON STEMBORERS AND THEIR LARVAL PARASITOIDS

In terms of pest management, information on benefits of intercropping and mixed cropping common among smallscale farmers in Zambia is anecdotal among smallscale farmers. Maize and sorghum is often intercropped by smallscale farmers with a diversity of crops such as beans, cowpea, groundnuts, cassava, pigeon peas, pumpkins, etc. It is not clear what benefits in terms of stemborer control are obtained from such diversity. As an important aspect of the PESTNET mandate to investigate IPM benefits of such practices in various agroecological regions in Zambia, studies were undertaken during the 1993/94 season to understand the combination of crops with maize and sorghum that would benefit the small-scale farmers in reducing infestation levels and damage to their crops, and assure household food security. The objectives of the study were to identify maize or sorghum intercrop combinations that increase/reduce stemborer attacks and to examine intercrop combinations that improve natural enemy populations with special reference to the larval parasitoid, *Cotesia sesamiae*.

The trial was carried out at the Golden Valley Research Centre. Maize cultivar MM601 and grain sorghum cultivar Sima with the dwarf determinate bean *Phaseolus vulgaris* (L.), cultivar Carioca as a companion crop were used in these studies. The experiment comprised 5 treatments, namely maize/ beans; sorghum/beans; maize/sorghum; sole maize and sole sorghum. In maize/beans and sorghum/beans intercrop treatments, a strip of 2 rows of maize or sorghum were alternated by 1 row of beans. Thus each plot had 10 rows of maize or sorghum and 6 rows of beans. In the maize/sorghum dicrop, each plot had 8 rows of maize alternating with 8 rows of sorghum.

There were no significant differences ($P > 0.05$) in the mean egg population among treatments. The sorghum crop, however, had a numerically higher mean stemborer egg population than other treatments. In terms of borer numbers, the maize/sorghum dicrop had a significantly higher number of borers/plant ($P > 0.05$) than the sole or bean intercrop. The highest mean number of stemborer larvae (1.66 larvae per plant) were recorded on sole sorghum. When levels of stemborer damage were compared by the F-test, significantly higher foliar damage, exit holes and stem tunnelling ($P > 0.05$) in maize/sorghum dicrop than in maize/bean intercrop were observed. On the other hand, the sorghum/bean intercrop had a significantly higher foliar damage but low stem tunnelling compared to the sole crop.

Cotesia sesamiae was the most abundant stemborer parasitoid recovered from all the three larval species. Other parasitoids present but in very low incidence were identified as *Dentichasmias busseolae* (Heinrich) and *Pediobius busseolae* (Gahan). Towards the end of the

Table 1. *Cotesia sesamiae* parasitism among stemborer populations in maize and sorghum intercrop combinations

Intercrop	Stemborer larvae/plant	Parasitised larvae/plant	Percent parasitism
Maize/beans	0.86 ± 0.34 d	0.19 ± 0.07 a	22.1
Sorghum/beans	1.50 ± 0.12 ab	0.67 ± 0.14 a	44.7
Maize/sorghum Maize	1.32 ± 0.39 bc	0.34 ± 0.07 a	25.8
Maize/sorghum Sorghum	1.17 ± 0.26 c	0.70 ± 0.14 a	59.8
Sole maize	0.90 ± 0.26 d	0.05 ± 0.03 a	5.6
Sole sorghum	1.66 ± 0.24 a	0.17 ± 0.14 a	10.2
CV	22.6%	78.5%	
F value	3.91*	1.48	
P	0.0246	0.2675 NS	

Means followed by the same letter in the same column are not statistically significant at $P = 0.05$ (DMRT).

season, some parasitoids belonging to the genus *Chelonus* spp. (Polaszek, personal communication) were recovered. Parasitism by *C. sesamiae* was first observed during the WAE and increased progressively as the season came to a close. As shown in Table 1, there were no significant differences in the number of parasitised larvae among the different treatments. Percent parasitism was evidently higher (59.8%) in the sorghum/maize dicrop than in the monocrops (5.6% in sole maize and 10.2% in sole sorghum).

The maize/sorghum intercrop accounted for most of the significant increases in infestation and damage observed. This observation is consistent with assertions made in 1983 at ICIPE's MPFS and reaffirms the dangers of combining sorghum and maize in the same plot as it increases infestation and damage by stemborers.

The lack of significant differences in the numbers of parasitised larvae/plant among the different treatments indicated that either the number of borers present, the density of crops per plot or other parasitism-enhancing factors were lacking in the crop combinations employed. On the other hand, the lower percent parasitism observed in sole maize and sorghum monocrops reaffirmed the role rendered by crop mixtures in the conservation of parasitism as alluded to in the natural enemy hypothesis.

6. FIELD OBSERVATIONS ON STEMBORER POPULATION DYNAMICS AND INCIDENCE AND ABUNDANCE OF THEIR NATURAL ENEMY *COTESIA SESAMIAE*

Current knowledge on population dynamics of stemborers and their natural enemies on their host plants in Zambia is scanty. This is partly due to the fact that stemborers were, until recently, of minor pest status on the Zambian agricultural scene. Consequently, only a few published accounts of stemborer generations, mortality patterns and agents during developmental stages are available. Our preliminary studies carried out at Mt. Makulu Research Station (Region 2) showed that the indigenous stemborer parasitoid *Cotesia sesamiae* Cameron (Hymenoptera : Braconidae) exerted parasitisation rates on maize and sorghum stemborers ranging from 7–30 percent. These findings aroused an interest in its biocontrol potential through augmentation. A clear understanding of the population dynamics of the pest was needed in order to serve as a starting point for subsequent investigations.

Thus, an on-farm study was initiated with the objective of determining population dynamics of stemborers in relation to their indigenous parasitoid, *C. sesamiae* under diverse agronomic and post-harvest practices; a mass rearing programme for *C. sesamiae* was also initiated. The studies were deliberately carried out on-farm so as to involve farmers and cause them to appreciate the role and significance of biocontrol agents in pest management. This trial was conducted on-farm at two different agroecological locations in Zambia, Lusitu and Chipapa.

A randomised complete block design was used in this study. Each farmer was requested to reserve a piece of land measuring 100 x 50 m. Each piece was subsequently subdivided into two equal blocks (replicates). At Lusitu, the sorghum variety Sima was planted and at Chipapa, MM601 maize was planted. At each sampling occasion, 10 plants were randomly selected from the outer rows and used for dissection sampling, and another 10 plants were selected from the middle rows, tagged and used for weekly sampling of egg counts, foliar damage and yield.

Results showed that all three stemborer species in Zambia, i.e. *Chilo partellus, Busseola fusca* and *Sesamia calamistis*, were found in both locations. No stemborer eggs were encountered on maize or sorghum at either site; only larval and pupal stages were recorded. At Chipapa, where the host crop was maize, *C. partellus* and *B. fusca* were the predominant borer species which also displayed a similar population distribution pattern during the first generation with a peak of 0.3 borers/plant between 4–7 WAE. The borer population in both species rose gradually during the first 8 WAE then fell to zero levels during the 11th, 12th and 13th WAE. During the 14th week a new population build-up was observed, but since our sampling lasted only up to harvest time (17 WAE) only a partial second generation was recorded. The seasonal population pattern of *S. calamistis* fluctuated around 0.05 larvae per plant throughout the season without any pronounced peaks and was the lowest of the borer species.

At Lusitu, where sorghum was the host plant crop, a different seasonal stemborer population pattern was observed. First generation *C. partellus* was more abundant than *B. fusca* with a peak of about 0.18 borers/plant at 10 WAE, while the first generation *B. fusca* peaked at 13 WAE. At the time of harvest at 17 WAE, *C. partellus* had completed one and a half generations, while *B. fusca* had only managed one. The *S. calamistis* population was too low to decipher any pattern.

There was no *C. sesamiae* parasitism in larvae obtained from grain sorghum plants at Lusitu. At Chipapa, however, parasitism was observed among *S. calamistis* and *C. partellus* larval populations during the 6th and 9th WAE respectively, i.e. during peak larval periods of the first generation and none on *B. fusca*. Percent parasitism at 6 WAE was 6% and 20% at 9 WAE. The mean number of cocoons/clutch was 63.6 while the mean number of emerging adults was 47.6 with a male:female sex ratio of 1:3. No parasitism was recorded after 9 WAE.

The agroecological difference between Chipapa and Lusitu was also reflected in the seasonal distribution of the stemborer species. Climatic conditions at Chipapa appeared more favourable to stemborers than at Lusitu. This was reflected in the high numbers of *C. partellus* and *B. fusca* recovered during the growing season and the late arrival of the same at Lusitu (Figure 1). The perpetual presence of *S. calamistis* at Chipapa with no clear-cut generations throughout the season was an indication that its population (which does not diapause) was very stable with a complete overlap of generations being sustained, probably by wild host plants during the off-season. It is therefore easy to see why there was no *C. sesamiae* parasitism in larvae obtained from sorghum plants at Lusitu as compared to the situation at Chipapa, where very low parasitism was observed in *S. calamistis* and *C. partellus* larval populations.

Suitable biocontrol agents in an augmentation programme are those that already occur in the ecosystem but are not common enough to effectively control the pest. The presence of *C. sesamiae* at Chipapa *(and not in Lusitu)* fits this description, although surveillance is required to determine the optimum timing of releases. In Chipapa, parasitism was observed at a time when larvae were about to complete their first generation at 9 WAE. The period starting from 4 WAE would therefore be suitable for commencement of releases.

Absence of parasitism on *B. fusca* larvae was significant, considering that it is an indigenous pest which has been regarded as a preferred host at Mt. Makulu and Golden Valley. This indicates that *C. sesamiae* at Chipapa appears to be shifting from their indigenous hosts to using *C. partellus* and *S. calamistis* as alternative hosts. A similar observation has been made in South Africa and more detailed surveys are required to establish the prevalence of this phenomena.

7. LIFE CYCLE AND LABORATORY REARING OF *COTESIA SESAMIAE*

Larvae collected from the field were maintained on sorghum stems for about 10 days in the laboratory at room temperature (25–28°C) and 45% RH to allow parasitoids to emerge from the larvae. Soon after pupation, cocoon batches were separated from host larvae and kept in glass vials measuring 7 x 2.5 cm and plugged with cotton wool until adult emergence. Upon emergence they were transferred into larger 650 ml capacity glass jars (19 x 7 cm) containing a thick layer of 2.5% agar about 4 cm deep at the bottom. The agar provided moisture which was crucial for parasitoid survival. Each jar was capable of accommodating up to 100 individuals, and in order to prevent them from escaping, it was closed with a paper towel with the help of an elastic band. Food for the parasitoids consisted of a 20% pure bee honey/water solution soaked in wool. Jars were then kept in an incubator at an optimal temperature of 22°C. Rearing methods of mass exposure and hand stinging techniques were used simultaneously in achieving parasitism.

The results showed that oviposition response by parasitoids to stemborer larvae using the mass exposure method was not as effective as the hand stinging method. Life cycle studies showed a mean larval period of 17.2 days (n=41) and pupal period of 10.1 days (n=16). Development of *C. sesamiae* from oviposition to adult emergence therefore took 27.3 days. Each cocoon clutch had a mean number of 50.7 cocoons (n=39) and the sex ratio of their progeny was 1:1.3 (M:F). Temperatures of 22–25°C and 80% RH enabled adult parasitoids to live up to 72 h compared to 6 h under ambient laboratory conditions. Percent mortality in females was slightly higher than in males. At day 2, mortality was 68% in females and 50% in males and oviposition response by females appeared best on this same day. It appeared that high moisture in the rearing jars played a very crucial role in prolonging parasitoid lifespan and made all the difference in the survival of the parasitoids to sexual maturation.

The period of development of *C. sesamiae* from oviposition to adult emergence of 27.3 days was found to be longer than that reported in *C. flavipes* in Kenya

which is 20.7 days (Overholt, ICIPE, unpublished). These preliminary observations need to be investigated further.

More detailed work on population estimation and analysis through life table studies will be required to determine the exact role of *C. sesamiae* as potential biocontrol agents. Other studies to determine the effectiveness of mass reared laboratory insects when released in the field in view of the attendant genetic and learned components of host preference and host location which can be acquired under laboratory conditions will have to be done.

8. EFFECT OF *TEPHROSIA VOGELII* WATER EXTRACTS ON STEMBORER OVIPOSITION AND EVALUATION OF EFFECTIVE FIELD DOSE IN CONTROLLING MAIZE STEMBORERS IN ZAMBIA

Resource-poor farmers in developing countries need low cost, non-polluting control agents if they are to achieve sustainable management of insect pests; botanical pesticides may be the answer. Natural plant derived substances can provide a renewable and locally available supply of IPM control agents.

Tephrosia vogelii Hook f. is a wild robust shrubby leguminous plant belonging to the family Papilionaceae. Although its aboriginal home is Africa, it is now grown in other parts of the world, notably in the United States and Puerto Rico. Leaves of *T. vogelii* contain at least four compounds, collectively known as rotenoids, which have been proven to possess insecticidal properties; these are rotenone, deguelin, tephrosin and 6a,12a-dehydrodeguelin. In other *Tephrosia* species, compounds collectively known as flavonoids are found, and these also have profound effects on insect development and behaviour. The insecticidal and acaricidal properties of *Tephrosia* have been demonstrated in several cases.

In Zambia interest in the use of *T. vogelii* was aroused from oral reports from local farmers in the northern province, who use the extracts to control maize stemborers. This prompted PESTNET scientists to start a series of investigations on its efficacy. Their preliminary findings demonstrated that the aqueous leaf extract of *T. vogelii* caused less feeding and induced mortality in first and third instar *C. partellus* when applied topically on leaf discs. Our studies were carried out in two trials during 1992/93 and 1994/95 seasons in order to determine the effective field dose and the role of the extract in oviposition behaviour of stemborers.

Freshly picked *T. vogelii* leaves were collected and weighed to make solutions of concentrations of 15% w/v, as well as 12.0, 9.0, 6.0 and 3.0% concentrations.

An oviposition bioassay was carried out using a single dose of 10% w/v extract on 3-week-old potted MM752 maize. The experiment comprised of three treatments: leaves sprayed with water (control); leaves sprayed with 10% extract; choice test in which half number of leaves are sprayed with water and the other half with extract. On each plant, a pair of newly emerged male and gravid female *C. partellus* moths were introduced and left for three days to oviposit. The leaves, net pot and soil surface in each cage were examined for eggs. Results of the oviposition bioassay showed that the most eggs were laid on the plant parts sprayed with water. In the no-choice treatment where all leaves were sprayed with the extract, moths laid on the soil as well as the leaf surface. There was, however, no significant difference in egg counts at the two sites. A t-test comparison of the number of eggs laid by moths in the control plants and those sprayed with *T. vogelii* showed no significant difference ($t = 0.95$, $P > 0.38$). In the choice test, however, moths laid significantly more eggs on water-treated surfaces ($F = 6.81$, $P < 0.007$) than on extract-treated surfaces.

Field trials with hybrid maize MM752 were also conducted to evaluate the most effective spray dose of *T. vogelii* in suppressing stemborer infestation and damage. Planting was done in the middle of the season to ensure high levels of infestation. Each experimental unit was comprised of 4 rows of twenty plants protected on either side by two guard rows. Weeding was done twice as basal compound D fertilisers were applied at the time of planting and a top dressing of urea at 200 kg/ha were added when plants were 3 weeks old.

From 3–7 WAE, each *T. vogelii* concentration was sprayed using a knapsack sprayer. Control plots were sprayed with pure water. At harvest, the percentage of plants showing foliar damage were recorded, and individual stems were then dissected and data on plant height, number of larvae recovered, exit holes, stem tunnelling and yield were recorded. The oviposition bioassay showed that moths avoid laying eggs on maize leaf surfaces treated with extracts, and that the number of eggs were fewer.

As evident from the field results, stemborer infestation as expressed by foliar damage was highest in unsprayed plots. At maturity, the percentage of maize plants showing foliar damage in control plots was almost three times higher than those sprayed with the extract. Further examination of other damage parameters revealed no significant differences among treated plots and control plots for plant height, stem tunnelling and grain yield at harvest. However, the 15% w/v extract dose elicited significant reduction in foliar damage and exit holes.

Lack of significant results with regard to other damage and infestation characteristics could have been due to a combination of late onset of spray or a short duration of spray period or a combination of both. Further studies on the spray regime are needed to determine which spray regime produces the best results. The current limitation in the application of these extracts now lies in the lack of information on environmental, ecological and health hazards emanating from their use. Hence, there is need for further studies on mammalian toxicity, effect on non-target organisms, biodegradability and studies on residues.

III. Classical Biological Control of Cereal Stemborers

Donor: *Directorate General for International Cooperation, the Netherlands*

Collaborators: *Wageningen Agricultural University, Texas A&M University, IITA, IIBC, IIE, NARS in Tanzania and Zanzibar*

Background and overview

A collaborative project between ICIPE and Wageningen Agricultural University (WAU) on classical biological control of cereal stemborers was initiated in January 1991. The project has concentrated on *Chilo partellus*, an introduced stemborer from Asia, because of its economic and regional importance in East and southern Africa, and its potential for being regulated through the introduction of exotic natural enemies.

In the initial stages of the project, research was focused on determining the species abundance and seasonal occurrence of stemborers in Kenya. Surveys were conducted in western Kenya, the central highlands, and at the Kenya coast. The coastal area was selected for intensive investigations because of the high abundance of *C. partellus*. Sampling maize, sorghum, and three wild grasses over four years revealed that *C. partellus* was the predominant stemborer, often accounting for 80% or more of the total stemborer population. Other commonly recovered species included *Chilo orichalcociliellus* and *Sesamia calamistis*. In contrast, *Busseola fusca* was the predominant stemborer at higher elevations in Kenya.

Life table studies revealed that generational mortality of *C. partellus* due to native parasitoids was typically less than 3%, suggesting that there was room for the establishment of old association natural enemies from the aboriginal home of *C. partellus*. *Cotesia flavipes*, a small braconid wasp native to the Indo-Australian Region, had been used successfully in several countries for biological control of *C. partellus* and other closely related stemborers. *Cotesia flavipes* is a gregarious endoparasitoid that attacks medium and large-sized stemborer larvae in their feeding tunnels. Once a host larva is located, 30–50 eggs are injected into the host which hatch in about 3 days. The complete life cycle takes about 17 days.

There have been several attempts to establish *C. flavipes* in Africa, starting in 1968 in Uganda. Later releases were made in Tanzania, Kenya, Ghana, and South Africa. For unknown reasons, all attempts resulted in failure. The ICIPE, with assistance from the International Institute of Biological Control (IIBC), imported *C. flavipes* from Pakistan into Kenya in 1991 for laboratory investigations. A colony was readily established in the laboratory on *C. partellus*, and it was found that the same parasitoid could also successfully parasitise *C. orichalcociliellus* and *S. calamistis*, but not *B. fusca*. Studies were also conducted to determine whether *C. flavipes* would interbreed with a closely related native parasitoid, *C. sesamiae*. Mating occurred in an enclosed laboratory arena and sperm was transferred, but no progeny were produced. Bioassays in olfactometers indicated that while there was signficant attraction between *C. flavipes* males and females, there was no attraction to *C. sesamiae*. Thus, interbreeding in nature was considered to be unlikely. In addition to the initial importation from Pakistan, the ICIPE has imported *C. flavipes* from one other location in Pakistan with help from IIBC, and from India with assistance from ICRISAT. Genetic, behavioural, and life history traits are being compared between these strains in collaboration with Wageningen Agricultural University. A closely related parasitoid, *C. chilonis*, has been brought in from Japan for taxonomic and biological studies with assistance from Texas A&M University.

Cotesia flavipes collected from southern Pakistan was released in the coastal area of Kenya from May to July in 1993. Several recoveries were made during the season of release, indicating the parasitoid was able to successfully locate and parasitise stemborers in the maize agroecosystem in Kenya. The number of recoveries decreased later in 1993, and very few *C. flavipes* were found during the first 6 months of 1994. It began to look like the establishment had failed. However, from September until the end of the year the number of recoveries began to increase, and recoveries were made as far as 16 kilometres from the release sites. Recoveries 18 months after the last releases (about 30 generations) is firm evidence that *C. flavipes* has been established. It is expected that recoveries will become more common and the parasitoid population will continue to expand to all suitable habitats.

In addition to the work in Kenya, agricultural research and plant protection authorities have been contacted in

several other countries in East and southern Africa regarding the release of *Cotesia flavipes*, and visits have been made to Zanzibar and Tanzania. A regional training programme was held in August 1994, and a second one will be held in 1995 on methodologies for the release and evaluation of *C. flavipes*. It is anticipated that collaboration on stemborer biological control will be established in 1995/96 in several East and southern African countries. In West Africa, the ICIPE and IITA have been conducting collaborative work on stemborer biological control in West Africa since November, 1992. The ICIPE has supplied *C. flavipes*, *C. chilonis*, *C. sesamiae* to IITA in Benin for screening against West African stemborer populations. The initial work at IITA indicates that *C. flavipes* can successfully parasitise West African populations of *Sesamia calamistis*.

Work in progress

1. ESTABLISHMENT OF *COTESIA FLAVIPES* IN TWO ECOLOGICAL ZONES IN KENYA

Participating scientists: *W. A. Overholt*, C. O. Omwega, J. Mbapila, P. Lammers (*Project Coordinator)*

Assisted by: *S. P. Ojwang, M. O. Odoyo, P. O. Agwaro, R. K. Orengo, T. M. Ondiek, B. Musyoka*

A major milestone was reached in 1994 when evidence became conclusive that the exotic parasitoid, *Cotesia flavipes*, had been established in Kenya. The parasitoid was released at three locations during the long rains of 1993 (May–July). Within the season of release, there were 298 recoveries at release sites, indicating that *C. flavipes* had successfully colonised the maize agroecosystem at the Kenya coast. However, the number of recoveries decreased to 20 during the following short rains (October–December). From January to July 1994, *C. flavipes* was recovered only twice. The trend was reversed in September–December 1994 when 37 recoveries were made, nearly double the number that were recovered during the same period the previous year (Figure 1). This is firm evidence that *C. flavipes* has established on the Kenya coast, and based on experiences in other countries, densities are expected to increase as *C. flavipes* becomes adapted to local conditions and disperses to all suitable habitats.

In addition to the work at the Kenya coast, sampling of stemborers in western Kenya has also been conducted. Surprisingly, stemborers parasitised by *C. flavipes* were recovered during a survey in southwestern Kenya in July 1994. The ICIPE never made releases of *C. flavipes* in that area of Kenya, but did maintain a colony at Mbita Point Field Station in southwestern Kenya in 1991. It is possible that the parasitoids escaped from the colony and established. Alternatively, *C. flavipes* may have established from releases made by the Commonwealth Institute of Biological Control in Tanzania in 1969–70. However, examination of museum specimens indicates that *C. flavipes* was not found in the area prior to 1994. Furthermore, electrophoretic comparisons of *C. flavipes*

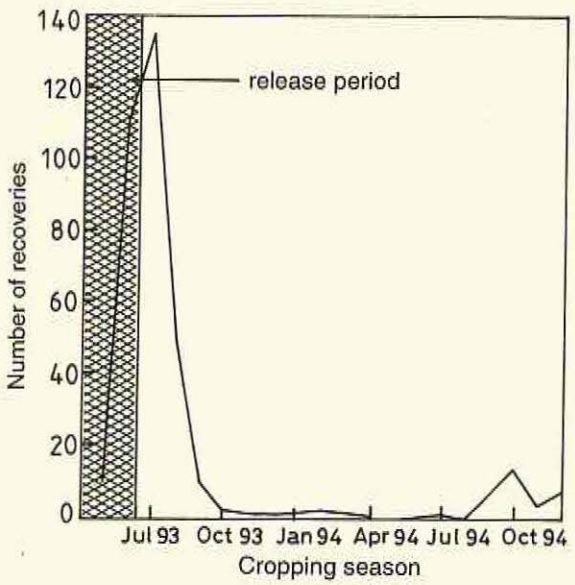


Figure 1. Recoveries of *Cotesia flavipes* at the Kenya coast from May 1993 to December 1994.

recovered in western Kenya and individuals from the project's laboratory colonies strongly suggest they are from the same population.

2. BIOSYSTEMATICS OF *COTESIA* SPECIES

Participating scientist: *S. W. Kimani*

Assisted by: *J. O. Okello, J. O. Ochieng, G. O. Ogola*

Collaborators: *Wageningen Agricultural University, the Netherlands; Texas A&M University, USA; Natural History Museum, London, UK*

The species of the *Cotesia flavipes* complex are gregarious endoparasitoids of lepidopteran stemborers of gramineous plants. The complex is thought to consist of three morphologically similar species: *C. flavipes*, in the Indo-Australian Region, *C. sesamiae* in sub-Saharan Africa, and *C. chilonis* in Japan and China. Thus, it was important to be able to accurately distinguish *C. flavipes* from the indigenous *C. sesamiae*.

Several morphological character states were scored and evaluated for their use in the diagnosis of the species. The overall shape of the male genitalia separated the complex into two groups, *C. flavipes* and *C. sesamiae/chilonis*. Intraspecific variations within these two groups were noted. The male genitalia of populations of *C. flavipes* from Mauritius differed substantially from the typical genitalia of populations from Pakistan. The genitalia of *C. sesamiae* from Malawi also differed from the genitalia from other African *C. sesamiae* populations.

Morphometric studies conducted in collaboration with Texas A&M University, USA and the Natural History Museum, London, UK indicated that canonical discriminant functions developed from several allopatric populations in the complex could be used to classify new specimens into their respective species.

The gene products of 22 loci were detected. Five loci were diagnostic and could be used to consistently separate populations believed to represent the three species. Genetic distance analyses using allele frequencies suggested that the three taxa are closely related when compared to an outgroup, *C. glomerata*. Phylogenetic studies on 14 enzyme systems and Random Amplified Polymorphic DNA Polymerase Chain Reaction (RAPD-PCR) suggest that *C. sesamiae* and *C. chilonis* are a monophyletic group while allopatric populations of *C. flavipes* are polyphyletic.

Gas liquid chromatography of cuticular hydrocarbons showed that *C. flavipes* and *C. chilonis* are more similar to each other than to *C. sesamiae*. However, the two parasitoids were reared on the same host, and cuticular hydrocarbons may be influenced by the host environment. The pattern of cuticular components cannot therefore be reliably used to separate species in the *C. flavipes* complex. Further investigations to determine the identity of compounds in the hosts and parasitoids are necessary. This would help to determine whether cuticular components of parasitoids are species specific.

Preliminary results using RAPD-PCR conducted in collaboration with the genetics department of the National Museums of Kenya showed specific banding patterns for each of the three species. However, the banding patterns did not reveal any intraspecific polymorphism. Non-genic, internal transcribed spacer region-2 (ITS2) of the rDNA of selected populations for the *C. flavipes* complex is being sequenced in collaboration with the Departments of Entomology and Molecular Genetics of Wageningen Agricultural University. Results of this study will hopefully resolve the phylogenies and rates of base substitution (divergence time) of strains in this complex.

3. HOST FINDING AND ATTACK BEHAVIOUR OF *COTESIA* SPP.

Participating scientist: *A. J. Ngi-Song*

Assisted by: *G. O. Ogola, J. O. Ochieng, J. O. Kokungu, P. E. W. Njoroge*

An understanding of the mechanisms by which parasitoids locate their hosts may be useful in designing parasitoid releases, evaluating competition between parasitoid species, and defining host specificity.

Experiments conducted prior to 1994 demonstrated that *C. flavipes* and *C. sesamiae* responded to volatile odours from uninfested stemborer host plants, plants infested with several different stemborer species and to stemborer frass. Frass samples from all stemborer/host plant combinations tested were highly attractive. Infested plants were more attractive than uninfested plants. Attraction of parasitoids to volatiles has been confirmed through coupled gas chromatography and electroantennography, and through bioassays on isolated substances.

Research in 1994 was concentrated on the identification of the volatile odours. Anisole, hexenyl acetate, and farnesene gave strong antennal responses.

4. LABORATORY LIFE TABLES OF *COTESIA* SPP. REARED AT DIFFERENT TEMPERATURES ON *CHILO PARTELLUS*

Participating scientist: *J. Mbapila*

Assisted by: *G. O. Ogola, J. O. Ongata*

Laboratory life tables are one method of estimating potential population growth under ideal conditions, and may be useful for comparing potential population growth among species.

Life tables were constructed for *C. flavipes* and *C. sesamiae* reared on *C. partellus* at four temperatures ranging from 22°C to 31°C. At all temperatures *C. flavipes* had a higher intrinsic rate of population growth than *C. sesamiae*, suggesting that *C. flavipes* may be able to respond more rapidly to changes in host population density (Figure 2). The difference in population growth was attributable to a higher fecundity and survival rather than to a shorter generation time. The longevity of both *C. flavipes* and *C. sesamiae* were much higher when moisture and food (agar + honey) were provided than when moisture alone or food alone was provided.

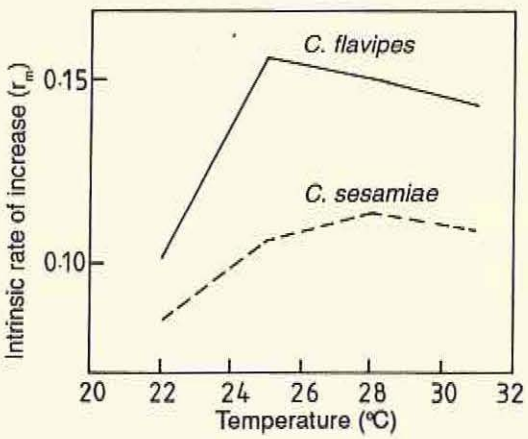


Figure 2. Intrinsic rate of increase of *Cotesia flavipes* and *C. sesamiae* reared on *Chilo partellus* at four temperatures.

5. ACCEPTABILITY AND SUITABILITY OF VARIOUS STEMBORERS SPECIES FOR THE DEVELOPMENT OF *C. FLAVIPES, C. CHILONIS* AND *C. SESAMIAE*

Participating scientist: *A. J. Ngi-Song*

Assisted by: *G. O. Ogola, J. O. Ochieng, J. O. Kokungu, J. O. Ongata*

In many areas of Africa, stemborers exist as a complex of species whose niches often overlap in space and time. When an exotic parasitoid such as *C. flavipes* is introduced, it is important to understand not only its ability to locate and parasitise the target host, but also its response to other potential hosts that share the same habitat.

Laboratory studies have been conducted on the acceptability and suitability of *Busseola fusca*, *Chilo partellus*, *Chilo orichalcociliellus* and *Sesamia calamistis* for oviposition and development of *C. flavipes*, *C. chilonis* and *C. sesamiae*. The four species of borers were equally acceptable for oviposition by *C. flavipes* with 83.8, 94.8, 97.4 and 94.9% of *B. fusca*, *C. partellus*, *C. orichalcociliellus* and *S. calamistis* being parasitised, respectively. *Sesamia calamistis* was the most acceptable host for *C. sesamiae*, and *B. fusca* the least accepted. All four stemborers were accepted by *C. chilonis*.

The borer species were all suitable for the development of the three parasitoids, with the exception of *B. fusca*, which was not successfully parasitised by any of the parasitoids. Suitability varied with the parasitoid species. *Sesamia calamistis* was the most suitable host for *C. sesamiae*, while *Chilo* spp. were most suitable hosts for the development of *C. flavipes*. *Sesamia calamistis* and *C. partellus* were most suitable for *C. chilonis*, while *C. orichalcociliellus* was an inferior host based on the number of parasitoid progeny. These studies suggest that both *C. flavipes* and *C. chilonis* have potential for establishing in Africa. Immunological experiments revealed that total haemocyte counts in *C. partellus* larvae parasitised by *C. flavipes* were higher than in non-parasitised larvae. With funding provided by the Rockefeller Foundation, more detailed immunological investigations will be initiated in 1995 in collaboration with Texas A&M University.

6. MEASURING GENETIC CHANGES DURING LABORATORY REARING OF *COTESIA FLAVIPES*

Participating scientist: *C. O. Omwega*

Assisted by: *J. O. Okello, J. O. Ochieng, J. O. Ongata*

One of the major challenges in classical biological control is to capture and preserve useful traits through all phases of the programme starting with sampling at the native home, followed by importation, quarantine, laboratory rearing, and finally during field colonisation. Perhaps the phase during which the most genetic decay takes place is during laboratory rearing. Electrophoretic techniques were used to measure genetic changes occurring during laboratory rearing of *C. flavipes*.

Two geographic collections of *Cotesia flavipes* from Pakistan were imported for biological control of African stemborers. Separate colonies were initiated from the two importations and examined for electrophoretic variation at 14 isozyme loci over 22 generations of laboratory rearing. Two out of 14 loci examined were found to be polymorphic. In the first 12 generations of sampling when approximately 1000 breeding females were used to perpetuate both colonies, there was a slight increase in heterozygosity at the Mdh locus in the colonies of the two strains. In the last 10 generations of sampling when only 500 females were used, there was a rapid decrease in electrophoretic variation in the two colonies.

The effective population sizes for the two colonies was estimated at 3.4 and 9.0% of the number of breeding females used to continue the colonies. These data indicate that using 1000 mated females to perpetuate the *C. flavipes* colonies maintained greater genetic variation than using 500 females.

7. POPULATION GENETIC STRUCTURE AND GENE FREQUENCY CLINES OF TWO SYMPATRIC SPECIES, *CHILO PARTELLUS* (SWINHOE) AND *CHILO ORICHALCOCILIELLUS* (STRAND) (LEPIDOPTERA: PYRALIDAE) FROM THE KENYA COAST

Participating scientist: *C. O. Omwega*

Assisted by: *J. O. Okello, S. P. Ojwang*

Chilo partellus and *C. orichalcociliellus* occur sympatrically at the Kenya coast. The former is an exotic pest of gramineous plants which was accidentally introduced into Africa some time around the turn of the century. The two species are ecologically very similar. Electrophoresis has been used to document differences between the two species.

Allozyme data showed differences not only in certain loci, but also in some allele frequencies. Heterozygosity was lower in *C. partellus* than *C. orichalcociliellus*, and populations of the latter showed greater genetic substructuring. The lower overall heterozygosity of *C. partellus* may be attributed to the colonisation event at introduction which constituted a genetic bottleneck, and to the expanding range of *C. partellus*. Clinal variation with latitude and elevation in certain alleles of *C. partellus* and *C. orichalcociliellus* were observed.

8. BIOLOGY OF *COTESIA FLAVIPES* ON *CHILO PARTELLUS* LARVAE REARED ON ARTIFICIAL DIET CONTAINING NEEM SEED POWDER

Participating scientists: *S. Okech, W. A. Overholt, R. C. Saxena*

Assisted by: *G. O. Ogola, P. E. W. Njoroge*

The additional mortality to stemborer populations caused by *C. flavipes* may not be sufficient to suppress stemborer populations below levels acceptable to farmers, and therefore it may be necessary to integrate classical biological control with other management tactics.

In 1994 experiments were conducted to evaluate the impact of the botanical pesticide, neem, on the development and survival of *C. flavipes*. Parasitoids were reared on *C. partellus* larvae fed on artificial diet containing 5, 10, 25, and 50 ppm neem seed powder. Low concentrations of neem (5 and 10 ppm) did not affect *C. partellus* larvae nor the parasitoids. A medium concentration (25 ppm) lengthened the developmental period of host larvae and reduced the pupal weight without causing significant mortality. High concentration (50 ppm) lengthened larval development and caused very high mortality (>90%). Parasitoid developmental

time was longer at 25 ppm than at the lower dosages. At the highest dosage, no parasitoids emerged from their hosts. This study suggests that stemborers which consume small amounts of neem may be suitable for *C. flavipes* development, but higher dosages may inflict significant mortality on parasitoids.

9. PRODUCTION AND SUPPLY OF INSECTS

1. *Production of stemborers at Duduville*

Participating staff: *J. P. R. Ochieng'-Odero, G. W. Oloo, P.E. Njoroge, M. Gitau, A. Majanje, D. Jabuto, J. O. Kokungu*

The rearing of stemborers in Nairobi was maintained sparingly due to low resources available. The demand for *Chilo partellus* was the highest among the four target stemborers. Other stemborers that were maintained in smaller colonies included *C. orichalcociliellus, Busseola fusca*, and *Sesamia calamistis.*

The ICIPE/WAU Collaborative Project which normally uses *C. partellus* to maintain parasitoids used 68.74% of the 189,000 insects produced by the Duduville unit. Other high users which obtained *C. partellus* in Nairobi included students in ARRPIS (22.2%), and the Behavioural and Chemical Ecology Unit (6.2%).

2. *Production and supply of cereal stemborers for pest management at Mbita Point Field Station*

Participating staff: *F. O. Onyango, M. D. O. Bungu, J. P. R. Ochieng'-Odero, J. O. Kokungu*

(a) *Chilo partellus*

The *C. partellus* colony was maintained on an artificial diet throughout the year. An average of 60 jars of diet was prepared daily, each jar containing approximately 200 g of diet. Peak demand for larvae occurred during the long planting season in the months of April, May, and June, and also in the short rainy season in October and November. The level of production met the requirements of all insect users, who were drawn mostly from the Plant Pests Research Programme. A total of 50.0 million egg equivalents (MEQ) were produced, and 12.3 MEQ were distributed to users (Table 1).

Larvae and pupae were dissected from sorghum and maize stubble at sites approximately 15–20 km away from Mbita Point Field Station, and used to completely replace the laboratory colony which had advanced to 83 generations. The new colony multiplied sufficiently, and by the 8th generation, it could supply the number of larvae required by the various users.

(b) *Busseola fusca*

The *Busseola fusca* colony was maintained on an artificial diet continuously for 26 successive generations in the laboratory. A total of approximately 2.7 and 1.7 MEQ were produced and supplied, respectively (Table 1).

(For publications about breeding of insects and their pests, see under the Animal Breeding and Quarantine Unit report.)

Table 1. Production and supply of *Chilo partellus and Busseola fusca* at Mbita Point Field Station in 1994*

Month	*Chilo partellus*		*Busseola fusca*	
	Produced	Supplied	Produced	Supplied
January	2.9	1.0	0.3	0.1
February	2.7	0	0.2	0.0
March	2.1	0.1	0.2	0.1
April	6.8	1.5	0.2	0.0
May	3.4	1.8	0.2	0.2
June	4.2	1.2	0.1	0.1
July	5.1	0.6	0.2	0.2
August	4.5	0.4	0.2	0.2
September	3.7	1.0	0.2	0.2
October	8.9	2.3	0.5	0.4
November	3.7	1.8	0.3	0.1
December	2.5	0.6	0.1	0.1
Total	50.5	12.3	2.7	1.7

*Number of eggs produced/supplied in million egg equivalents (MEQ).
**1 adult = 160 egg equivalents.

REGIONAL ACTIVITIES

Zanzibar: A preliminary survey revealed the presence of four stemborers in maize, sorghum and wild grasses: *Chilo partellus, Chilo orichalcociliellus, Sesamia calamistis,* and *Busseola fusca*. The introduced species, *C. partellus* was the most abundant species. A workplan that would lead to the release of *C. flavipes* in 1995 in Zanzibar was developed in collaboration with the Plant Protection Division (PPD). The workplan outlined pre-release studies on stemborers and their indigenous natural enemies that should be completed before *C. flavipes* is released. Additionally, a representative of the Zanzibar PPD attended a training programme held at the ICIPE in August 1994 on the identification of cereal stemborers and their natural enemies. After the training programme, the Zanzibari participant remained at the ICIPE for a few extra days for additional training on stemborer and parasitoid rearing.

Tanzania: Visits were made to Tanzania in late May 1994 and possibilities for establishing a collaborative programme on stemborer biological control were discussed with the relevant authorities. Approval must be granted by the National Plant Protection Advisory Committee prior to the introduction of exotic natural enemies. The ICIPE will be invited to the next meeting of the committee to make a presentation on stemborer biological control using *Cotesia flavipes*. Release activities in Tanzania may be conducted in collaboration with a German - funded IPM project.

IITA: In November 1992, an agreement to work collaboratively on stemborer biological control was established between the ICIPE and IITA. Since that time, the ICIPE/WAU project has provided the IITA with a protocol for determining the acceptability and suitability

of stemborers for parasitisation by *Cotesia* spp. The project sent several shipments of *Cotesia* spp. and other parasitoids to IITA in 1994 for screening against West African stemborers.

Training

An International Group Training Course on 'Components Essential for Ecologically Sound Pest and Vector Management Systems', was held at the ICIPE from 14 August to 10 September 1994. Project personnel participating in the instruction were W. A. Overholt, C. O. Omwega and A. J. Ngi-Song.

Another course, 'Cereal Stemborers in Africa: Taxonomy, Natural Enemies and Control', was held at the ICIPE from 8–19 August 1994. This course was organised by the 'Cereal Stemborers and their Parasitoids in Africa Project', which is a collaborative project between WAU and the International Institute of Entomology that is funded by DGIS. Project personnel participating in the instruction included W. A. Overholt, S. W. Kimani, A. J. Ngi-Song, J. Mbapila, and C. O. Omwega.

Completed studies

Kimani S.W. and Overholt W.A. Biosystematics of the *Cotesia flavipes* Cameron complex (Hym:Braconidae): Interspecific hybridisation, sex pheromone and mating behaviour studies. *Bulletin of Entomological Research* (in press).

Mating behaviour, sex pheromone and reciprocal breeding were studied for *Cotesia flavipes* Cameron (Hymenoptera: Braconidae), *Cotesia sesamiae* (Cameron) and *Cotesia chilonis* Matsumura. These three putative species comprise the *Cotesia flavipes* complex. Wing fanning and antennal vibration were the initial courtship signals from the males. Antennal stroking by the male was also an important contact signal and a prerequisite to successful mounting and copulation. Interspecific crosses revealed that males of *C. flavipes* exhibited courtship behaviour, mounted and copulated with females of *C. chilonis* and *C. sesamiae*; the males transferred sperms but progeny for these crosses did not include females. Males of *C. sesamiae* copulated with females of *C. chilonis* and the progeny included viable females. The backcrosses of progeny of the hybrid females to male parents also included viable females. Sex pheromone experiments were conducted in a Y-tube olfactometer and in large field cages. Males and females of *C. flavipes* perceived and responded to odours emitted by the opposite sex. There was no significant response to odours from conspecific individuals of the same sex in any of the three species. Pheromone bioassays in field cages using sticky traps baited with live virgin *C. flavipes* females attracted conspecific males.

Kimani S.W., Overholt W. A., Woolley J. and Walker A. Biosystematics of the *Cotesia flavipes* species complex (Hym:Braconidae) II: Morphometrics and morphology of selected allopatric populations. *Bulletin of Entomological Research* (in press).

Morphometric studies of 11 allopatric populations of the *Cotesia flavipes* species complex representing three putative species: *C. flavipes*, *C. sesamiae* and *C. chilonis* were conducted. Sixteen characters were measured. Principal component analysis separated the complex into three somewhat overlapping groups that corresponded well to previous concepts of the species. Canonical variate analysis separated the complex into three distinct clusters with populations from Africa together, populations from Asia and the Neotropics forming a second cluster, and material from China and Japan forming a third cluster. The Mahalanobis squared distances between the three clusters were nearly equal. A survey of five morphological characters scored from 16 populations indicated that there is a fair amount of intra- and interpopulation variation between and within species. However, a combination of the following characters; the number of hairs on the scutellum, the scuto-scuteller-sulcus and the rugosity on the propodeum could be used to separate the females and males in the complex. Results support recognition of three species in the *C. flavipes* complex.

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

Twelve enzyme systems were electrophoretically analysed for specific differences between the larvae of *Chilo orichalcociliellus* (Strand) and *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae). The banding patterns of three enzyme systems, glucose phosphate isomerase, aspartate amino transferase and lactate dehydrogenase, were found to be useful in differentiating larvae of the two taxa and could be considered valid taxonomic criteria for the identification of these stemborers. The electrophoretic results are in agreement with the results of morphological studies based on asetose tubercles. Enzyme analysis allowed a rapid distinction of aestivating and very young larvae of the two species which had no asetose tubercles and were morphologically indistinguishable. Electrophoresis of *Chilo* spp. larvae collected in maize and sorghum fields in the coastal belt of Kenya indicated that 26.8% were *C. orichalcociliellus* and 73.2% were *C. partellus*.

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

Four cereal stemborers occurring in Kenya, *Chilo partellus* (Swinhoe), *Chilo orichalcociliellus* Strand, *Busseola fusca* (Fuller) and *Sesamia calamistis* Hampson, were exposed to females of the larval endoparasitoids *Cotesia flavipes* Cameron and *Cotesia sesamiae* (Cameron) to assess their acceptability for oviposition and suitability for the development of the parasitoids. There was no difference in the acceptability of the four hosts exposed to *C. flavipes*. In contrast, *C. sesamiae* preferred *S. calamistis* larvae (92%), followed by the two *Chilo* species; *Busseola fusca* larvae were attacked least (48.8%) by *C. sesamiae*. The suitability of the four hosts also varied with the parasitoid species. In *B. fusca* both parasitoid species did not develop and egg encapsulation was observed. *Chilo partellus*, *C. orichalcociliellus* and *S. calamistis* were suitable hosts for the development of *C. flavipes*. However, a higher mortality of immature parasitoids was observed in *S. calamistis* as compared to *C. partellus*. No difference was found in the mean number of progeny per female, and the sex ratio. The most suitable host for *C. sesamiae* was *S. calamistis*, followed by the two *Chilo* species which were equally suitable. When third, fourth, fifth and sixth instars of *C. partellus* were exposed to *C. flavipes* females, third instars were less suitable than fourth, fifth or sixth instars as measured by immature parasitoid mortality.

Okech S. H. O. and Overholt W. A. Comparative biology of *Cotesia chilonis* (Hymenoptera:Braconidae) on selected

African gramineous stemborers. *Biocontrol Science and Technology* (in press).

Observations were made on the development, mortality and fecundity of the gregarious endoparasitoid, *Cotesia chilonis* (Matsumura),when reared on four African stemborers, *Chilo partellus* (Swinhoe), *Chilo orichalcociliellus* Strand, *Sesamia calamistis* Hampson and *Busseola fusca* (Fuller). *Cotesia chilonis* accepted the four stemborers for oviposition, but parasitoid eggs were encapsulated in *B. fusca*. The percentage of *C. partellus*, *C. orichalcociliellus* and *S. calamistis* successfully parasitised was not different and ranged from 65.4–73.4%. Mortality of parasitoid larvae was higher, and immature development longer, in *C. orichalcociliellus* than in *S. calamistis* or *C. partellus*. The number of ovarian eggs in adult *C. chilonis* females reared from *C. partellus*, *C. orichalcociliellus*, *S. calamistis*, were 125.3, 79.5 and 120.6, respectively. High temperature accelerated the rate of development of immature stages and reduced adult longevity. High humidity (70–80%) extended adult longevity.

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

Cotesia flavipes Cameron (Hymenoptera: Braconidae) has been released several times in Africa for biological control of gramineous stemborers. Establishment has been reported on the Indian Ocean Islands of Mauritius, Reunion and Madagascar, however, several attempts to introduce *C. flavipes* into continental Africa are reported to have failed. The most recent attempt to establish *C. flavipes* in Africa occurred in 1993 when large numbers of the parasitoid were released at three sites in the coastal area of Kenya. Recoveries of *C. flavipes* more than one year after the last releases are compelling evidence of establishment. In addition to the recoveries in the coastal area of Kenya, several cocoon masses of *C. flavipes* have been recovered from southwestern Kenya where the parasitoid was not released. Identifications of the parasitoids from southwestern Kenya were based on morphological characters, allozyme frequencies, and mating experiments with laboratory populations of *C. flavipes*. It is hypothesised that *C. flavipes* established from individuals escaping from a laboratory colony maintained in southwestern Kenya in 1991.

Omwega C. O., Okello J. O., Kioko E. N. and Overholt W. A. electrophoretic survey of *Chilo partellus* in Kenya. In*Beneficial African Insects: A Renewable Natural Resource.* Proceedings of the 10th Meeting and Scientific Conference of the African Association of Insect Scientists 5–10 September 1993, Mombasa, Kenya, pp. 185–189.

Ten enzyme-coding loci were examined by means of horizontal starch gel electrophoresis in samples of *Chilo partellus* larvae from eight sites from the Kenya coast, one site from central Kenya and six sites in western Kenya. Samples were obtained from maize and sorghum stalks. Four loci (Gpi, Idh-1, Idh-2 and Pgm) were polymorphic and six Aco, Ald, Fum, Gpd, Ldh and Sdh) were monomorphic. Number of alleles per locus was 2.75 for the coast populations and only 0.8 for central and western Kenya. Generally, average heterozygosity (H) was higher for samples from the coast (range 0.1164 to 0.1314) as compared to central (0.0668) and western Kenya (0.0111 to 0.1128). These data indicate geographical variation of *C. partellus* populations in Kenya. It is also hypothesised that *C. partellus* populations from western Kenya constitute a smaller effective population size relative to populations from other sites.

Overholt W. A. The rearing of *Cotesia flavipes* for classical biological control of *Chilo partellus*. In *Techniques of Insect Rearing for the Development of Integrated Pest and Vector Management Strategies*. Vol. II. (Edited by Ochieng-Odero J. P. R.), pp. 331–346. ICIPE Science Press.

Cotesia flavipes Cameron (Hymenoptera: Braconidae) is a gregarious endoparasitoid of gramineous stemborers that has been imported by ICIPE for a classical biological control programme against the exotic stemborer, *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae). The life cycle of *C. flavipes* lasts approximately 22 days, and ca. 30 parasitoids develop in each host larva. The facilities and equipment necessary for the rearing of *C. flavipes* are very simple and relatively inexpensive. A 'hand-stinging' rearing procedure is described in detail, along with specifications on rearing facilities and equipment. Quality control through accurate record keeping and bioassays is discussed.

Overholt W. A. A review of classical biological control of gramineous stemborers in Africa. In *Cereal Stemborers in Africa: Taxonomy, Natural Enemies, and Control* (Edited by Polaszek A.). Technical Centre for Agricultural and Rural Cooperation (CTA), Ede, the Netherlands (in press).

Over the past 60 years there have been several attempts to establish exotic parasitoids in mainland Africa, Madagascar and the Mascarene Islands for biological control of lepidopteran stemborers of maize, sorghum, and sugarcane. The only reported establishments have been on Mauritius, Reunion and Madagascar against the introduced sugarcane borer, *Chilo sacchariphagus* (Bojer), and in Mauritius and Reunion against *Sesamia calamistis* Hampson in maize. There is recent evidence that the exotic parasitoid, *Cotesia flavipes* Cameron, has established in southwestern Kenya on *Chilo partellus* (Swinhoe). The results of past biological control introductions, and their implication for future programmes are discussed.

Overholt W.A., Ngi-Song A. J., Kimani S. K., Mbapila J., Lammers P. and Kioko E. Ecological considerations of the introduction of *Cotesia flavipes* Cameron (Hymenoptera: Braconidae) for biological control of *Chilo partellus* (Swinhoe) (Lepidoptera:Pyralidae), in Africa. *Biocontrol News and Information* 15(2), 19N–24N.

The exotic parasitoid, *Cotesia flavipes*, was released in 1993 in Kenya for biological control of the introduced stemborer, *Chilo partellus*. The release has been criticised in some quarters as being potentially ecologically disruptive. This review of the programme explains why this is unlikely to be the case. Pre-release studies indicated that two indigenous stemborers, *Chilo orichalcociliellus* and *Sesamia calamistis*, occur sympatrically with *C. partellus* in native and agricultural habitats in the area of introduction. Investigations on the host selection behaviour of *Cotesia flavipes* demonstrated that the two indigenous stemborers were acceptable and suitable hosts for *C. flavipes* in the laboratory. A third indigenous species that occurs outside of the release area, *Busseola fusca*, was not a suitable host. It is anticipated that *C. flavipes* will only become established in areas where the dominant stemborer species are suitable for its development. An indigenous congener of *C. flavipes*, *Cotesia sesamiae*, is an ecologically similar species that may be displaced in certain habitats if *C. flavipes* is successfully established. The ecological implications of the introduction and establishment of *C. flavipes* in East Africa are discussed.

Overholt W. A., Ochieng J. O., Lammers P. M., and Ogedah K. Rearing and field release methods for *Cotesia flavipes* Cameron (Hymenoptera: Braconidae), a parasitoid of tropical

gramineous stemborers. *Insect Science and its Application* 15(3) (in press).

Hand-stinging and mass exposure methods of rearing the parasitoid, *Cotesia flavipes* Cameron (Hymenoptera: Braconidae), on the stemborer host, *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae), were compared. The percent of hosts successfully parasitised, progeny production, percent female progeny, and host mortality did not differ between the two methods. However, there was evidence of superparasitism of mass exposed hosts. Releases of *C. flavipes* as adults and as cocoons were both effective methods for field colonisation of the parasitoid. A device for the release of *C. flavipes* in the cocoon stage is described.

Overholt W.A., Ogedah K. and Lammers P. M. Distribution and sampling of *Chilo partellus* (Lepidoptera:Pyralidae) in maize and sorghum on the Kenya coast. *Bulletin of Entomological Research* 84, 367–378.

The seasonal occurrence and spatial distribution of the crambine stemborer, *Chilo partellus* (Swinhoe) were investigated in maize, *Zea mays*, and sorghum, *Sorghum bicolor*, fields at the Kenya coast. During the vegetative growth stage, small-sized larvae were typically found behind leaf sheaths and in whorls in maize and sorghum. In reproductive and senescent maize, small-sized larvae were also found feeding in ears. Later immature life stages were located predominantly in stems in sorghum, and in the stems and ears in maize. Density and variance estimates of small, medium-, and large-sized larvae and pupae in maize and soghum were fitted to Taylor's power law which provided significant regressions in all cases. The between-plant distribution was aggregated in all life stages. In maize, the distribution remained aggregated through the larval and pupal life stages, but in sorghum the distribution became progressively less aggregated as insects aged. The relationship of *C. partellus* density to the proportion of plants infested also suggested aggregation. Optimal sample sizes were determined for both binomial and enumerative sampling plans at two levels of precision, and a discussion is included on the relationship of optimal sample sizes to economic injury levels. Additionally, a presence/absence sequential sampling plan is proposed.

IV. Role of Wild Habitat in the Invasion of Cereal Crops by Stemborers in Africa with Special Reference to *Chilo partellus* and *Busseola fusca*

Donor: *Gatsby Charitable Foundation, UK*

Collaborators: *Rothamsted Experimental Station, UK; Kenya Agricultural Research Institute (KARI)*

Background

ICIPE and the Rothamsted Experimental Station (RES) in the United Kingdom are collaborating on this 4-year project initiated in March 1994. In view of the crucial importance of the cereal stemborers in reducing yields of maize and sorghum in Africa, ICIPE and RES scientists are undertaking in-depth studies on the dynamic relationship between the population of stemborers and their natural enemies on wild hosts and cultivated crops.

The general objective of the project is to study the multiple interactions among cultivated crops, wild hosts plants, various stemborer species, and natural enemies affecting the dynamics of pest populations, and to use this information in development of a sustainable integrated pest management approach. Some wild hosts act as trap plants, whereas others are reservoirs for pests; the latter are responsible for higher infestations on cultivated plants. By learning as to what accounts for the differences in pest dynamics between natural wild systems and agroecosystems, one can learn much about the underlying ecological processes that create the observed patterns of distribution and abundance of stemborers in nature, and about those allelochemicals that protect the wild plants from herbivory. The plant breeders and entomologists can use such information in developing resistant/tolerant crop varieties. The project aims to identify wild grasses of economic importance to farmers, which could serve as 'trap crops' for stemborers, as well as reservoirs and shelter for borer natural enemies.

The project is carried out in three different ecologies in Kenya: the coast, the lake shore, and the high altitude regions in the west of the country. The RES is collaborating with the ICIPE in the fields of insect genetics, plant chemistry, and insect movement. ICIPE scientists are collaborating closely with agronomists and entomologists from the Kenya Agricultural Research Institute (KARI) conducting field trials and identification of wild hosts. This project and the Wageningen Agricultural University (WAU) Project at ICIPE are collaborating in the field of identification of natural enemies and conducting field trials on stemborer colonisation processes. Recommendations for stemborer management and other techniques arising from this project will be distributed widely through KARI.

In 1995 we will assess if preserving wild grass biodiversity would be an effective means of habitat manipulation for stemborer control by using them as 'trap plants' and through enhancing the impact of natural enemies.

1. SELECT AREAS OF WILD HABITAT FAVOURABLE AND UNFAVOURABLE TO STEMBORERS, AND STUDY DISTRIBUTION PATTERN OF STEMBORERS RELATIVE TO DISTRIBUTION OF WILD HOSTS

Participating scientists: *Z. R. Khan*, K. A. Nyarko*
*(*Project Coordinator)*

Assisted by: *P. Chiliswa, G. Asino, N. Mwelesa*

Work in progress

Based on destructive sampling, field sites were selected in three different ecologies—hot and humid (Kenya coast, up to 1080 m elevation), warm and semi-arid (lakeshore area, about 4300 m altitude), and high altitude, wet and cool area (Trans Nzoia district, more than 6500 m altitude). From each ecological zone, eight different locations, based on pest abundance, cropping pattern, and abundance of different grass species, were selected. Extensive surveys were undertaken four times during the year. Several wild host plants of various stemborer species (*Chilo partellus, Busseola fusca, Sesamia inferens* and *Eldana saccharina*) were recorded (Table 1). Seasonal changes in larval density on cultivated and wild host plants were also recorded. Studies on

Table 1. Wild hosts on cereal stemborers

Family/Host name	CL*	BF	SC	ES	UN
Poaceae					
Dactyloctemium bogdanii	++	–	–	–	–
Echinochloa pyramidalis	++	++	++	–	++
Hyparrhenia cymbaria	–	++	–	–	–
Hyparrhenia filipendula	++	–	++	–	–
Hyparrhenia rufa	++	++	++	–	–
Panicum deustum	++	++	–	–	–
Panicum maximum	++	++	++	++	++
Pennisetum purpureum	++	++	++	++	++
Phragmites sp.	–	–	++	–	++
Rottboellia cochinchinensis	++	++	–	++	–
Setaria incrassata	–	++	–	–	–
Setaria sphacelata	–	++	++	–	–
Sorghum arundinaceum	++	++	++	++	–
Sorghum versicolor	++	++	++	++	–
Vossia spp.	–	–	++	–	–
Cyperaceae					
Cyperus immensis	–	–	++	++	++
Cyperus maculatus	–	–	–	++	++
Cyperus papyrus	–	–	++	++	++
Typhaceae					
Typha domingensis	–	–	++	–	–

*++ recorded as host; –, not recorded; CL, *Chilo* spp.; BF, *Busseola fusca*; SC, *Sesamia calamistis*; ES, *Eldana saccharina*; UN, unidentified borer species.

population dynamics of stemborers on cultivated versus wild host plants are underway.

Future activities

Chilo partellus and *Busseola fusca* pheromones will be used in collaboration with KARI to study the relative abundance of these insects and to confirm the relevance of the sites selected by destructive sampling. Destructive sampling will be continued at six-week intervals to study population dynamics of stemborers on wild and cultivated host plants.

2. STEMBORER ABUNDANCE AND DISTRIBUTION ON CULTIVATED AND WILD HOST PLANTS, AND THEIR MOVEMENT BETWEEN TWO HABITATS

Participating scientists: *Z. R. Khan, W. A. Overholt*

Assisted by: *P. Chiliswa, G. Asino, N. Mwelesa, J. Randriamananoro* (*ARPPIS PhD student)*

Collaborators: *W. Powell, I. Woiwod, L. Smart (Rothamsted Experimental Station), J. Wandera, M. Mulla (KARI, Kitale)*

Work in progress

During the short rainy season of 1994, a 6 x 6 field trial was established at Mbita Point Field Station incorporating cultivated and selected wild host species to study colonisation processes of stemborers on various plants. They included a susceptible maize (INB-A), a susceptible sorghum (IS 18363), *Hyparrhenia rufa*, *Panicum maximum*, *Pennisetum purpureum* and *Sorghum versicolor*. Each plant species was replicated six times in plots of 6 x 6 m. The study revealed interesting aspects of multiple interactions among cultivated plants, wild hosts, various stemborer species, and their natural enemies. Oviposition by *C. partellus* was maximum on cultivated sorghum, followed by wild sorghum (*S. versicolor*) and maize (Figure 1). *Hyparrhenia rufa*, *P. maximum* and *P. purpureum* were the least preferred hosts for oviposition. On maize, oviposition was maximum on 5-week-old plants, whereas on sorghum and wild sorghum, oviposition increased with the age of plants, because of new tillers. Sorghum and wild sorghum were the most suitable hosts for stemborer development, whereas *Hyparrhenia rufa*, *P. maximum* and *P. purpureum* were least suitable. *Hyparrhenia rufa* was, however, a more preferred host as compared to maize or sorghum.

Studies on the behavioural and biological responses of *Busseola fusca* adults and larvae to various cultivated and wild hosts have been conducted. In both choice and no-choice tests, *S. versicolor* and *S. arundinaceum* elicited the highest rates of oviposition. In choice oviposition tests, *H. rufa* was preferred over both susceptible and resistant maize. In no-choice tests, however, *H. rufa* and *Echinochloa pyramidalis* were least effective in eliciting oviposition. The rates of larval survival, growth and development were highest on *S. versicolor* and *S. arundinaceum*. Food consumption and utilisation by third-instar *B. fusca* larvae was significantly higher on *S. versicolor* and *S. arundinaceum* as compared to *P. purpureum*, *E. pyramidalis* and *H. rufa*.

Future activities

Quantitative assessment of the influence of naturally occurring wild host plants, and agroecological factors on the dynamics of stemborers will be assessed. To further expand our knowledge on stemborer colonisation processes in different ecologies, a 6 x 6 experiment incorporating new wild hosts will be planted at KARI stations at Mtwapa and Kitale during 1995. Behavioural and physiological responses of *Chilo partellus* to selected wild hosts will be studied to assess the suitability of the grasses as hosts. Studies on the movement of stemborers between cultivated and wild host plants will be initiated in collaboration with RES at Kenya coast.

3. IDENTIFY PARASITES, PREDATORS AND PATHOGENIC MICROORGANISMS ASSOCIATED WITH STEMBORERS IN CULTIVATED AND WILD HABITATS

Participating scientists: *Z. R. Khan, W. A. Overholt*

Assisted by: *P. Chiliswa, G. Asino*

Work in progress

In collaboration with the Wageningen Agricultural University (WAU) Project at ICIPE, various parasitoids have been identified from stemborer larvae collected from wild and cultivated plants. Major among these

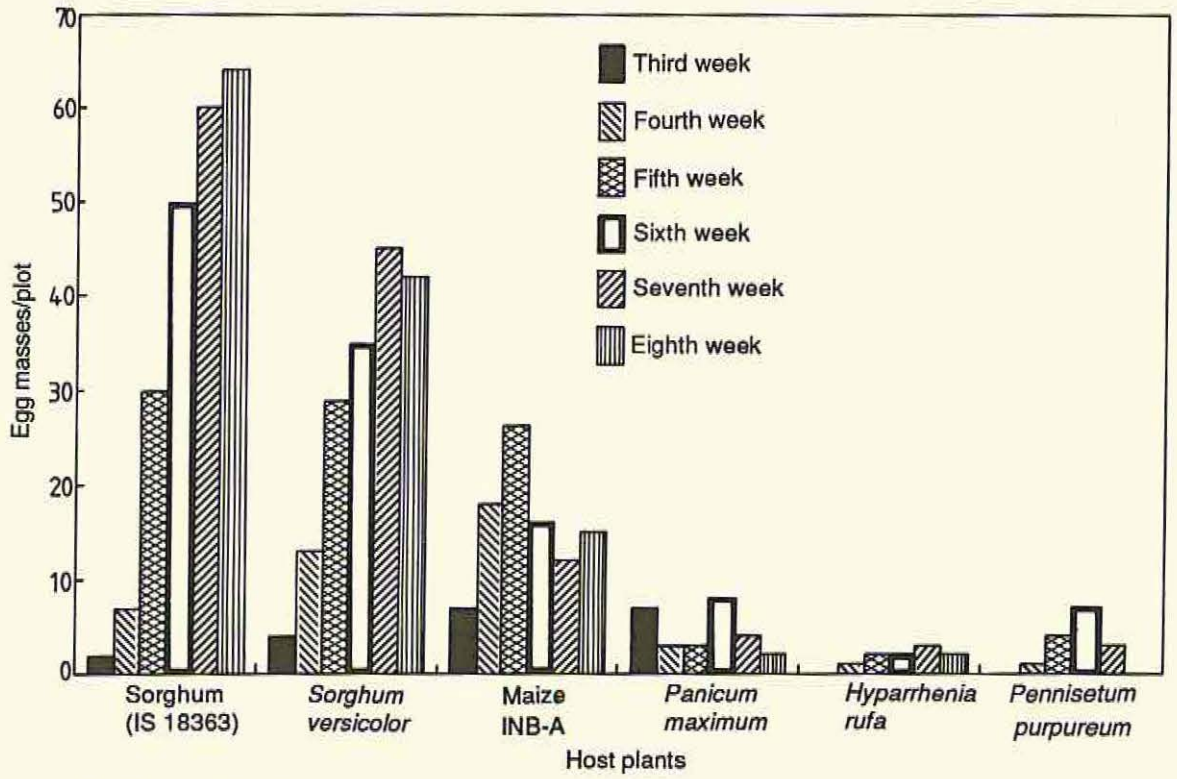


Figure 1. Distribution of egg masses of *Chilo partellus* on cultivated and wild host plants in a field experiment at Mbita Point, Kenya, 1994.

were *Cotesia flavipes, Cotesia sesamiae, Dentichasmias busseolae, Euvipio rufa*, and *Pediobius fud and wild hosts have* , introduced in Kenya two years ago by WAU Project, seems to be well established on both cultivated cereals and wild grasses. Levels of stemborer parasitisation on cultivated and wild hosts is being studied.

Future activities

Collection and identification of the natural enemies from cultivated and wild hosts will continue in 1995.

4. IDENTIFY AND EVALUATE BEHAVIOUR-MODIFYING PLANT CHEMICALS FROM CULTIVATED AND WILD HOSTS AND NON-HOST PLANTS FROM STEMBORERS AND THEIR NATURAL ENEMIES

Participating scientists: *W. Lwande, S. Waladde, Z. R. Khan*

Assisted by: *E. Nyandat, H. M. Kahoro, L. M. Moreka, G. Asino*

Collaborators: *L. Wadhams, J. Pickett (Rothamsted Experimental Station)*

Work in progress

To test plant allelochemicals for eliciting oviposition by *B. fusca* gravid females, a 'surrogate stem' was designed and evaluated. The surrogate stem was made of wax paper (18.5 cm long, 17.5 cm wide) tightly rolled on a wooden rod (20 cm long, 1 cm diameter). The surrogate stem closely simulated the maize stem with intact leave sheaths. *Busseola fusca* readily inserted their ovipositors into the gaps between the surrogate stem and leaf sheaths and laid eggs in linear rows as they did in maize plant stems. The surrogate stem provided physical stimuli necessary for eliciting *B. fusca* egg laying and has greatly facilitated bioassay of plant allelochemicals to the insect's ovipositional response.

Contact chemical stimuli, extracted from maize plants, do not seem to play a key role in influencing choice of oviposition sites by *C. partellus*. Therefore, efforts are underway to identify volatile allelochemicals from various cultivated and wild host plants. Volatile allelochemicals are being collected using the dynamic headspace collection method in the laboratory. Volatiles trapped on Porapak Q or C-18, will be analysed by GC-MS and bioassayed using combined gas chromatography-electroantennography (GC-EAG) at Rothamsted Experimental Station.

Future activities

Electrophysiologically-active compounds in the volatile samples will be located using GC-EAG. Separation of the samples will be done by AI 93 gas chromatograph and FID. Electrophysiologically active compounds in the samples will be identified by coupled GC-MS. The activity of the compounds will be confirmed by behavioural and electrophysiological bioassays.

5. EXAMINE GENETIC DIVERSITY AMONG PEST POPULATIONS FROM CULTIVATED AND WILD HOSTS

Participating scientist: *Z. R. Khan*

Assisted by: *P. Chiliswa*

Collaborators: *H. Loxdale, C. Brooks (Rothamsted Experimental Station)*

Work in progress

The aim of this study is to look for genetic differentiation between stemborer populations collected from cultivated and wild hosts. ICIPE and RES are closely collaborating on this activity. The cheapest, quickest and best understood technique currently available is enzyme electrophoresis and so far this method was used to do all the investigations. Deep frozen larvae, pupae and moths collected from cultivated and several wild hosts were transported to RES. The only stemborer species examined so far is *C. partellus*. Initially out of the 17 soluble enzymes and three running buffers screened, ten enzymes stained and resolved well enough to warrant further investigation. These are EST, GOT, G6PDH, HBDH, HK, IDH, MDH, MPI, PGI and PGM.

Future activities

The preliminary results on insect genetics are encouraging. Similar studies with *B. fusca* will be initiated in 1995. More samples of *C. partellus* and *B. fusca* will be collected from different host plants and from different ecological regions. When allozyme electrophoresis work is near completion, Randomly Amplified Polymorphic DNA (RAPD) profiles from samples taken from selected hosts will be compared.

Training activities

The following ARPPIS students participated in the research project:

- Jean J. Randriamananoro, PhD student from Madagascar
- Sumaya E. R. M. Kheir, PhD student from Sudan.

V. Development of Methods for Application of Pheromones in the Management of Stemborers on Maize and Sorghum

Participating scientists: *S. A. Lux*, A. Hassanali, W. Lwande (*Project Leader)*

Assisted by: *N. Gikonyo, F. Njogu≠, I. Jalloh* (*ARPPIS PhD student, ≠MSc student)*

Donor: *SAREC*

Background

Females of *Chilo partellus* and *C. orichalcociliellus* release a pheromone that attracts male counterparts for mating. Synthetic compounds of the major components of this pheromone could be used to lure male *C. partellus* and *C. orichalcociliellus* to traps for monitoring of the population of this insect.

1. CROSS ATTRACTION BETWEEN *CHILO PARTELLUS* AND *C. ORICHALCOCILIELLUS*

Last year, we reported that where *C. partellus* and *C. orichalcociliellus* coexisted, males of the two species were lured to traps baited with the two major components of the female sex pheromone of *C. partellus*, Z-11-hexadecenal and Z-11-hexadecen-1-ol. Further studies in 1994 revealed that the major components of the pheromone of *C. orichalcociliellus* were the same as those of *C. partellus*.

Ethological observations were conducted to observe responses of 1-day-old male *C. partellus* and *C. orichalcociliellus* to female *C. partellus*, *C. orichalcociliellus* and to a dispenser of synthetic *C. partellus* female sex pheromone consisting of Z-11-hexadecenal and Z-11-hexadecen-1-ol. The dispenser was constructed using filter paper *(ICIPE 1992 Annual Report)*. The observations were conducted between the 8th and 9th hour of the scotophase under red light. Tables 1 and 2 summarise the results of the observations.

As can be seen from the tables, in the case of both species, *C. partellus* males tended to locate their conspecific females first. They spent more time flying, walking and fanning wings around the conspecific females than around any other pheromone source. Males of both species were also attracted to the filter paper dispenser. In both cases, the relative attractiveness of the filter paper dispenser was at a level of about 50% and was very similar to that of conspecific females (attractiveness estimated on the basis of time spent flying or walking with wing fanning around the source). This may have important practical implications as it would allow the use of the dispenser for monitoring of both stemborers using the same trap.

Table 1. Response of *C. partellus* males to virgin females of the two species and to the filter paper dispenser (mean ± SE)

Type of behaviour	*C. partellus* female	*C. orichalcociliellus* female	Dispenser
Flight around source*	32.6 ± 1.38	17.8 ± 4.17	18.6 ± 3.3
Fanning wings/ walking*	86.8 ± 16.4	40.9 ± 47.7	49.8 ± 11.6
Source located first≠	3.7 ± 0.29	1.9 ± 0.27	2.9 ± 0.35
Landing on the source≠	4.1	3.0	4.0

*Time spent on activity (min); ≠number of observed events.

A remarkable difference was, however, noticed in the reaction of males towards females of the other non-conspecific species. Males of *C. partellus* responded

Table 2. Response of *C. orichalcociliellus* males to virgin females of the two species and to the filter paper dispenser (mean ± SE)

Type of behaviour	C. *partellus* female	C. *orichalcociliellus* female	Dispenser
Flight around source*	9.8 ± 1.4	30.8 ± 7.24	12.4 ± 2.7
Fanning wings/ walking*	6.3 ± 1.25	73.0 ± 12.7	41.9 ± 10.96
Source located first#	3.1 ± 0.0	3.6 ± 0.27	2.0 ± 0.21
Landing on the source#	4.1	18	2

*Time spent on activity (min); #number of observed events.

to females of *C. orichalcociliellus* with an intensity similar to that of response to the filter paper dispenser. Contrary to this, males of *C. orichalcociliellus* nearly ignored females of *C. partellus*. This may have profound implications on the ecological competition between the exotic *C. partellus* species and the indigenous *C. orichalcociliellus*.

2. CROSS MATING BETWEEN *C. PARTELLUS* AND *C. ORICHALCOCILIELLUS*

Studies were undertaken to observe if *C. partellus* and *C. orichalcociliellus* could crossmate. One-day-old males of *C. partellus* and *C. orichalcociliellus* were paired with their conspecific and foreign females, which resulted in four pairs of combinations. The single pairs were kept in separate jars covered with a net and supplied with a piece of moist cotton wool to maintain humidity. The moths were paired in the 8th hour of the scotophase and the observations were carried out until the end of the scotophase. In an independent preliminary experiment, it had been established that the calling periodicity in both species is highly overlapping, with maximum calling occurring between the 8th and 10th hour of the scotophase. Any pairs that mated were recorded and on dislodging, the males and females were separated. In the following scotophase, observations of the females were continued to determine whether any of them called and whether mating occurred or not. This was repeated until the 8th scotophase. Thirty pairs were observed in the case of each combination of the experiment. The results of these observations are summarised in Table 3.

The data indicate remarkable differences between the reproductive systems of the two stemborer species. Females of *C. partellus*, when paired with their conspecific males, mated only once and out of 30 females observed, calling was noticed 31 times; 22 females mated within the first two days. No calling and no mating was observed after that. In contrast, females of *C. orichalcociliellus*, when paired with their conspecific males, mated several times during their life and out of 30 females observed, calling was noticed 43 times and 46 matings were observed. It is interesting that during the third scotophase, 15 matings were observed without any visible calling activity. The difference in the reproductive systems between the two species may have implications for both their ecological competition in the field and for future prospects for the application of any control methods based on manipulation of their reproductive behaviour.

The most apparent difference, however, was noticed in male behaviour between inter-specific pair combinations. Males of *C. partellus* responded to and mated with females of *C. orichalcociliellus*. Also, the females of *C. orichalcociliellus* easily accepted mating with foreign males and in this combination the number of females which called and mated was nearly the same as in the

Table 3. Crossmating between *C. partellus* and *C. orichalcociliellus**

Pair combination	1 scotophase	2 scotophase	3 scotophase	4 scotophase	5 scotophase	6 scotophase	7 scotophase
C. partellus male *C. partellus* female	28c./20m.	3c./2m.	-/-	-/-	-/-	-/-	-/-
C. partellus male *C. orichalcociliellus* female	29c./17m.	14c./11m.	0c./5m.	0c./4m.	0c./4m.	1c./0m.	0c./1m.
C. orichalcociliellus male *C. orichalcociliellus* female	27c./19m.	16c./12m.	0c./15m.	-/-	-/-	-/-	-/-
C. orichalcociliellus male *C. partellus* female	26c./2m.	-/-	0c./1m.	-/-	-/-	-/-	-/-

*The data in the table represent the number of females observed calling (c.)/number of females mating (m.)

conspecific pairs. Contrary to that, males of *C. orichalcociliellus* nearly ignored females of *C. partellus*. Although the calling behaviour of the females was the same as in the case of conspecific combination, only three matings were observed.

These results correspond very well with results of the previous experiment on cross attractiveness between the two species. It seems clear that there is considerable, but non-symmetrical, overlap in communication systems between the two species. The ecological and practical consequences of these observations remain to be explored.

3. MONITORING THE TWO STEMBORER SPECIES *C. PARTELLUS* AND *C. ORICHALCOCILIELLUS* USING THE SAME BLEND OF THE TWO MAJOR PHEROMONE COMPONENTS OF *C. PARTELLUS*

Studies were undertaken to find out if traps baited with the synthetic female sex pheromone of *C. partellus* could also trap males of *C. orichalcociliellus*. A monitoring system using filter paper dispensers *(ICIPE 1992 Annual Report)* was set in one location (Mtwapa) at the Kenya coast. In this location the pheromone traps were used. Thirty-five traps were arranged in a grid pattern 7 x 5 with a distance between traps of 20 m. The filter paper dispensers were changed twice a week, and the experiments lasted almost three months (December 1993–February 1994). The catches were recorded twice a week and the stemborer species caught were identified.

The results indicated fluctuations in the dynamics of the stemborer populations. Both species of stemborer, *C. partellus* and *C. orichalcociliellus*, were caught regularly. The fluctuations were fairly synchronised for the two stemborers, with some tendency for the first generation of *C. partellus* to occur a bit earlier than *C. orichalcociliellus* and at a significantly higher level (Figure 1). The following conclusions were drawn from these observations:

1. The filter paper dispenser, baited with a blend of the two major pheromone components, effectively catches both stemborer species, *C. partellus* and *C. orichalcociliellus*.
2. The assessment of the population pattern seems to be accurate and realistic for the two stemborer species.
3. During the first generation, *C. partellus* seems to dominate over *C. orichalcociliellus*, since it occurs a bit earlier and in higher numbers.

4. AGE-DEPENDANCE OF MATING BEHAVIOUR OF *C. PARTELLUS*

Ethological observations were made on the mating behaviour of wild *C. partellus* moths of various age categories. Observations were made on single pairs at the time of maximum calling. The pairs were compared for various age categories in an observation chamber.

The following behavioural categories were registered: passive, active, wing fanning, pre-flight walk, flight, post-flight walk, walk alongside female, clasping, and copulation.

Observations were performed for four different combinations of age categories: 0-day-old male x 0-day-old female (0m-0f); 0-day-old male x three-day-old female (0m-3f); three-day-old female x three-day-old male (3m-3f); three-day-old male x 0-day-old female (3m-0f). A set of observations was performed for insects from the field in the Mtwapa region of the Kenya coast (Figure 2). The order of these observations was systematically rotated. Every day, four observations were recorded, one for each combination of age category.

The results showed clearly that the mating performance in this species was strictly age-dependent, in particular it was male age-dependent. Although males tended to emerge a bit earlier than females, they reached full maturity 1–3 days after emergence, which provides for a good synchronisation in the peaks of mating capabilities between sexes. It is interesting that immature

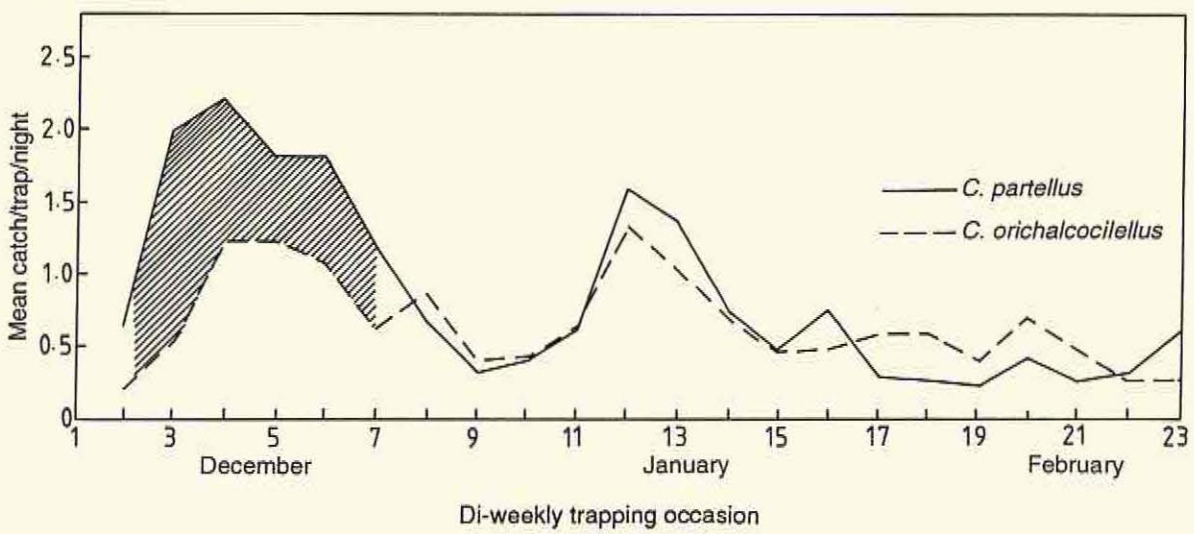


Figure 1. Population dynamics of two *Chilo* species caught in synthetic pheromone-baited trap at the Kenya coast.*

*Both species were caught in the same trap equipped with filter paper dispenser baited with a blend of two synthetic pheromone components over the period December, 1993 to February, 1994.

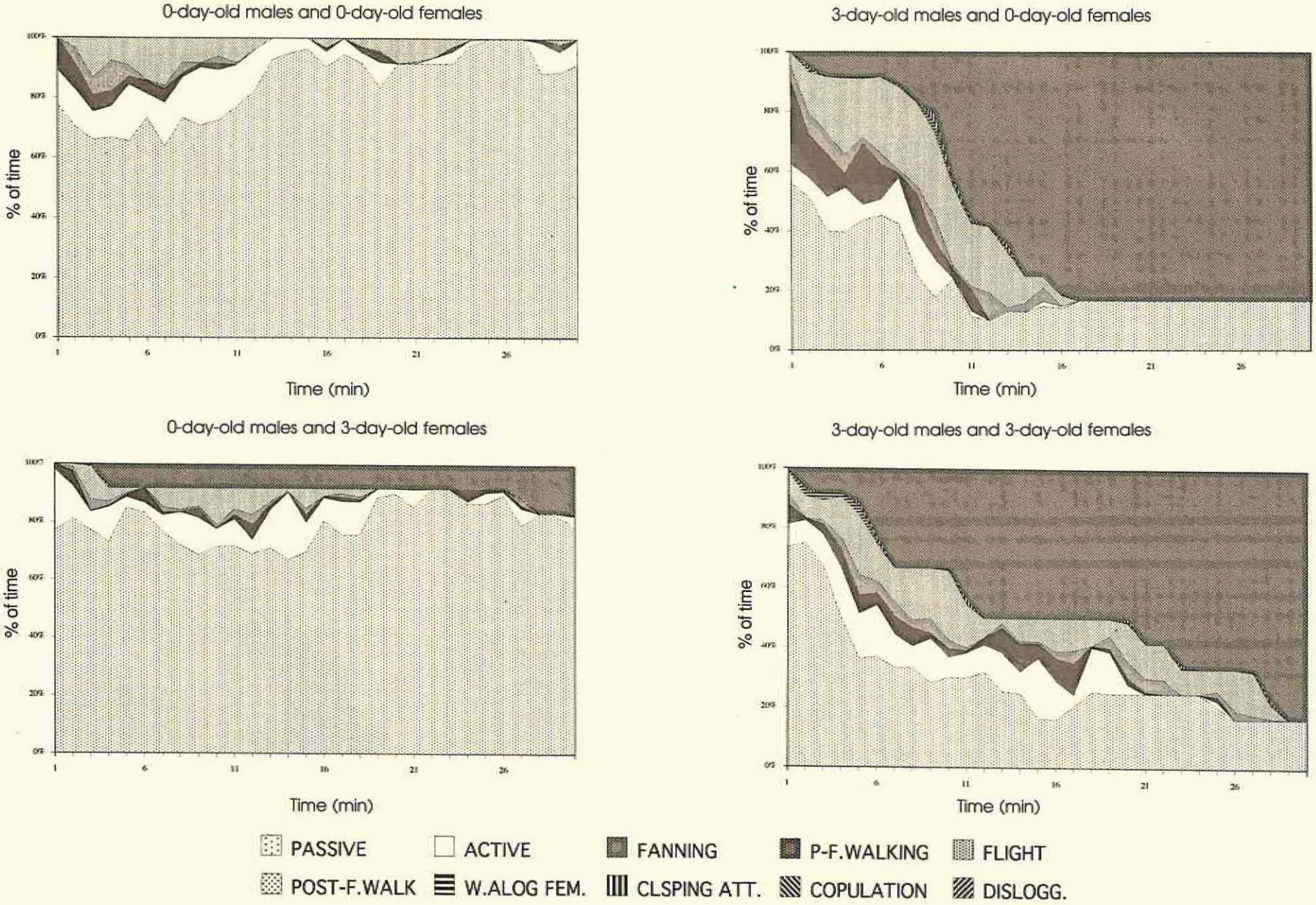


Figure 2. Mating behaviour of wild *Chilo partellus* moths collected from fields at the Kenya coast.

males (0-day-old) showed some preference towards elder females while fully mature males (3-day-old) seemed to prefer very young, newly emerged females.

5. DEVELOPMENT OF DISPENSERS FOR *C. PARTELLUS* PHEROMONE

Various types of dispensers for the *C. partellus* pheromone were developed and evaluated both in the screenhouse and in the field. Two types of dispensers, one made out of polythene and the other of glass capillaries, were found to be most suitable for dispensing of the *C. partellus* pheromone.

Completed studies

Lux S. A., Hassanali A., Lwande W. and Njogu F. N. Proximity of release points of the pheromone compounds as a factor confusing males of the spotted stemborer, *Chilo partellus* approaching the trap. *Journal of Chemical Ecology* 20(8), 2065–2075.

The effect of proximity of the release points of the two pheromone components (Z)-11-hexadecenal and (Z)-11-hexadecen-1-ol of the spotted stemborer, *Chilo partellus* (Lepidoptera: Pyralidae) on behaviour of the males and on trapping efficiency was investigated. Separating the dispensers of the two components in the trap by a mere 3 cm resulted in a three-fold decrease in trap performance, compared to very close release of the components. The result is attributed to possible distortion of the pheromone signal, resulting in confused behaviour of *C. partellus* males in the vicinity of the trap. The ethological and practical implications of the phenomenon are discussed.

Training activities

Students supervised: I. Jalloh (ARPPIS PhD student), F. Njogu, MSc student.

VI. Awareness Building and Facilitating the Use of Neem as a Source of Natural Pesticides and Other Useful Products in Sub-Saharan Africa

Donors: *The Finnish International Development Agency (FINNIDA), United Nations Environment Programme (UNEP)*

Collaborators: *The International Centre for Research in Agroforestry (ICRAF) (Coordinator, Component Interactions: M. R. Rao); Kenya Agricultural Research Institute (KARI)*

Background

Plant-derived substances have been used for pest control since ancient times. Several plant species, such as neem, *Azadirachta indica* A. Juss., possess a pot-pourri of novel chemicals with selective toxicity and varied behavioural and physiological effects on pests, such as repellence, feeding and oviposition deterrence, insect growth regulator effects, and chemosterility. Neem derivatives have weak or negligible side effects on pests' natural enemies, pollinators, and non-target organisms. For the last three years we have been evaluating simple neem derivatives against pests of major food crops and stored grains in Africa. Neem is widespread in Asia and Africa and can be a renewable source of natural pest control materials and other useful products.

ICIPE's work on the pest control potential of neem was strengthened by financial grants from FINNIDA and UNEP received last year. The long-term objective of the project is the increased awareness of the use of neem materials in Ethiopia, Kenya, Malawi, Tanzania, Uganda and Zambia in eastern and southern Africa to safeguard the environment by replacing pesticide use and promoting neem to improve income, nutrition, health and to mitigate rural poverty.

The first short-term objective is the improvement of the knowledge base regarding the production and potential use of neem products through interaction and collaboration with national and international programmes and participating farmers.

Work in progress

1. DEMONSTRATE REDUCED PEST INFESTATION AND A CORRESPONDING INCREASE IN CROP YIELDS OR BIOMASS WITH THE USE OF SIMPLE NEEM DERIVATIVES IN TARGET CROPS AND AREAS

Participating scientist: *R. C. Saxena* (*Project Coordinator)*

Assisted by: *J. C. Olela, E. L. Kidiavai*

Field trials were conducted during the long rains (LR) and short rains (SR) cropping seasons at the ICIPE's Mbita Point Field Station, at ICRAF's Experimental Farm at Machakos, at Kitale Regional Research Centre of KARI, and at farmers' fields at Mbita and Rongo. The trials were directed primarily against thrips affecting cowpea, stemborers affecting maize and sorghum, and termites affecting saplings of trees of agroforestry importance. A PhD student from Ethiopia tested the effectiveness of neem seed powder against stemborers *Busseola fusca* and *Chilo partellus* in Ethiopia and Kenya. A PhD student from Kenya is evaluating the effectiveness of neem leaves, kernel, cake, and oil against the maize weevil *Sitophilus zeamais* in stored maize.

Effectiveness of neem seed extract (NSE) against cowpea thrips

During LR 1994, cowpea grown at the Mbita Point Field Station and in a farmer's field at Mbita was sprayed with 5, 10, and 20% NSE or with cypermethrin using an ultra-low volume (ULV) applicator. Each treatment was replicated four times. Initially, at 33 days after emergence, cowpea crops at both sites were uniformly infested with thrips adults and larvae in all treatments. However, with time larval infestation increased significantly in untreated control plots than in plots treated with cypermethrin or 20% NSE. Although neem did not kill, it probably repelled thrips and affected their growth, development and

reproduction. Grain yield in plots in the farmer's field sprayed with 5% NSE (1450 kg/ha), 10% NSE (1630 kg/ha), or 20% NSE (1760 kg/ha) was significantly higher than in control plots (1290 kg/ha) and next only to that obtained with expensive cypermethrin (2130 kg/ha). Compared with cypermethrin, the cost of neem treatment was negligible and therefore the net gain was higher than with the insecticide treatment. A similar trend in thrips population and cowpea grain yield was obtained with 20% NSE at the Experiment Station.

Neem cake (NC) for management of maize stemborers

Neem cake was evaluated for management of the spotted stemborer, *Chilo partellus* in Pwani Hybrid maize crop in a farmer's field at Kenya coast (low altitude) and *Busseola fusca* in H622 maize at the KARI Station and in a farmer's field in Kitale (high altitude). At the coast, compared with the grain yield of 4463 kg/ha in untreated control and 6973 kg/ha in dipterex-treated plots, application of NC applied once at 5 or twice at 5 and 7 weeks after plant emergence (WAE) at the rate of 3 g/plant gave yields of 5053 kg/ha and 7018 kg/ha, respectively. NC-treated plants were much taller and remained green for longer periods than control or insecticide-treated plants.

At Kitale, there were no significant differences in grain yield in various treatments because *B. fusca* infestation was low due to unusually high rainfall in LR 1994.

Management of maize stemborers with neem cake (NC) prepared from seed stored for varying periods

During LR 1994, ICZ5, a maize cultivar moderately resistant to the spotted stemborer, *Chilo partellus*, was planted at the Mbita Point Field Station. When the crop was 3 weeks old, each plant was artificially infested with a *C. partellus* egg mass at the blackhead stage. Neem cake was prepared from seed collected in 1992, 1993 and 1994 by crushing with an electrically operated, cold-press, oil expeller. One week after infestation, maize plants in different plots were treated with NC of 1992, 1993 and 1994 seed by manually dropping 3 g of NC into the whorl of each plant. In another plot, dipterex was applied at recommended rate of 1 g/plant; control plants were not treated. The treatments were replicated four times. Regardless of the neem seed storage duration, application of NC significantly reduced foliar damage, stem tunnelling and tassel breakage, and increased the plant vigour compared to untreated controls. Also the number of *C. partellus* larvae/10 plants was significantly fewer than in the control and similar to that in insecticide-treated plots. Also, NC-treated plots were less infested by the late-occurring stemborer, *Eldana saccharina*, than control and insecticide-treated plots. Grain yield in plots treated with NC prepared from 1992 seed (7469 kg/ha), 1993 seed (7609 kg/ha), and 1994 seed (7458 kg/ha) was equal to that obtained with dipterex (7271 kg/ha) and was almost 1.5 times higher than in the control (5088 kg/ha).

We also evaluated the effectiveness of NC in plots in a farmer's field artificially infested with the maize stemborer, *Busseola fusca*. As the level of infestation achieved was not high enough and as *B. fusca* is a slow feeder, the differences in foliar damage and plant heights in treatments with NC applied once or twice, or dipterex, and in untreated control were not significant. However, NC- or insecticide-treated plants had significantly less stem tunnelling and fewer surviving *B. fusca* larvae than the control plants. Tassel breakage was also less in neem- or insecticide-treated plots. Grain yield was highest in insecticide-treated plots (5675 kg/ha), followed by that in plots treated with NC once (4950 kg/ha) or twice (5156 kg/ha); the yield was lowest in untreated control plots (4313 kg/ha).

NC for management of C. partellus *in sorghum*

In field trials conducted at the Mbita Point Field Station (MPFS) and in a farmer's field at Mbita, the foliar damage, stem tunnelling, the number and size of *C. partellus* larvae/10 plants was significantly lower in Serena sorghum plots treated with NC once at 4 or twice at 4 and 6 WE at the rate of 3 g/plant than in untreated control plots and at par with that in plots treated with dipterex at 4 WE at the rate of 1 g/plant. Also sorghum plants treated with NC or dipterex were relatively taller than control plants. Both at the MPFS and in the farmer's field, grain yield was higher in NC or insecticide-treated plots than in control plots (Figure 1).

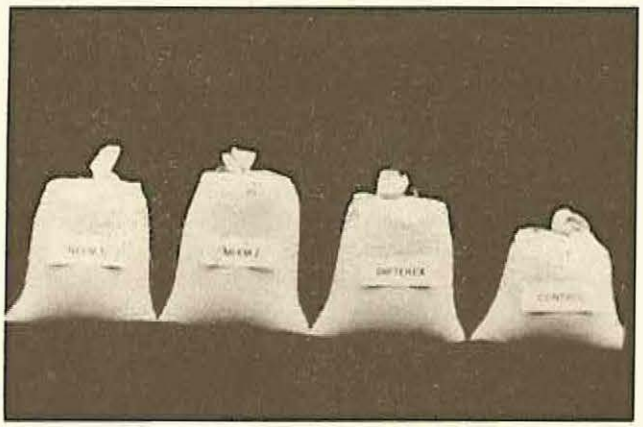


Figure 1. Comparison of maize grain yields sampled from plots treated with 1 g of powdered neem cake per plant at various times after plant emergence. Application of the neem cake once (Neem 1) or twice (Neem 2) during the growing season gave a grain yield comparable to the application of dipterex, a synthetic pesticide, at a fraction of the cost.

2. GROWTH, DEVELOPMENT AND REPRODUCTION OF *C. PARTELLUS* ON DIET CONTAINING NEEM SEED POWDER (NSP)

Participating scientist: *R. C. Saxena*

Assisted by: *F. O. Onyango*

To determine the cause of poor establishment and low plant damage by the stemborer *Chilo partellus* on neem-

treated maize and sorghum plants, we studied the growth and development of neonate larvae on a standardised diet containing 25, 50, and 100 ppm of NSP. We found that growth and development of larvae were significantly reduced on the diet containing ≥50 ppm NSP. Exposure of larvae during development to diet containing NSP also reduced the fecundity of emerged females and the hatchability of eggs laid by them.

3. EVALUATION OF NC TO PREVENT TERMITE AND ROOT-KNOT NEMATODE ATTACKS IN AGROFORESTRY

Participating scientists: *M. R. Rao (ICRAF), R. C. Saxena*

During establishment of seedlings of trees of agroforestry importance, termite attack is a major cause of seedling mortality. Trials are going on at various sites to test the efficacy of NC applications against termite attack on seedlings. Neem cake is also being evaluated against root knot nematodes on *Sesbania* plants.

The second short-term objective is creation of a network of trained persons and establishment of a system of neem raw material supply and production of information material.

4. AWARENESS AND CAPACITY-BUILDING

The objectives of this activity are to build awareness and train agricultural trainers, extension personnel, and local NGOs for multiplier effect, establish neem nurseries and distribution systems for high grade neem seed, and produce booklets, newsletter, audio-visual tutorials, and a neem film.

A neem nursery was established at the ICIPE's Mbita Point Field Station (MPFS) and more than 5000 seedlings sold or distributed to farmers, schools, churches, and other interested groups. Also, viable neem seed was distributed free for nursery establishment in rural areas in Kenya and neighbouring target countries.

The First Neem Awareness Workshop held at MPFS was inaugurated by Mr Mikko Pyhala of UNEP and by Mr Ilkka Raisanen of the Embassy of Finland in Nairobi on 29 August 1994. About 60 farmers, administrators, schoolteachers and children, and women group leaders attended the Workshop. The Project Coordinator discussed the scope of the neem tree in pest management and its other uses in public health, veterinary uses, contraceptives, etc. More than 50 seedlings were planted by the dignitaries at strategic locations in Mbita.

The Second Awareness Workshop was officially opened by the District Officer of Mbita Division on 24 November 1994 and was attended by all divisional educational officers, heads of primary schools, and teachers and students from more than 120 primary schools. In addition, the Project Coordinator gave invitational lectures at the Rusinga United Women and Youth Group, at Kenyatta University, and at Homa Bay Farmers' Training Centre and County Council between July to October 1994.

Since its launching in August 1994, the Neem Awareness Project has been featured regularly in the local press, radio and television.

Completed studies

Saxena R. C. The neem tree: Its potential for developing countries. *Global Pesticide Campaigner* 4 (2), 3–5.

Raguraman S. and Saxena R. C. Effects of neem seed derivatives on brown planthopper symbiotes. *Phytoparasitica* 22 (4), 299–307.

Saxena R. C. Contribution of insect rearing to the management of rice pests. In *Techniques of Insect Rearing for the Development of Integrated Pest and Vector Management Strategies* (Edited by Ochieng'-Odero J. P. R.), pp. 31–48. Proceedings of the International Group Training Course on Techniques of Insect Rearing for the Development of Integrated Pest and Vector Management Strategies. ICIPE, Nairobi, 16 March–3 April 1992. ICIPE Science Press.

Future activities

- Demonstrate that tassel breakage in maize can be used as an indicator of stemborer damage in maize plants than destructive sampling.
- Demonstrate phytotonic effects of neem on maize and sorghum plants.
- Demonstrate effectiveness of neem cake applications against maize stalkborers.
- Enhance nitrogen efficiency by mixing neem cake with nitrogenous fertilisers.
- Demonstrate the effectiveness of various neem products for minimising damage by stored grain pests (PhD student thesis).
- Conduct training workshops on 'How to Grow and Use Neem' to create a network of trained persons and establishment of a system for neem raw material supply and production of information material.
- Compile current state of research on neem. More than 2000 papers published on neem have been reviewed, abstracted and established as a database.
- The first number of *African Neem Newsletter*, containing executive summaries of presentations made by resource speakers and action plans by participants of the June 1995 Training Workshop, will be brought out in September 1995.
- Videos and a documentary film on 'Neem—A Tree of Wonder and Struggle' will be released for viewing in December 1995.

VII. Development of Banana-Based Integrated Pest Management (IPM) Strategies for the Lake Victoria Basin Countries

Participating scientists: *K. V. Seshu Reddy*, J. S. Prasad, A. S. Mbwana (*Project Leader)*

Assisted by: *L. Ngode, M. Kithokoi, I. O. Mayoga, P. Ochanjo*

Donor: *The Federal Ministry of Economic Cooperation, Republic of Germany*

Collaborators:

(a) *Institut für Pflanzenkrankheiten, University of Bonn, Germany*
(b) *Agricultural Research Institute (ARI) Maruku, Bukoba District, Commission of Research, Ministry of Agriculture, Tanzania*
(c) *Ministry of Agriculture, Animal Husbandry and Fisheries, Kawanda Perennial Crops Research Institute, Kampala, Uganda*
(d) *Kenya Agricultural Research Institute (KARI), Kenya*
(e) *The University of Leuven, Belgium*
(f) *The International Network for the Improvement of Banana and Plantain (INIBAP), Gitega, Burundi*
(g) *The International Institute of Tropical Agriculture (IITA), Biological Control Programme in Uganda, and Plantain and Banana Improvement Programme in Nigeria (PBIP)*

Background

The banana weevil and nematode complex are devastating pests of bananas worldwide. In the eastern African region they are considered as the most destructive pests of banana. The recommended chemicals represent a short term strategy that most local farmers are incapable of utilising, and many adversely affect the health and environment of entire communities. There is considerable need, therefore, to develop a broader ecologically based and sustainable approach to banana weevil and nematode control that suits the poor resource and management capacities of the millions of small-scale banana growers in the eastern African region and other parts of Africa. It is therefore, in this context, that there is need for development of banana-based integrated pest management (IPM) strategies for the Lake Victoria basin countries in eastern Africa.

The objective of the research is to build on the progress made in Phase I of the joint cooperative research and training project funded by BMZ in order to develop sound banana-based IPM for long-term management of the banana weevil *(Cosmopolites sordidus)* and nematode problem in Uganda, Tanzania and Kenya and to strengthen the critical research manpower necessary for sustainable banana pest management research and development in Uganda and Tanzania through postgraduate training.

Work in progress

1. EFFECT OF SPACING, TRAPPING AND CROPPING SYSTEMS ON THE WEEVIL/ NEMATODE COMPLEX

An experiment was started at Oyugis with the popular banana cultivar, Nakyetengu in May 1992. The objective was to study the effect of spacing, weevil trapping and cropping systems on the management of weevil/ nematode complex and banana yields.

In the experiment, there were two spacing regimes, viz. 5 x 5 m and 3 x 3 m for banana, monocropped and intercropped with groundnut. The treatments also included trapping of weevils using split pseudostem traps and no-trapping in a randomised complete block design. In all, there were nine treatments replicated three times.

The results showed that groundnut yields were not affected by banana during the first two seasons in both the spacing regimes. Beyond this, the yields of groundnut in 3 x 3 m spacing were significantly affected but not in 5 x 5 m spacing which performed as good as monocropped groundnut. The incidence and damage

due to the banana weevil, *Cosmopolites sordidus* (Germar) on the banana has been low, showing that the build-up is slow. However, it was higher in trapped plots. This indicates that intercropping banana with legumes is advantageous and early trapping delays the build-up of the weevil and damage to banana. Groundnut was found to be susceptible to *Pratylenchus brachyurus*, but it was not recorded on banana.

2. REHABILITATION OF A RUNDOWN BANANA PLANTATION INFESTED WITH WEEVILS AND NEMATODES

In a field experiment where mainly two treatments, viz., trapping and no-trapping were adopted, high nematode population build-up was observed in the former and high infestation of weevils in the latter. Taking this as an advantage for each of the above treatments, four sub treatments, viz. untreated control, calcium ammonium nitrate (60 g), farmyard manure and carbofuran (60 g) were introduced in a split plot design in three replicates. The observations on plant growth characters, weevil populations, percentage coefficient of infestation and nematode population are in progress.

3. COLLECTION AND MAINTENANCE OF BANANA GERMPLASM

The Ungoye field site where the banana germplasm is being maintained was found to be inaccessible to farmers, not being a traditional banana growing area or endemic area for the diseases. The entire collection of 167 cultivars was duplicated and established at Oyugis field site. About 50% of banana production of Kenya comes from this area. This field was intercropped with coriander, groundnut and beans to study the effect of these crops on behaviour of weevil and nematode populations.

4. INFLUENCE OF TRAPPING OF WEEVILS ON BANANA YIELDS AND NEMATODE POPULATIONS

Continuous trapping of weevils has brought about 50% reduction in weevil numbers in comparison with no-trapping and increased banana yields by 31%. However, the yield obtained from plots where weevils were trapped was 5.1 t/ha which was very low when compared to the potential yield of cultivar Nakyetengu, the cultivar planted for this experiment. Such low yields were explained when nematode population build-up was taken into consideration. Up to 13 to 14 times more *Pratylenchus goodeyi* were recorded in plots where weevils were trapped than in plots where no trapping was done.

5. STANDARDISATION OF PSEUDOSTEM TRAPS FOR THE BANANA WEEVIL

Both the 15-cm-long split pseudostem trap and 5-cm-thick disc trap were found to be equally effective in the attraction and catch of the weevils. However, the disc trap was found to be more economical as from the length one can get three traps in comparison with split pseudostem traps where only two could be obtained.

6. EVALUATION OF BANANA CULTIVARS FOR RESISTANCE/TOLERANCE TO THE BANANA WEEVIL

Out of 24 cultivars evaluated for resistance/ tolerance to the banana weevil, six dessert types, viz. Golden Beauty, Kampala, Neg, Pelipita, Kakamega and Paz were found to be least susceptible and recorded PCI of below 30.

7. ADVANCED *MUSA* YIELD TRIAL-1 IN EAST AFRICA

This trial material received from IITA was planted at Ungoye field site. Very low incidence of black sigatoka disease was recorded. Of the twelve entries, PITA-1, FHIA-3, PITA-5, and Nakitengwa were found to be highly susceptible to *C. sordidus* infestation. Least number of weevils was recorded in the variety KM 5.

8. CHARACTERISATION OF NEMATODE PROBLEMS OF BANANA-BASED CROPPING SYSTEMS

A species of *Trophurus* was found prevalent around Mbita Point Field Station on bananas. This was identified as a new species and it was confirmed by C.A.B. International Institute on Parasitology, UK. High numbers (500 to 1000/100 g soil) were recorded on Kainja and Bogoya varieties of banana. *Rotylenchulus clavicaudatus* was recorded for the first time on banana.

9. EMBRYONIC DEVELOPMENT OF *PRATYLENCHUS GOODEYI*

The gravid females of *P. goodeyi* were observed with one or two eggs in the uterus. Presence of two eggs in the uterus was not uncommon. The passage of eggs after formation from uterus to vagina took 5–13 h. In the females with two eggs, the first egg passed out within 2–4 h. Eggs were two- to multicelled at the time of egg laying. In some cases, early two-germ band stage was also observed, however, viviparity was not noticed.

Depending on the stage in which the egg was laid, the development time from 2–3-celled stage to 8-celled stage was 13 to 20 h, 2-germ band stage at 39 to 45 h, larval differentiation at 72 to 86 h, first appearance of prorhabdion at 85 to 110 h, moulting at 112 to 130 h, fully developed larva was observed at 128 to 155 h after egg laying. Eclosion of the juvenile was effected in 22 to 34 h. The embryonic developmental duration was found to be 6.8 to 8.9 days.

10. POST-EMBRYONIC DEVELOPMENT OF *PRATYLENCHUS GOODEYI*

Second stage juveniles of *P. goodeyi* in 60 replicates were inoculated to two banana cultivars, i.e. Sukalindizi and

Nakyetengu by inserting the growing root tips in paper pipes. Three replications from each cultivar on every second day up to 30 days were removed, fixed, stained, teased and observed for different developmental stages and eggs. The invasion was observed by the second day. The 3rd stage juveniles were recorded by 8th day and 6th day, 4th stage juveniles by 16th and 12th day, the adults by 24th day and 20th day, eggs by 30th day and 24th day, respectively in Sukalindizi and Nakyetengu. In the susceptible cultivar Nakyetengu, *P. goodeyi* completed its life cycle 6 days earlier than in Sukalindizi.

11. FECUNDITY IN *PRATYLENCHUS GOODEYI*

One gravid female was inoculated to growing root of two banana cultivars, Nakyetengu and Sukalindizi in 90 replicates. The roots from 5 replicates were collected on days 2, 5, 10, 15, 20, 25, 30, 35 and 40 after inoculation. The roots were fixed, stained, teased and observed for the presence of eggs. In the cultivar Nakyetengu up to 29.3 eggs were laid by a single female in 35 days. It became difficult to continue the observations as the emerged adults started laying eggs. During the first 15 days, the rate of egg laying was 1.16/day/female. Then later it dropped to 0.6/day/female. In comparison, in Sukalindizi up to 20 days, the egg laying was at the rate of 0.66/day/female. In the next 20 days, the rate of egg laying dropped to 0.41/day/female. Total number of eggs laid by a female was 21.3 eggs in 40 days.

12. EVALUATION OF BANANA CULTIVARS FOR RESISTANCE/TOLERANCE TO *PRATYLENCHUS GOODEYI*

(a) Eight cultivars consisting of three sweet (Giant Bogoya, Kainja, and Sukalindizi), three cooking (Lusumba, Kivuvu and Nakyetengu), a brewing type (Mbidde) and a roasting banana (Gonja) were evaluated for resistance/tolerance to *P. goodeyi*. The entries were grown in three replicates in a randomised block design. Each replicate had five plants. The cultivars Giant Bogoya (1000/100 g root), Kainja (2400/100 g root) Lushumba (1000/100 g root) and Sukalindizi (2000/100 g root) recorded least number of *P. goodeyi*. Kivuvu (110,000/100 g root) and Nakyetengu (88,500/100 g root) were highly susceptible. It is interesting to note that Lusumba is tolerant though it is a cooking type.

(b) With an objective of identifying banana cultivars with resistance/tolerance to the main important pests of banana *P. goodeyi* and *C. sordidus*, a total of 25 cultivars, 14 cultivars which showed promising reaction to both these pests in Tanzania and 11 other promising cultivars, were selected for this study. These included 11 sweet, 8 cooking, 4 beer and 2 roasting types of cultivars. They were Matumbo, Manjono, Mbwazirume Munyoni, Kamara Masenge, Kivuvu, Spambia, Dwarf Cavendish 1, Nakabululu, Njuru, Kayinja, Lusolyo, Mutika, Soth, Boko, Mshare Muraru Giant, Mguoguo, Ngome, Nyoro, Lusumba, Gonja 2, White Muraru, Molu Mgeni, Mpologoma, Nyar Sauset and Millie. These entries were introduced in two replications (5 plants per replicate) in a randomised block design in 3 x 3 m spacing. This experiment was started in April, 1994 on a farmer's field in Oyugis in western Kenya.

13. ASSESSMENT OF YIELD LOSSES DUE TO *P. GOODEYI* IN BANANA

With the objective to estimate the magnitude of yield losses caused by *P. goodeyi* in banana, a field experiment was laid out in a farmer's field at Oyugis. This field was under banana cultivation for over 40 years. By the time the field was taken over, the nematode population had built up to 30,000/100 g root. The farmer abandoned the field as it was not remunerative. This experiment was laid out in March, 1994, and the following four treatments were introduced in three replications in a randomised block design in 3 x 3 m spacing.

T-1 Suckers from an infested field (25,000/100 g root without paring and hot water treatment);
T-2 Suckers from a nematode-free field without paring and hot water treatment;
T-3 T-1 + pared and hot water - treated;
T-4 T-3 + pit - treated with carbofuran at 60 g per pit.

14. LONGEVITY OF *P. GOODEYI* IN BANANA SOILS

With an objective of studying the survival capacity of *P. goodeyi* in the soil in the absence of a crop, an experiment was designed and started in April, 1994 at Oyugis. This experiment included three treatments, viz. T-1 — clean fallow, T-2 — weed fallow and T-3 — non-host crop *(Ipomaea batata)* in three replicates in a randomised block design.

Observations on the nematode populations after three months revealed presence of nematodes in the clean fallow (120/100 g soil), in the weed fallow (2000/100 g root) and no nematode population in roots of non-host crop. The results of this experiment will be useful in assessing the survival rate of *P. goodeyi* and in advising the farmers of the periods for which they have to keep their fields free of bananas under a non-host crop.

15. AWARENESS OF PROBLEMS AND MANAGEMENT STRATEGIES IN BANANA PRODUCTION

In the survey conducted in Oyugis and Kisii areas in western Kenya, all the farmers were unanimous in agreeing that banana is an important crop for them and it provides them with food and economic security. Ninety percent of their knowledge on banana farming comes from relatives, neighbours, parents and friends and 7% from government extension services. Government extension services' impact on other crops is up to 50%. Only 15% of farmers had knowledge on the damage

caused by the weevils and all the farmers interviewed had no knowledge of the nematodes or the damage caused by them.

16. ENHANCEMENT OF NATIONAL AGRICULTURAL RESEARCH SYSTEMS (NARS) CAPACITY

PhD degree programme and training

Mr Japheth Magyembe-Mwesigwa (Ugandan) a scholar in the Project, and Dr J. S. Prasad, ICIPE Nematologist, visited University of Bonn. Mr Magyembe-Mwesigwa discussed and analysed his data and used the library facilities. Prof. Stanley Waudo, Dean of the Graduate School, Kenyatta University, Nairobi and the past counterpart in BMZ Banana Project has selected and sent one student, Mr John W. Kimanju to Bonn for initial training as part of the PhD programme. Another student will be joining him shortly. As no Tanzanian student was available for the PhD programme, Mr Lucas Ngode, a Kenyan, who was working as a Scientific Officer (Agronomy) in the Project, joined the training programme.

17. COOPERATIVE ACTIVITIES

An Advanced *Musa* Yield Trial (AMYT) involving 12 hybrids from IITA was continued at Ungoye field site of ICIPE. IITA scientists visited ICIPE regularly during 1994 for discussion and collaboration. A Belgian Scientist, Mr Johan Deseager working with ICRAF, Nairobi, received one week's orientation in Nematology at Mbita Point Field Station of ICIPE. Dr K.V. Seshu Reddy, Coordinator, Banana IPM Project, attended the Inaugural Meeting of the Technical Steering Committee for East and Southern Africa (Regional Centre for the Improvement of Cassava, Banana and Plantain, IITA) and also the Regional Advisory Committee (RAC) Meeting for Eastern and Southern Africa in Kampala, Uganda.

Completed studies

Koppenhöffer A. M., Seshu Reddy K. V. and Sikora R. S. Reduction of banana weevil populations with pseudostem traps. *International Journal of Pest Management* 40 (4), 300–304.

One-week-old traps made from split banana pseudostems were 1.5–1.7-fold more attractive to adult banana weevils than 2–3-week-old traps. In one experiment, all available pseudostem material was used for trapping, and weekly collection of weevils over an 11-month trapping period led to a 50% reduction in weevil catches in one field. In another field with a lower initial weevil density the trapping did not reduce weevil populations. In another experiment, the effect of intensive use of pseudostem traps and daily collecting of trapped weevils was estimated by a mark and recapture method over a period of 6 weeks. Reductions in weevil densities were calculated using a modified version of the Lincoln Index. Weevil populations were reduced by 48.5% after 3 weeks and by 62.5% after 6 weeks. Trapping efficiency declined during the experiment and appeared to be related to weevil population densities. This cultural control system may be effective in weevil control in small-farm situations where labour availability is not a limiting factor.

Koppenhöffer A. M. and Seshu Reddy K. V. A comparison of rearing methods for the banana weevil, *Cosmopolites sordidus* (Germar) (Coleoptera: Curculionidae) on its natural host. *Insect Science and its Application* 15 (2), 191–195.

Koppenhöffer A. M., Sikora R. A. and Seshu Reddy K. V. Eidonomy and ecology of *Dactylosternum abdominale* (Coleoptera: Hydrophilidae), a predator of the banana weevil *Cosmopolites sordidus* (Coleoptera: Curculionidae). *Entomol. Gener.* 19 (4), 303–313.

Observations of the biology of *Dactylosternum abdominale* (Fabricius 1792) were made in western Kenya in banana plantations. The three larval instars are polyphagous predators in decomposing plant tissues where pupation occurs. Development from egg to adult (Ig) takes 17–33 days. Ig feed on the micro-fauna and -flora of decomposing plant tissues, on eggs and small larvae of insects and the plant tissues. Life-span is approximately 95 ± 2 days. The sex ratio is 1.6 in favour of the males. Females lay an average 1.7 egg cases per week, each containing 4 eggs. The pre-oviposition period is 16.6 days, post-oviposition period 3 days. At unnaturally high population densities fecundity declines. Decomposing plant tissue is more attractive to Ig than fresh plant tissues, and banana pseudostems more attractive than banana rhizomes. In poorly managed fields and during the rainy seasons population densities are higher due to the large amounts of decomposing plant tissue available. Observed population densities: 0.5–1.8 Ig/m^2.

Prasad J. S. and Seshu Reddy K. V. Hot water treatment for banana planting material made easier. *InfoMusa* 3(2), 16.

Prasad J. S., Seshu Reddy K. V. and Sikora R.A. Hosts of the banana root-lesion nematode, *Pratylenchus goodeyi*, in East Africa. *Nematologia Mediterranea* (submitted).

Four crop plants, one agroforesty plant and nine weeds are reported as hosts of *Pratylenchus goodeyi* in a banana plantation in Kenya.

Prasad J. S., Seshu Reddy K. V., Ngode L. and Mbwana A. S. S. Pest and disease problems of bananas in Kenya. *FAO Plant Protection Bulletin* (submitted).

Prasad J. S., Seshu Reddy K. V. and Sikora R.A. Life cycle and fecundity of *Pratylenchus goodeyi* in banana (submitted).

Seshu Reddy K. V. Prasad J. S., Ngode L. and Sikora R. A. Influence of trapping of the weevil, *Cosmopolites sordidus* on the root lesion nematode, *Pratylenchus goodeyi* population densities and subsequent banana yield. *Acta Oecologica* (communicated).

VIII. Chemical Ecology of the Banana Weevil, *Cosmopolites sordidus*

Participating scientists: *I. O. Ndiege, S. Lux, A. Hassanali* (*Project Leader)*

Assisted by: *D. Otieno*

Donor: *Norwegian Government*

Background

The banana weevil, *Cosmopolites sordidus*, is a serious pest of banana and is particularly difficult to control, even with insecticides, as the larvae that cause the damage are deep inside the plant tissue and are therefore inaccessible to spraying. Also, the weevils are long-lived, with an average lifespan of over two years. Semiochemicals, the chemicals that are derived from organisms that help to control various interactions among organisms, play an important role in mediating aggregation and host location by the banana weevil. If these semiochemicals are known, they could be used in the development of highly selective, environmentally safe methods of control of banana weevils such as trapping technologies. In 1994, the Behavioural and Chemical Ecology Unit continued with research on the identification of semiochemicals of the banana weevil, *Cosmopolites sordidus*.

Work in progress

1. 1, 8-CINEOLE AS AN ATTRACTANT FOR THE BANANA WEEVIL, *COSMOPOLITES SORDIDUS*

Volatile compounds were trapped from pseudostems of the susceptible cultivar of banana that is locally known as Githumo. GC-EAD analysis of the volatiles using banana weevil antennae revealed many minor and one major electrophysiologically active compound.

The major active component was identified by GC-MS and by coinjection with an authentic sample to be 1,8-cineole (Figure 1). Bioassay of synthetic 1,8-cineole showed that it was attractive to the banana weevil. Table 1 shows the responses of female banana weevils to different amounts of 1,8-cineole in a still-air olfactometer bioassay.

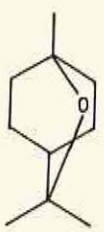


Figure 1. 1, 8-cineole.

Table 1. Responses of female *Cosmopolites sordidus* to different amounts of 1,8-cineole

Dose(mg)	N	T	C	T/C	(T-C)/N
0	18	7	9	0.78	-0.11 ± 0.20
10^{-3}	18	18	15	1.20	0.17 ± 0.39
10^{-2}	18	19	8	2.38	0.61 ± 0.23*
1^{-1}	18	13	9	1.44	0.22 ± 0.33
1	18	32	6	5.33	1.44 ± 0.33***
10	18	34	3	11.33	1.72 ± 0.41***

N = Replicates, T = Number of visits to treatment, C = No. of visits to control. * $P<0.05$, *** $P<0.001$ probability that the number of extra visits to the treatment is different from zero.

1,8-cineole was found to be present in all the banana cultivars that are susceptible and tolerant to banana weevils, but was conspicuously absent in the resistant cultivar, Mbuu (ABB).

2. BANANA WEEVIL FEEDING STIMULANTS

In the *ICIPE 1993 Annual Report*, we reported on studies on the search for banana weevil feeding stimulants in the pseudostem of banana plants.

Initial banana weevil feeding bioassays using cellulose discs had indicated that the polar extracts of the banana pseudostem of the susceptible banana cultivar, Githumo were most stimulatory. Fractionation of the water extract of the banana pseudostem using a reverse phase column and bioassay led to the isolation of active fractions which were purified further by preparative high pressure liquid chromatography to yield several compounds. The most feeding-stimulatory compounds were identified as (2-hydroxymethyl)-phenyl-β-D-glucopyranoside (Figure 2) and glucose by ^{1}H and ^{13}C NMR, FAB, MS and EI MS of its acetylated derivative. The compounds acted synergistically.

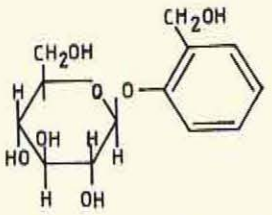


Figure 2. (2-Hydroxymethyl)-phenyl-β-D-glucopyranoside.

IX. Interactive Socioeconomic Research for Biointensive Pest Management Project (ISERIPM)

CROP PESTS COMPONENT

Project coordinators: *F. G. Kiros (Project Coordinator, Economist); P. Chitere (Field Coordinator, Sociologist), G. T. Lako (Economist)*

Donor: *Rockefeller Foundation*

Collaborators: *Kenya Agricultural Research Institute (KARI); Ministry of Agriculture, Livestock Development and Marketing (MOALDM), Kenya; Provincial Administration, Kenya and participating farmers*

A. SOCIOECONOMIC ASPECTS

Participating scientists: *F. G. Kiros, P. Chitere, G.T. Lako, G. O. G. Nyambane*

Assisted by: *O. Nyapela, G. Nengo, S. Oluoch, N. Dibogo, S. M. Jembe, B. A. Omolo*

Background

The ISERIPM project was jointly conceived by ICIPE's biologists and social scientists with two main objectives: (1) to undertake adaptative and evaluative research on pest management technologies pertaining to selected staple food crops in appropriate agroecological zones of Kenya; and (2) to develop interactive socioeconomic interface methodologies for crop pests management. The main IPM components that are being adapted to the coastal conditions are:

- insect-pest resistant cultivars of maize and sorghum;
- strip and relay intercropping of the above cereals with fast maturing cowpea varieties; and
- biological control using *Bacillus thuringiensis (Bt)*.

The project is being implemented in Kwale and Kilifi Districts of the Coast Province, Kenya. The implementation is in three one-year phases of:

- I—on-station trials (1993),
- II—on-farm scientist- managed trials (1994), and
- III— on-farm farmer-managed trials (1995).

A combination of GIS, socioeconomic surveys and participatory research methods have been used in the selection of sites for the on-farm trials and of farmers who are participating in the trials.

KARI's Mtwapa station scientists assisted in identification of six on-station trials sites. MOALDM's extension and provincial administration staff and local leaders and farmers provided information which facilitated the selection of project sites and farmers that are participating in the on-station trials.

The implementation of each phase of the project is guided by a set of objectives. The objectives that guided socioeconomic research work during the second phase of on-farm scientist-managed trials were: (1) working with farmers, to identify and select project participants, create their awareness of IPM options and organise them for participation in the trials; (2) monitor farmers' attitudes and perceptions of IPM menus in terms of suitability and benefits; (3) train farmers and extension workers on available IPM options; and (4) undertake comparative economic performance analysis on the critical variables in on-farm trials and farmers' fields. Each of these objectives had a set of activities that had to be achieved. For example, the first objective necessitated analyses of socioeconomic data, discussions with farmers and community leaders, and development and use of socioeconomic indicators.

Work in progress

1. RESULTS OF SOCIOECONOMIC RESEARCH

On the basis of GIS, and macro- and village-level surveys, four sub-locations and eight villages (half in each district) were selected as project sites. A household-level survey entailing interviews of 228 heads of households provided indicators such as willingness to participate in the trials, awareness of stemborers as a problem, crops grown, intercropping of maize and any other crop; and resource endowment indicators including wealth status, education, knowledge and adoption. The indicators were used in the selection of 89 farmers to participate in the

on-farm trials. With the help of farmers of each of the selected villages, 8 farmers on whose fields on-farm scientist-managed trials were to be located were selected. Additional criteria used by the farmers in this selection process included those who were: full-time farmers and resident on the farms, able to set aside adequate land from his/her farm for the trial, willingness to learn from the project staff, and ability to get along with other farmers, welcome them in his/her home and share knowledge gained with them. These 8 farmers were designated as trial farmers (TFs) and the rest of the project farmers as non-trial participating farmers (NTPFs).

The crops in the trials were planted at the beginning of the long rainy season, 1994. Each of the trial farmers served as a 'contact' farmer and the crop trial field as a demonstration plot for members of the project village.

Whereas the farmers, especially the TFs, assisted with some of the operations such as planting, thinning, weeding and *Bt* application, this phase of the project concentrated on awareness creation and imparting of know-how about IPM to both participating farmers and MOALDM's extension agents. This was aimed at preparing them for participation in the on-farm farmer-managed phase. The know-how was imparted through training activities which included: four one-day workshops held both for participating farmers and the MOALDM's extension agents, one-day education tour that was made by the participating farmers in Kilifi District, 8 meetings held (two in each sub-location) at which the farmers evaluated insect-pest resistant cultivars in the first set of meetings and intercropping practices in the second set.

Farmers' attitudes and perceptions of IPM components were studied during meetings at which they evaluated the components. Their criteria for preferences of insect-pest resistant cultivars included: height of plants, big cobs or heads, strong and healthy stems, potential for high yield, etc. The evaluations were partly used by the biologists in selecting cultivars for entering in the on-farm farmer-managed trials to be conducted in 1995. Criteria for the farmers' preferences of strip and relay intercropping practices included: healthy plants and potential for high yield.

Economic data were collected and are currently being analysed.

Completed studies

Ajala S. O., Ssennyonga J. W. and Chitere P. O. Developing maize genotypes resistant to *Chilo partellus* (Swinhoe). In *African Crop Science Conference Proceedings* (Edited by Adipala E., Bekunda M. A., Tenywa J. S., Ogenga-Latigo M. and Mugah J. O.), Vol. I, pp. 329–333. Kampala, Makerere University Printery.

Chitere P. O. and Kiros F. G. Farmer's participation in the adaptation of IPM technology in the Coast Province, Kenya. *African Crop Science Journal* (in press).

Participation of resource-limited farmers in agricultural research projects in ways that can help ensure their adoption and sustenance of farm technologies is a challenge for most agricultural research agencies. The Interactive Socioeconomic Research for Biointensive Pest Management (ISERIPM) project is an adaptive research project which, among other things, explores methods of involving farmers in various phases of its implementation. The involvement is based on ICIPE's approach of IPM technology development which provides for minimal involvement at on-station trials, somewhat increased involvement at on-farm researcher-managed trials, and a high level of involvement at on-farm farmer-managed trials. At on-station trials which were carried out in 1993, farmers' participation was restricted to evaluation of some of the IPM components which included maize and sorghum cultivars and various forms of intercropping.

The sites for the on-farm trials (4 sub-locations and 8 villages), and 89 farmers as potential participants were selected following GIS characterisation of the research districts of Kwale and Kilifi on the basis of agroecological and socioeconomic conditions, and macro-, village- and household-level surveys. In subsequent meetings, members of the chosen villages selected 8 trial farmers (TFs)—one per village—from among those chosen as project farmers. The rest of the farmers who met the selection criteria are termed non-trial participating farmers (NTPFs) and participated in the various educational activities of the researcher-managed trials in 1994.

Future activities

Phase III of this project is that of on-farm farmer- managed trials which will be implemented in 1995. During this phase, socioeconomic research work will be guided by the following objectives: (1) application of suitable IPM options with some guidance by scientists; (2) monitoring adoption of IPM options and modification of IPM by both project- and non-project farmers and emerging constraints to adoption of the options; (3) enhancement of farmers' management capabilities in the use of resources; (4) economic analyses and evaluation of IPM options; and (5) determination of potential for sustainability of IPM technologies.

B. BIOLOGICAL ASPECTS—ON-FARM SCIENTIST-MANAGED TRIALS

1. PHASE II. ON-FARM TRIALS OF IPM MENUS IN PARTNERSHIP WITH FARMERS AND COMPARISON OF FARMERS' PRACTICES WITH EXPERIMENTAL TRIALS

Participating scientists: *K. Ampong-Nyarko, M. O. Odindo, S. O. Ajala, A. M. Nour*

Assisted by: *Z. N. Ngalo, S. M. Othieno, J. A. Mwanda, P. O. Akello*

Background

The rationale of IPM menu selection was based on the following considerations, after which various IPM components were advanced from the on-station experiments to on-farm scientist-managed trials.

Work in progress

Genotypes

1. Genotypes considered stable for the area and possessing relatively higher yield in addition to being resistant to stemborers were selected.

2. Genotypes were selected based on visual evaluation of farmers' preference for genotypes: ICZ 5 (an open pollinated genotype), IC92-M2 and IC92-M5, both varietal crosses for maize; and for three sorghum cultivars—HYD-6, DRIV-1 and Gaddam El Hamam).
3. In addition, the three genotypes have been nominated as candidates in various stages of the nationally coordinated pre-release trials for the Coast Province of Kenya.

Cropping pattern

From the on-station trials, the following were concluded:

1. Farmers' current practice of relay cropping cowpea 6–8 weeks after maize has little stemborer reduction potential.
2. Broader row ratios in strip cropping can be used by the farmer without sacrificing the pest reduction potential of intercropping.
3. Early planting of cowpea is more productive than late planted cowpea when the cowpea crop is protected.
4. The common companion crops in the project areas are compatible for intercropping in terms of pest reduction; therefore, the choice of companion crop to use in intercropping depends on ecological and socioeconomic factors.
5. Cassava is a dominant companion crop in the cropping systems of Kwale and Kilifi districts.

Based on the above conclusions a new cropping pattern alternative, 'strip-relay cropping', was tested on-farm in 1994. In this system, the cereal is planted simultaneously in strips of 4 rows, with 3 rows of cassava and 2 rows of early maturing cowpea. After harvesting the first crop of cowpea, a second crop of cowpea is planted in the same season. In the second season maize or sorghum is planted again with another planting of cowpea, while the cassava continues to mature. It is then possible to obtain two crops of maize or sorghum, three of cowpea and one of cassava in the same year.

The cropping pattern was tested with tolerant cultivars of maize (IC92M5, either IC92M2 or ICZ 5, and Coast Composite as local check). Protection was with *Bacillus thuringiensis* (*Bt*) treatment at 3 and 4 weeks after planting and a no-treatment control on farmers' fields managed by scientists. For each site the experiment was repeated for sorghum using the following cultivars: HYD-6, DRIV-1 or Gaddam El Hamam and Serena (local check).

The studies were carried out on-farm, in four villages in Kwale (Tswini, Mwaliwa, Makambani and Mamba) and four villages in Kilifi (Tandia, Silala, Pinglikani, Lutsangani). A part of the criteria for selection of villages was that half of the villages would be in the high rainfall/high potential areas, whereas the other half would be in marginal areas.

For the two sites where the data were complete, the target plant population of strip relay cropping was easier to achieve in sorghum; consequently, there were no significant differences between the actual sorghum yields and the control. But in maize, the plant population of strip cropping was about 30% less at some sites, which reduced absolute maize yields of the strip. Strip relay cropping increased the multiple cropping index (the sum of the areas planted to different crops harvested during the year divided by the total cultivated area) and land use intensity (the number of days where crops occupy the land during the year, divided by 365). Strip cropping gave a significant reduction in border density at six weeks after planting compared to farmers' cropping practices. The sorghum, HYD-6 was the most tolerant among the cultivars used, whilst ICZ 5 was the most tolerant maize cultivar. *Bacillus thuringiensis (Bt)* gave significant reductions in insect densities.

C. TRAINING ACTIVITIES/CAPACITY BUILDING/OUTREACH

Following one of the project's objectives of training of farmers and extension agents on available IPM options, a number of educational forums were held:

- A workshop for the trial farmers was held in May, 1994 and was attended by TFs and MOALDM's frontline agents as observers;
- A workshop for the MOALDM's frontline agents was held in July, 1994 and was attended by frontline and divisional- and district-level agents; and
- A farm education tour in Kilifi District was organised with the help of MOALDM's extension staff in which project and non-project farmers participated.

X. Kwale/Kilifi Adaptive Research Project on Sustainable Management of Insect Pests and Tsetse in Coastal Kenya

Participating scientists: *S. Sithanantham*, A. Oendo, C. Kyorku (ICIPE), G. M. Kamau, M. Kiarie, L. Otieno (KARI), F. M. Mukendi (MOALDM) (*Project Leader)*

Assisted by: *E. N. Wambugu, G. Ambajo, P. Munyambu, D. Karuri, F. Mshote, E. Okiri, W. M. Sowa (KARI), J. Cherioyot, J. E. Tsetse, G. O. Odhiambo, J. Matheka (MOALDM)*

Collaborating ICIPE scientists: *V. O. Musewe, J. J. Ondieki (IBIRI), K. V. Seshu Reddy, A. Nyarko, S. O. Ajala, A. M. Nour, M. O. Odindo (Plant Pests), F. G. Kiros, G. T. Lako (Social Sciences), L. H. Otieno, R. K. Saini, M. L. A. Owaga (Tsetse Research), A. Odulaja (Biomathematics)*

Donors: *UNDP, Government of Kenya*

Collaborators: *Kenya Agricultural Research Institute (KARI); Ministry of Research, Technology and Technical Training (MRTTT), Kenya; Ministry of Agriculture, Livestock Development and Marketing (MOALDM), Kenya*

Background

This is a PESTNET-related project, involving close collaboration between ICIPE and the Kenyan national agricultural research system (NARS). The project was launched in two districts (Kwale and Kilifi) of coastal Kenya in 1992. This region experiences considerable food security problems, which are traceable to substantial yield losses in food crops, due to insect pests and in cattle due to tsetse vectors. The farmers have largely been aware of these problems, but have seldom adopted the control measures so far developed, which are based on the use of expensive and toxic pesticides. This PESTNET-related project was visualised to test and adapt the environment-friendly technologies identified and developed at ICIPE, such as resistant genotypes and cultural practices for managing crop pests and trapping of tsetse for trypanosomiasis management. The project activities are largely based on the researcher-extensionist-farmer linkages.

The project activities were broadly grouped under four components: Crop Pests Management Technology, Tsetse Trapping Technology, Socioeconomic Interface and Capacity Building.

The highlights of the crop pest component are furnished in the following sections, and those of tsetse are to be found in the UNDP-funded tsetse section of the Disease Vectors Management Programme. The socio-economic interface component contributed both directly on specific topics as well as in perception studies integrated with the two biological components.

A. CROP PESTS MANAGEMENT COMPONENT

During this year, the focus was on the on-farm evaluation of the yield benefits of the chosen pest-resistant genotypes of maize, sorghum and cowpea under farmers' own management.

Work in progress

1. STEMBORER-RESISTANT/TOLERANT MAIZE GENOTYPES

In maize, two promising stemborer-resistant genotypes (IC92M4, IC92M5) were grown in large plots along with a local check (Pwani Hybrid) by farmers at two sites—Shimba Hills and Vitengeni. The management of the different plots was according to farmers' own pattern and affordability of inputs. The yield advantage of the two new genotypes over check (local) variety was found to be in the range of 10–20%. Back-up trial plots in the two sites confirmed that yield loss due to stemborer was reduced by over 20% in the two promising genotypes. Farmers were also able to recognise the less severe attack by the pest on these two genotypes compared to the local cultivar. Some farmers preferred the latter genotype for use in the short rainy season because it tends to mature earlier by 5–7 days. This trait was also perceived to give

an indirect advantage in the long rainy season (in Shimba Hills), because the crop could be harvested a few days earlier, thus minimising the risk of crop damage at harvest time by wild animals.

2. STEMBORER-RESISTANT/TOLERANT SORGHUM GENOTYPES

This year the farmers also evaluated two promising stemborer-resistant genotypes—Gaddam El Hamam and ICS3, along with a local variety Kacherina in large plots in their farms under their own management at the above major sites. The yield benefit due to these new types was estimated to range between 15 and 30%. Back-up trials confirmed that the yield loss due to stemborer was significantly lower in these genotypes compared to the local variety. Among the two new genotypes the former was regarded useful for both crop seasons because of its early maturity, while the latter was found to confer some advantage because of being less prone to grain damage by birds during the maturation phase.

3. PEST-TOLERANT COWPEA GENOTYPES

Three promising pest-tolerant cowpea genotypes—ICV3, ICV11 and ICV12 were also evaluated on-farm during the short rains, along with two check varieties—K.80 and Local ('Macho ya paka'). They were grown in adjacent blocks, with one block being protected from insects by pesticides. From the block where the natural pest infestation was permitted, the grain yield advantage of the three genotypes was in the range of 10–30% over the released check (K.80), while the increase in yield was over 100% when compared to the local 'Macho ya paka', which is mainly a leaf producing cultivar. The released check (K.80) yielded as well as the tolerant cultivars under pesticide protection, which confirmed that the latter suffered less yield loss due to insect pests. The farmers also perceived these attributes during discussion in field days.

4. INTERCROPPING OF MAIZE WITH COWPEA

On-farm, large plot evaluation of early intercropping of cowpeas in maize as an improvement over the traditional relay intercropping was also launched at the two sites. Such early intercropping was found to reduce the stemborer severity in maize. The farmers expressed willingness to shift from their traditional relay planting practice so as to derive the benefit of such investment-free reduction in stemborer damage on their maize crop by adopting the new practice, which also helped to control the early season weeds through the smothering effect of cowpea planted earlier on in between maize rows.

B. SOCIOECONOMIC INTERFACE COMPONENT

Work in progress

1. CONSUMER ACCEPTABILITY STUDIES

The consumer acceptability of the produce from promising pest-resistant genotypes and local cultivars was evaluated by locally organising taste panels at Shimba Hills (Kwale District) and Vitengeni (Kilifi District). Sorghum grains were tested as porridge *(uji)* while cowpea grains were evaluated as *githeri* (boiled and mildly spiced). While the taste differed between the varieties tested, they were all found to be within the range of acceptability.

2. CULTURAL PRACTICE ADOPTION STUDIES

The improved cultural practice of early intercropping of cowpeas in maize was studied for its adoption potential among the participating farmers. Two strategies were identified towards minimising the biological constraint (leaf beetle damage) to this practice. Planting larger areas under cowpea in the farm and/or vicinity was found to cause a dilution effect on beetle damage severity. Alternatively, farmers also appreciated the scope for spraying the seedlings of cowpea with neem seed extract (10%) which offered satisfactory protection from the weevils. By these refinements, the farmers developed a positive attitude towards shifting from the traditional relay planting to the improved early planting of cowpeas, to confer the pest management benefit to the maize crop against stalkborer damage when pesticides are not used on maize.

3. COMMUNITY STRUCTURES FOR TSETSE TRAP DEPLOYMENT

The presently available range of organisational structures were studied for their potential for supporting the community-based mass deployment of tsetse traps in and around Shimba Hills. It was found that none of the existing groups or clusters can support this activity. So, the farmers in the target sites along with their local leaders, were sensitised and assisted to form their own special groups with elected coordinators.

C. CAPACITY BUILDING

1. ADVANCED TRAINING

Two scientists of KARI were supported for continuing the doctoral training under ICIPE's ARPPIS programme. Their research topics are centred on evolving environment-friendly as well as sustainable insect pest management strategies relevant to the coastal Kenya ecology.

2. SHORT-TERM TRAINING FOR NARS

Short-term training courses for over 40 officials of the Kenyan NARS were organised at two levels, one for trainers and the other for frontline staff, on tsetse trapping technology and mass deployment.

Future activities

The Government of Kenya (GOK) has expressed a keen interest in expanding this work to reach larger areas and a wider range of beneficiaries, especially those farmers in the ASALs (arid and semi-arid lands). To enable this, ICIPE will be providing backstopping in the next phase.

During the next phase, three activities are proposed:

1. Adaptation testing and selection of suitable options among pest-resistant cultivars and intercropping for coastal ASAL ecology.
2. Validation and/or verification of indigenous pest control practices, including the use of local botanicals, both on-station and on-farm.
3. Dissemination of adoptable technology options through training and demonstrations. The technologies will include:
   (i) pest-resistant genotypes, mainly maize and sorghum, with cowpea and cassava used as intercrops
   (ii) cultural practices
   (iii) indigenous technologies, including botanicals.

LOCUSTS RESEARCH

XI. Locust Semiochemicals Research

1. AGGREGATION/GREGARISATION

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

Assisted by: *H. C. Amiani, P. M. Njiru*

Donors: *SAREC, IFAD, AFESD through IFAD*

Previously, we had demonstrated from olfactometric assays that the pheromone system of the gregarious desert locust is a complex of volatiles emitted by different developmental stages of the insect and their waste products. The pheromone system of mature adults was characterised by chromatographic, electroantennographic, spectroscopic and behavioural assays as a blend of four aromatic compounds. One of these compounds which disrupts aggregation in nymphal stages, is the subject of intensive field studies.

Semi-field validation of the adult pheromone blend dispensed from polyvinylchloride discs were carried out in large outdoor cages.

We have recently investigated the volatiles produced by fifth instars and isolated 18 electrophysiologically-active compounds which have been characterised by spectroscopic techniques as linear aliphatic compounds and which are the subject of detailed behavioural assays.

2. SEX ATTRACTION IN SOLITARIOUS LOCUSTS

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

Assisted by: *H. C. Amiani, P. M. Njiru*

Previous wind-tunnel studies had demonstrated that adult male solitarious desert locust were attracted to volatiles emanating from conspecific females. Volatile emissions from both males and females were compared and two common components were identified and reported in 1993. Detailed studies have been carried out on volatiles produced by females and three female-specific electrophysiologically active components isolated. One of these three components has been fully characterised and is the subject of detailed behavioural assays. Identification of the other two compounds is in progress.

3. MATURATION EFFECTS OF ADULT PHEROMONE BLEND

Participating scientists: *H. Mahamat*, A. Hassanali, B. Torto, S. El Bashir*

Assisted by: *H. Odongo*

A subtraction bioassay involving blends of five main components of mature male desert locust, *Schistocerca gregaria* was carried out on mature males of the insect. Maturation was studied by monitoring yellowing and mating assays. Subtraction of anisole did not significantly affect the maturation-accelerating effect of the blend. However, the subtraction of the other components affected the pace of maturation to varying degrees. Our results suggest that of the other four components, benzylcyanide is most important followed by benzaldehyde and then 4-vinylveratrole and veratrole. The first two were also previously shown to be behaviourally active as adult aggregants and thus to be responsible for the parsimony observed with the adult pheromone blend as an adult aggregation signal and as a maturation accelerant in young adults.

4. OVIPOSITION-AGGREGATION PHEROMONE OF THE DESERT LOCUST, *SCHISTOCERCA GREGARIA*

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

Assisted by: *H. Odongo, J. Wawiye*

Two major GC electrophysiologically active peaks from froth volatiles were identified as acetophenone and veratrole (Figure 1). The amount of acetophenone and

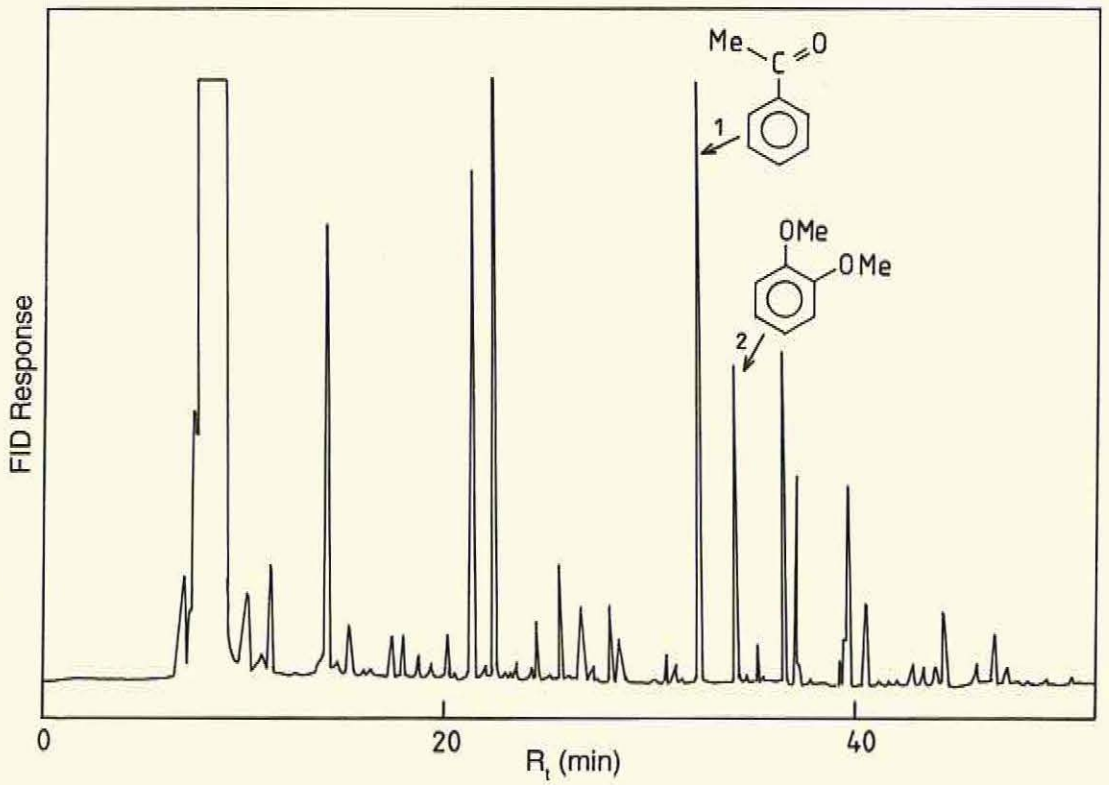


Figure 1. Gas chromatogram (carbowax column, 50 m x 20 m capillary x 0.2 mm ID film thickness) of the volatiles collected from froth of egg pods of the gregarious desert locust, *Schistocerca gregaria*. EAG-active peaks are labelled as compounds 1 (acetophenone) and 2 (veratrole).

veratrole present in the volatiles trapped from froth plug for 12 h was calculated as 64.05 and 37.02 ng, respectively. Various concentrations of these compounds (individually and in combinations) were tested behaviourally. Among the three concentrations (0.05, 0.5, and 2.0 egg pod equivalents) of acetophenone tested, only one dose (2.0 egg pod equivalents) attracted significantly more females for oviposition. Two doses (0.05 and 0.5 egg pod equivalents) of veratrole have been tested so far.

5. LOCUST REARING

Participating scientists: *J. P. R. Ochieng'-Odero, G. W. Oloo, M. M. Rai*

Assisted by: *S. M. Ndugo, J. Ongudha*

The stock of the desert locust colony originated from Addis Ababa, Ethiopia and the Red Sea Coast, Sudan in 1989 and 1990, respectively. These were maintained initially in crowded condition and then in isolated condition to obtain solitarious individuals.

The two groups of locusts were successfully produced during the reporting period. The level of production was limited to the number of insects required for various studies. Most of the locusts were supplied to the researchers in the Behavioural and Chemical Ecology Unit and other scientists within the Locust Project, and to ARPPIS scholars.

1. Crowded locust

Staff: *J. Ongudha, G. M. Nganga, J. Onyango*

The crowded colony is in the 32nd generation. It is maintained throughout the year using wheat (*Triticum* sp.) bran and seedlings. A total of about 28,584 insects (20,295 nymphs and 8289 adults) or 2382 insects per month were supplied for research purposes. Selective breeding technique has been followed to avoid infection by trans-ovarian transmitted diseases. The average mortality was maintained below 15% by reducing infections by various pathogens. Female fecundity, egg hatchability, and morphometric characters (E/F, F/C ratio) were monitored throughout the generations and only adults having gregarious characters were used for breeding.

2. Isolated locust

Staff: *J. T. Kilori, S. A. Patya, M. M. Miti*

Isolated locust colony is in the 23rd generation. Wheat (*Triticum* sp.) seedlings and bran were used as a regular diet. The number of eggs per pod recorded was 80–85 with an average of 92–95% egg hatchability. Average mortality of about 5% was recorded in each generation and was not due to any pathogenic infection. Selective breeding was done to maintain the healthy individuals of solitarious characters. About 2520 insects (882 nymphs and 1638 adults) were supplied during 1994.

3. *Feeding period and weight of the last instar nymph in relation to final moulting in both phases of the desert locust*

Staff: S. A. Patya, M. M. Rai

The critical feeding period and threshold weight of the last instar nymphs for final moult have been investigated for both phases (gregarious and solitarious) of the desert locust. The gregarious fifth instar nymphs achieved a body weight of 0.915 g male and 1.255 g female when they received food for about 4.8 and 5.8 days, respectively, which was critical for the initiation of the metamorphosis and moulting into an adult stage. In the case of solitarious individuals, sixth instar nymphs attained the threshold weight in only 2.2 days for males and 2.9 days for females, but the body weight was higher (0.97 g for male and 1.53 g for female) than the gregarious individuals. Although nymphs achieved the threshold weight in a few cases before the critical feeding time, they did not moult into adults, perhaps due to lack of food reserve for metamorphosis. It was concluded that the threshold weight of the last instar nymph is crucial and can be achieved only after feeding for the critical period during the initial days of development which leads to final metamorphosis.

Completed studies

Inayatullah C., El Bashir S. and Hassanali A. Sexual behaviour and communication in the desert locust, *Schistocerca gregaria* (Orthoptera:Acrididae): Sex pheromone in solitaria. *Environmental Entomology* 23(6), 1544–1551.

Mahamat H.*, Hassanali A., Odongo H., Torto B. and El Bashir S. Studies on the maturation-accelerating pheromone of the desert locust *Schistocerca gregaria* (Orthoptera: Acrididae). *Chemoecology* 4, 159–164.

The accelerating effect of mature males of the desert locust, *Schistocerca gregaria*, on the maturation of immature male and female conspecifics was confirmed. The onset of sexual activity was found to correlate with yellowing of the male insects. Using the colour as an indicator of maturation, the maturation-hastening effect of an hexane extract from mature males was also confirmed. Likewise, volatiles from mature males placed in the upper storey of a two-chamber bioassay system (no visual or tactile contact possible) and charcoal-trapped volatiles from the mature males also induced accelerated maturation in recipient males placed in the lower storey. GC and GC-MS analysis of volatiles collected from 4-week-old mature males showed the presence of anisole, benzaldehyde, veratrole, phenylacetonitrile and 4-vinylveratrole, roughly at the ratio 4.8:7.0:3.3:79.8:5.0. In addition, guaiacol, phenol, benzoylnitrile, benzyl alcohol and 2-benzoyloxyphenylacetonitrile were present in smaller amounts. These compounds were either absent or found only in trace amounts in the female volatiles. Earlier, we had shown that essentially the same blend collected from younger males (10–20 days old, not yet demonstrating signs of maturation) induced strong aggregation of both sexes of adult desert locusts, suggesting a parsimonious role for the pheromone system: as an adult aggregation signal and as a maturation accelerant in young adults.

Obeng-Ofori D., Njagi P.G.N., Torto B., Hassanali A. and Amiani H. Sex differentiation studies relating to release aggregation pheromones of the desert locust, *Schistocerca gregaria*. *Entomologia Experimentalis et Applicata* 73, 85–91.

Behavioural responses of nymphs and adults in the gregarious stage of the desert locust, *Schistocerca gregaria* (Forskal) (Orthoptera: Acrididae) were investigated in a single-chamber bioassay system to a choice of two columns of air, one permeated with airborne volatiles emanating from either sex of nymphs or adults and the other untreated. There was no sexual differentiation in the production of or response to nymphal volatiles. Young adults of either sex did not produce a stimulus with significant activity. Of the older adults, only the males produced the aggregation stimulus to which both sexes were equally responsive. Charcoal-trapped volatiles from the two sexes of nymphs and adults evoked similar aggregation responses. Antennae of the older adults showed significantly higher EAG responses than those of fifth instar nymphs to all four volatile collections, of which volatiles from older adult males were the most stimulatory and evoked the highest EAG amplitudes.

Obeng-Ofori D., Torto B., Njagi P. G. N., Hassanali A. and Amiani H. Faecal volatiles as part of the aggregation pheromone complex of the desert locust, *Schistocerca gregaria* (Forskal) (Orthoptera: Acrididae). *Journal of Chemical Ecology* 20 (8), 2077–2087.

Olfactometric bioassays showed that nymphs of crowded desert locusts, *Schistocerca gregaria*, aggregated in response to volatiles derived from their faeces and to volatiles emitted from the faeces of young adults, but were indifferent to volatiles emitted by older adult faeces. On the other hand, young and older adults were not only responsive to their own faecal volatiles but also cross-responsive to each other's and that of the nymphs. Charcoal-trapped volatiles from the faeces and synthetic blends of the fecal volatiles also elicited similar responses. Young adults responded moderately to a blend of nymphal volatiles and those derived from nymphal feces. GC-EAD and GC-MS analysis of trapped volatiles revealed the presence of guaiacol and phenol as predominant electrophysiologically active components of nymphal and young adult faeces. Faecal volatiles of older adult contained phenylacetonitrile in addition to guaiacol and phenol, which were present in relatively lower proportion. These results suggested that faecal volatiles are part of the aggregation pheromone complex of the desert locust, which includes the pheromone blends produced by nymphs and older adults, respectively.

Saini R. K., Rai M. M., Hassanali A., Wawiye J. and Odongo H. Semiochemicals from froth of egg pods attract ovipositing female *Schistocerca gregaria*. *Journal of Insect Physiology* (in press).

A chemical signal, originating from the froth of egg pods attracts gravid female *Schistocerca gregaria* (Orthoptera: Acrididae) to common egg laying sites. Behavioural experiments indicated that females preferred to oviposit in moist sand contaminated with froth (60% egg laying *vs* 34% in sterilised sand). Extracts and volatiles collected from froth were also attractive to gravid females. In fact, the latter were the most attractive with 80% of egg laying occurring in sand contaminated with froth volatiles. Results from froth extracts obtained by sequential extraction with solvents of increasing polarity suggest that both non-polar and polar compounds are involved in the attraction of gravid females. Electroantennogram recordings with extracts and volatiles

collected from froth confirmed the presence of olfactory receptors on the antennae that are responsive to compounds in the extracts and the volatile collections.

Torto B., Obeng-Ofori D., Njagi P. G. N., Hassanali A. and Amiani H. Aggregation pheromone system of adult gregarious desert locust, *Schistocerca gregaria* (Forskal). *Journal of Chemical Ecology* 20, 1749–1762.

Six electrophysiologically active aromatic compounds, viz., anisole, benzaldehyde, veratrole, guaiacol, phenylacetonitrile, and phenol, were identified in the volatiles of older-adult male desert locust. Young adults and females of all age groups produced none or only trace quantities of these compounds. Comparison of the aggregation responses of young and older adults to the crude, older-adult, volatile extract and different synthetic blends of the six compounds showed that the aggregation pheromone system of the adult gregarious locust consists of phenylacetonitrile, guaiacol, phenol, and benzaldehyde. Like the crude volatile extract of older males, neither the synthetic blend of the six compounds nor the adult pheromone blend evoked any significant aggregation responses from nymphs. These results confirm our previous report of sexual differentiation in the production of adult aggregation pheromone in the desert locust and of the evidence of two distinct aggregation pheromone systems in the two stages of the insect.

XII. Locust Biocontrol: Approaches in the Use of Pathogens for Desert Locust Management

Participating scientist: *S. K. Raina* (*Project Leader)*

Assisted by: *M. Ambeke, F. Ondieki, D. Ogala, A. S. Mohamed*, D. Dakouo*, K. Kambona* (*ARPPIS PhD students)*

Donor: *ICIPE Core Funds*

Background

The primary aim of the locust biological control research project is to develop virulent pathogenic organisms which can regulate populations of the desert locust, *Schistocerca gregaria* (Forskal), and prevent the outbreaks. Two approaches have been tried. The first, by the protozoan, *Malamoeba locustae* which has shown transovarial capability to conserve in the host generations. The second was the use of a fungus, *Beauveria bassiana*, which has shown promise as a contact pesticide under laboratory conditions.

Work in progress

In previous studies, the survivorship of the desert locust population showed a gradual decline in the groups infected with various dosages of the protozoan *M. locustae* in five filial generations. The age-specific fertility of females diminished with time, resulting in either a reproductive failure or delay in oviposition. Lectin was found to be one of the components enhancing tolerance to *M. locustae* infection in the desert locust. It was purified using an affinity column and its level in the haemolymph of infected locust was determined by ELISA.

A fungal pathogen, *Beauveria bassiana* was also found effective as a contact biocide. The fungus was pathogenic to all stages of the locusts. Corn oil formulations were developed with UV protectants and tested in field cage trials. The LT_{50} was attained in 10 days with the formulated mixture as compared to 15 days with the unformulated mixture.

To enhance the efficacy of the biocontrol agents, the synergistic effect of both protozoan and fungus was investigated. The LT_{50} values declined significantly ($P < 0.001$) as compared to the individual pathogenic effects. These results are being confirmed at each stage of development of the locusts. Similarly, a broad-range biocide of protozoan origin (*M. locustae*) has been developed by criss-crossing it in two hosts, *Locusta migratoria* and *S. gregaria*.

The use of the above microbial pathogens is expected to be part of a comprehensive strategy integrating biocontrol agents with semiochemicals, in particular with oviposition and aggregation pheromones.

This project was completed in December, 1994.

1. LOSS OF REPRODUCTIVE POTENTIAL IN THE DESERT LOCUST, *SCHISTOCERCA GREGARIA* INFECTED WITH THE PROTOZOAN, *MALAMOEBA LOCUSTAE*

Participating scientists: *A. S. Mohamed, S. K. Raina, S. El Bashir*

The reproductive potential of locusts infected with *M. locustae* was examined. The pathogen has delayed the maturation period of both males and females among the surviving locusts. The weight and development of the ovary were significantly ($P < 0.001$) retarded in infected females. The fecundity was low and longevity was decreased in the transovarially infected filial generation.

The fertile capacity of individual females diminished with time, resulting in either a reproductive loss or delayed oviposition. The repeated persistence of pathogen in the population suppressed the egg laying potential in all generations. Moreover, there was an intermittent gap between oviposition which extended from two weeks to more than ten weeks.

Oviposition was significantly lower ($P < 0.001$) in the parental generation than in controls, and this trend was repeated in the surviving populations of subsequent generations. Total protein concentration did not rise to the level of healthy individuals and the precipitin band of vitellogenin diminished in some diseased locusts and appeared late in others, indicating either a reproductive failure or a delay in oviposition. The proteins were determined using BCA assay and the vitellogenin by native gel and radial immunodiffusion assay. The data was analysed by Statistical Analysis System (SAS).

2. SURVIVORSHIP AND AGE-SPECIFIC FERTILITY IN THE TRANSOVARIALLY INFECTED POPULATION OF THE DESERT LOCUST INFECTED WITH THE PROTOZOAN, *MALAMOEBA LOCUSTAE*

Participating scientists: *A. Salih, S. K. Raina, S. El Bashir*

Survivorship (L_X) and age-specific fertility (M_X) were monitored in the five filial generations (F1 to F5) of *S. gregaria*, parents of which were infected with various dosages of the protozoan parasite *M. locustae*. These were indicated with time and the effect of pathogen was observed on the reproductive cycle. The survivorship curve of the host population showed a gradual decline in all the groups infected with various dosages of the pathogen.

The mean cumulative age-specific fertility in the five generations indicated that although the egg laying continued in the infected population, the values (M_X) remained considerably low as compared to controls. In the course of time, this has significantly affected the population build up. This indicated that even under favourable laboratory conditions for locust reproduction, a chronic infection with the protozoan *M. locustae* could retard the locust population. The data were analysed by statistical analysis system (SAS), the life tables as per Southwood (1966) and the mortality factor was corrected by Abbott's formula.

3. POSSIBLE ROLE OF A PURIFIED LECTIN FROM HAEMOLYMPH OF THE DESERT LOCUST IN DEFENCE MECHANISMS AGAINST THE PROTOZOAN, *MALAMOEBA LOCUSTAE*

Participating scientists: *D. Dakouo, S. Essuman, M. Brehelin, S. K. Raina*

Haemolymph from the desert locust showed agglutination activity for mammalian erythrocytes and protozoa. A purified lectin was isolated from plasma by affinity chromatography. Analysis of the purified lectin by SDS-PAGE gave a single band at 80 kD while on native PAGE, a single band was observed at 650 kD. Galactosides with an α-D configuration were found to inhibit agglutination activity. This activity was lost at 65°C in plasma while it remains intact up to 100°C in purified form. This lectin enhanced fixation of *Malamoeba locustae* cysts on locust haemocytes. Immunoblot analysis using antiserum raised against the purified lectin indicated that lectins from *S. gregaria* and *Locusta migratoria* share common immunological characteristics. ELISA tests used to assess the level of lectin gave higher titres in infected locusts as compared to controls. Phagocytosis appeared to be a major factor in the clearance of *M. locustae* from locust haemolymph. The highest level was reached 6 h post-inoculation, and clearance of cysts from live insects was completed after 48 h.

4. ENVIRONMENTAL STRESS ON THE FUNGUS, *BEAUVERIA BASSIANA* AFFECTING AGE-SPECIFIC MORTALITY IN THE DESERT LOCUST

Participating scientists: *K. Kambona, S. K. Raina*

The potential of *Beauveria bassiana* as a pathogen for the desert locust was assessed at a temperature range of 25 to 45°C at 70 ± 5% relative humidity (RH). The k values within a given temperature regime were found to decrease in the progressive stages from the first instar (L1) of locust to adults. The total k-factor decreased with the increasing temperature.

Total k-values increased with increasing relative humidity (40–100% at 30°C) and after 80% remained consistent. However, k factors declined with progressive age from L1 to adults. Stage survivorship was quite high at low humidity, since the pathogen efficacy was retarded. This declined considerably as humidity was increased.

The UV tolerance limit of the pathogen from 1 h to 48 h was found to decrease in terms of k-values with increasing exposure time and by 48 h had declined. The UV exposures proved deleterious to the potential of the pathogen resulting in increased survival of locusts.

5. FIELD CAGE TRIALS WITH THE FUNGUS, *BEAUVERIA BASSIANA* AGAINST THE DESERT LOCUST, *S. GREGARIA*

Participating scientists: *K. Kambona, S. K. Raina*

The field site was located in the temporary ICIPE Science Park at Kasarani, Nairobi. Nine blocks, each measuring 2.5 x 2.0 m and separated from one another by a minimum barrier strip of 2 m were demarcated on a 0.25 ha plot and were planted with wheat. Cages of mosquito nets measuring 2.5 x 2.0 x 2.0 m were used to cover the plots. In each cage 180 early third instar nymphs were released. An initial pre-treatment random sampling was conducted up to the 7th day to determine the stable population within each cage. Nymphs were sprayed with 5×10^{12} oil-formulated and unformulated conidia/ml suspension containing 5×10^{12} conidia/ml using a hand-held sprayer. Relative humidity range was between 43–63% while the average day temperature throughout the experiment fell between 27–32°C with a wind speed of 2 m/s at the time of application.

Sampling of nymphs was done using a 0.5 m^2 quadrat thrown randomly four times on the wheat plot in the cage and counting the nymphs which fell within. The average number of locusts was determined and was added to the number of locusts basking on the roof and walls of cages. Dead locusts were collected for 20 days. Mortalities were subjected to square root transformation and means were compared using Duncun's multiple range test. Differences from analysis of variance (ANOVA) were considered significant at $P < 0.01$.

It was observed that mortality of the nymphs increased with time and the LT_{50} was attained after 10

days in the formulated conidial suspension and delayed to 15 days in the unformulated suspension. The k values at each stage differed significantly ($P < 0.001$) with the controls. Results revealed that after 20 days, the oil-formulated conidial suspension gave a mortality of 85% as compared to 71% attained with the unformulated mixture. Thus, it is evident that once the contact between the pathogen and the host has been made, the presence of various abiotic parameters do not compromise the overall pathogenicity of the fungus, but do influence its capacity to cause mortality.

Completed studies

Raina S. K. Development of a biocontrol strategy for the management of the desert locust, *Schistocerca gregaria*. In *Biological Control of Locust and Grasshoppers*. IITA Cotonou, Benin. CAB publication UK ed., pp. 54–56.

Raina S. K., Das S., Rai M. M. and Khurad A. M. Transovarial transmission of *Nosema locustae* (Microsporida: Nosematidae) in the migratory locust, *Locusta migratoria migratorioides*. *Parasitology Research* 81, 38–44.

Disease Vectors Management Programme

Disease Vectors Management Programme

PROGRAMME OVERVIEW

*by S. Mihok, 1995 Programme Leader**

Africa is thought to be the "cradle of mankind", the location where our species evolved before dispersing throughout the world. It is blessed with a benign climate and fertile land, and is potentially capable of supporting large numbers of livestock. Unfortunately, these amenable conditions have also made Africa an ideal environment for harmful insects and arthropods. Two of these in particular, tsetse flies (*Glossina* species) and ticks, are responsible for enormous losses in livestock production. For example, ticks, and the many diseases they transmit, affect about 200 million cattle in Africa and account for an overall economic loss of about US$ 3.5 billion. Similarly, tsetse-transmitted animal trypanosomiasis results in direct economic costs of about US$ 0.6–1.2 billion, with indirect losses of about US$ 4 billion. Tsetse and ticks together limit or prevent livestock production in many of the best grazing lands in Africa. Ticks limit production throughout the continent, whereas tsetse limit production over an area of about 10 million km^2 south of the Sahara. About 60–90 million cattle are at risk of trypanosomiasis, as well as tens of millions of goats, sheep, camels, horses and pigs. By the year 2025, Africa will need to feed 800 million additional people. Just to maintain current levels (which are by no means acceptable), food production will have to grow at a rate of 2.75 percent per year. To improve the quality of life, a growth rate of 4% is required. These numbers contrast with the 1.7% growth rate achieved in the livestock sector from 1961 to 1988.

Tsetse research

In the case of tsetse, ICIPE's research in the 1980s was instrumental in the discovery of the attractiveness of phenols from bovine urine to widespread savannah species such as *Glossina pallidipes* and *Glossina morsitans*. These discoveries led to the adoption of attractive bait technologies for the control of tsetse in many African countries. Today, similar innovative research has continued with studies on the attractiveness or repellency to tsetse of a wide variety of wildlife and livestock hosts. These studies have been facilitated by the development of simple devices for trapping body volatiles for detailed chemical characterisation. Preferred hosts such as cattle and warthogs as well as animals very rarely fed on by tsetse, such as waterbuck, are currently being studied.

As reported in the *1993 ICIPE Annual Report Highlights*, considerable progress has already been made in elucidating the nature of the attractiveness of reptiles to riverine tsetse. At present, there are no chemical odour baits available for this group of tsetse. Work at ICIPE has now demonstrated clearly for the first time that species such as *Glossina fuscipes* locate preferred hosts (monitor lizards) through previously-unknown odour cues. The chemicals responsible have been isolated and are being identified for eventual use in attractive bait technologies.

A similar integrated research approach has been used to identify the ways in which female tsetse locate sites suitable for depositing their larvae. This work has led to a breakthrough in the identification of new pheromones. The major components of these larviposition pheromones of *G. morsitans* sspp. have now been identified as *n*-pentadecone and *n*-dodecane. The compounds show great promise for the development of control methods for gravid females. These females are refractory to existing attractive devices during late pregnancy.

While researching more efficient attractive bait technologies, ICIPE has continued to test and promote existing trap-based control methods for direct community use in a variety of pilot trials. These trials have been conducted in Kenya and Ethiopia with varying degrees of community participation. The successes and failures of tsetse control with traps have been analysed from both a social and an economic viewpoint. The lessons learned have been used to develop new socioeconomic models for the implementation of community-based projects in order to insure long-term sustainability. These models are now being implemented and monitored for impact and sustainability in on-going pilot trials in both countries.

In addition to adaptive research, ICIPE has made significant progress in three strategic areas that may lead to future practical applications.

- First, long-term research on the many factors controlling the refractoriness of tsetse to trypanosome infection has led to the identification of a trypsin-lectin complex that appears to control trypanosome establishment in the tsetse midgut. Full characterisation of this complex is nearly complete and may lead to novel strategies for the artificial construction of refractory tsetse in the wild.
- Second, experiments with biological control agents have led to the development of a simple field application technique for contaminating tsetse with a pathogenic fungus, *Metarhizium anisopliae*. The potential killing effect of a contamination chamber attached to traps has been validated in the field and now awaits more extensive trials.
- Lastly, new trap designs have been developed for sampling biting flies such as stable flies and tabanids. These new traps represent a first step towards the development of practical techniques for suppressing biting fly populations in areas where they are involved in disease transmission, or pose a significant nuisance.

Ticks research

Ticks are undeniably the most difficult pests and vectors to control, with most farmers still relying on the often haphazard use of acaricides. In the case of ticks, ICIPE has traditionally focused its research on tick ecology in relation to farming practices in order to develop strategies for minimising the use of acaricides. Presently, most African countries cannot afford to subsidise acaricides and farmers cannot afford to purchase them without subsidisation. African countries are spending about US$ 720 million per year to import acaricides. Even with these high expenditures, perhaps only 3% of cattle dips are functional at any one time. Clearly, affordable and sustainable alternatives to the use of acaricides are sorely needed.

ICIPE is currently making a unique contribution to tick control research by studying diverse management options based on many aspects of tick biology. In particular, ICIPE has led the field in promoting simple integrated strategies based on cultural practices and a sound understanding of tick biology. At field sites in western Kenya, ICIPE scientists have worked closely with farmers to develop low-cost methods of tick control such as hand-deticking, regulated grazing, mixed grazing, and predator facilitation (the use of chickens as tick predators). The adoption of these simple methods of tick control by farmers is being studied and promoted while other methods with longer-term payoffs are being researched.

Particularly significant advances were made in 1994 in the field demonstration of the efficacy of biological control agents for economically-important ticks. Sustained releases of the parasitoid *Ixodiphagus hookeri* of *Amblyomma variegatum* were successful in reducing tick loads on cattle by about 95% in a trial conducted in western Kenya. This parasitoid can now be reared in large numbers in the laboratory. These encouraging results suggest that effort should be put into searching for more parasitoid-tick combinations for the development of diverse control strategies.

Field trials of the pathogenic fungi, *Beauveria bassiana* and *Metarhizium anisopliae*, have been successfully conducted using a variety of cheap formulations. These fungi have been demonstrated to have pronounced effects on both the fecundity and survival of ticks such as the brown ear tick *Rhipicephalus appendiculatus*, the vector of East Coast fever (ECF) and *Amblyomma variegatum*, the vector of heartwater, both on and off the host. As ticks spend up to 95% of their lifetime off the host, the demonstration of effects on ticks on pastures is highly significant. If economic formulations compatible with diverse environmental conditions in Africa can be developed, pathogenic fungi could provide a useful alternative to acaricides.

Research also continued on the anti-tick properties of plants in the families Capparidaceae and Euphorbiaceae, revealing more weapons for potential use in the anti-tick arsenal. Extracts from a local plant, *Margaritaria discoidea* were shown to induce high mortalities in ticks in laboratory trials. Following up on previous studies, extracts from additional plants in the Capparidaceae were assessed for their repellency to *Rhipicephalus appendiculatus*. *Boscia mossambicensis* was found to be the most repellent of the four plants tested. Many chemicals responsible for tick repellency were also identified as a first step towards finding practical applications for anti-tick botanicals. Related semiochemical research also revealed that host odours play a key role in the location of sites of attachment for *Rhipicephalus* spp. These promising results have opened up the possibility of disrupting host location behaviour with false odour cues that could for example be dispensed in an odour-baited tick trap.

In 1994, ICIPE continued to explore promising alternatives related to vaccines against tick components using 'hidden' antigens. Good immunisation results in past years with solubilised tick gut antigens from *Rhipicephalus appendiculatus* were followed up with more experiments on semi-purified material and an enriched glycoprotein fraction. Effects on ticks were found to be facilitated by low doses of ivermectin. Ivermectin appears to increase gut permeability and hence enhance the anti-tick effects of the immune molecules induced. Protocols for immunisation are now being tested with cattle in the field. Although long-term in nature, this research has good potential for practical applications if integrated with other strategies for tick control.

Medical vectors research

Over the past 25 years, the former Medical Vectors Research Programme has addressed some of the most important vectors of human tropical diseases: the mosquitoes that carry yellow fever, malaria and bancroftian filariasis; the sandflies that carry cutaneous and visceral leishmaniasis (kala-azar), and the tsetse carriers of human sleeping sickness. Currently, this programme is undergoing a major revamping and reorganisation.

In the case of mosquitoes and sandflies, ICIPE's past research has focused on environmentally-friendly control methods which minimise insecticide use, and are adaptable to the lifestyles of rural people. Research at ICIPE resulted in the adaptation of the pyrethroid-impregnated *Mbu Cloth* for community use in the control of both vectors in rural settings where other methods are not appropriate.

The ever-increasing resistance to insecticides and therapeutic drugs has made the pursuit of radical alternative vector control technologies critical. Technology development is contingent on a thorough understanding of the bioecology, host-parasite relationship, vector competence and vector population dynamics, in addition to socio-cultural factors. ICIPE is well placed to make substantial contributions towards strategic research in these areas, and is now updating its approach in integrated disease vector management.

Sandflies research

Leishmaniasis is a disease caused by parasites of the genus *Leishmania*, transmitted to man by several species of phlebotomine sandflies. The phlebotomine sandfly genera, *Phlebotomus* and *Sergentomyia*, are the major vectors.

In 1994, experiments were carried out to contribute more evidence on phytophagy and evaluate its effect on fecundity and longevity of Kenyan phlebotomine sandflies, with reference to *Sergentomyia ingrami* Newstead and *Phlebotomus duboscqi* Neveu-Lemaire. The first species is suspected to harbour uncharacterised *Leishmania* parasites, whereas the second is a confirmed vector of *Leishmania major*, the causative agent of cutaneous leishmaniasis in the Old World and also in the Kenyan focus in Baringo District.

Mosquitoes research

Due to the difficulty in producing an effective vaccine for malaria, the development of other disease prevention measures assumes a greater importance.

Several strains of *Bacillus thuringiensis israelensis* (*Bti*), an entomopathogenic bacteria active against mosquito larvae, have been isolated by ICIPE scientists from infected larvae from a rice irrigation scheme in Kenya. This year, the ICIPE mosquito colonies of *Aedes aegypti*, *Anopheles* spp. and *Culex* spp. were revamped to permit bioassays of *Bti* clones obtained from the Hebrew University. The project's aim is to develop an improved larvicide by transferring genetic material coding for the toxic protein produced by *Bti* into another bacterium, *Bacillus sphaericus*, which has a longer persistence in the environment than *Bti*.

Filthflies control

Species of flies that frequent refuse and faeces have been controlled by the use of an ICIPE-produced *Bt* preparation, *Dudustop*. The slurry has been applied to pit latrines and refuse dumps in high density settlement areas in Kenya and in the refugee setting in Kenya and Ethiopia.

*(*1994 Programme Leaders were L. H. Otieno, Disease Vectors Research Programme and M. J. Mutinga, Medical Vectors Research Programme.)*

TSETSE RESEARCH

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

Donor: *European Union*

Collaborators: International

- *Ethiopian Science and Technology Commisssion (ESTC)*
- *The Regional Tsetse and Trypanosomiasis Control Programmes (RTTCP) of the SADC countries with its headquarters at Harare, Zimbabwe*
- *Tropical Pesticide Research Institute (TPRI), Arusha, Tanzania*
- *Tsetse and Trypanosomiasis Research Institute (TTRI) Tanga, Tanzania*
- *Robert von Ostertag Institute in Germany and CIRDES in Burkina Faso*
- *The International Laboratory for Research on Animal Diseases (ILRAD)*
- *The International Livestock Centre for Africa (ILCA)*
- *Tanzania National Parks (TANAPA)*
- *Yale University, USA*

National Collaborators:

- *The Kenya Trypanosomiasis Research Institute (KETRI)*
- *Veterinary Laboratories, Ministry of Agriculture, Livestock Development and Marketing (MOALD)*
- *University of Nairobi*
- *The Kenya Wildlife Service (KWS)*

Project rationale and overview

Project coordinator: *L. H. Otieno (1994), C. M. Mutero (1995)*

The European Union (EU) -funded tsetse project aims at contributing to improved livestock production in Africa for both food security and cash income, through the development and application of cost-effective, environmentally sustainable and culturally acceptable tsetse management strategies. Intensive research at ICIPE during the last several years has led to the development of several trap designs with great potential for controlling some of the most important tsetse species in eastern Africa. These recent advances, backed by very encouraging results from pilot trials in Kenya and Rwanda, have given new impetus and hope for achieving environmentally sustainable community-supported tsetse control.

The strategy adopted by the ICIPE to attain these objectives has involved intensive basic research in various disciplines encompassing tsetse and trypanosome biology.

The EU project contains six sub-projects whose activities include:

1. the evaluation of tsetse attractants and repellents for *Glossina pallidipes, G.f. fuscipes* and *G. morsitans* spp.;
2. determination of optimal trap densities required to maintain *G. pallidipes* populations at desired low levels;
3. investigation of the relationship between *G. pallidipes* densities and trypanosome transmission;
4. evaluation of potential tsetse pathogens as tsetse control agents;
5. identification of key sociological and economic factors influencing the sustainability of community-based trapping systems;
6. establishment of linkages with various national and international initiations through manpower development, information dissemination and collaboration arrangements.

Field sites for ecological and socioeconomic work are currently in Nguruman, southwestern Kenya, and around the shores of Lake Victoria at ICIPE's Mbita Point Field Station. Collaborative work is also being carried out at other field sites in Ethiopia.

Project 1

Research on the biology of *Glossina fuscipes fuscipes* on the shores of Lake Victoria confirmed that the monitor lizard was the main host of this tsetse. Many experiments

on visual and/or olfactory cues were conducted, culminating in an innovative experimental design based on an electrified pipe model containing a lizard or other attractants. For the first time, clear evidence was obtained that this tsetse species can locate monitor lizards by smell as well as by visual cues. Some differences were found in the response of males and females, but clear evidence was obtained for the presence of volatiles from live lizards attractive to both sexes. Identification of these volatiles was initiated with the intention of developing an entirely new odour attractant for riverine tsetse.

Olfactory sensitivities to common odour baits for tsetse were assessed for *G. pallidipes* from different areas in Kenya, but no receptor-level differences were found. Related semiochemical research on *G. pallidipes* confirmed the presence of a larviposition pheromone originating from larval secretions, as in *G. morsitans* sspp. Research on chemical identification of the component(s) was initiated. Discovery of this novel pheromone system may lead to a new method for attracting tsetse to traps and other control devices.

Project 2

The main study area at Nguruman was digitised in order to produce base maps for use in the ecological studies associated with the trapping control programme. Data collected from monitoring traps were integrated into a GIS database linked to this base map. Additional ecological studies on local variation in tsetse density were conducted in the Musenge area, focusing on the estimation of population sizes and movements between various thickets.

Isoenzyme studies of *G. pallidipes* at Nguruman were completed and revealed almost no evidence of genetic selection related to the trapping programme. Molecular genetics studies of *G. pallidipes* continued with attempts to screen, clone and sequence relevant microsatellite DNA markers.

Antisera to nearly all of the critical tsetse hosts were made species-specific in preparation for setting up rudimentary bloodmeal analysis facility at ICIPE.

Project 3

The trapping suppression programme at Nguruman was implemented with varying degrees of success over a 170 km^2 area throughout the year. Extensive monitoring data were collected on tsetse populations within this area in preparation for future strategic deployment of traps.

Trypanosome infection rates in flies and in a sentinel herd of cattle and goats were also monitored in detail. These studies revealed a good relationship between tsetse density and infection rates in livestock, but only weak links between infection rates in tsetse and infection rates in livestock.

A lectin-trypsin complex playing a pivotal role in the biology of trypanosomes within the vector was isolated following many years of research on trypanosome-vector interactions. The molecule is being fully characterised for possible use in novel strategies for blocking disease transmission.

Mechanical transmission of trypanosomes by biting flies other than tsetse was confirmed in laboratory experiments. The cryptic nature of wildlife reservoirs in the field was also confirmed through various collaborative studies using techniques such as xenodiagnosis and serum antigen-ELISA.

Trapping techniques for *Stomoxys* spp. were perfected and validated. Extensive experiments were conducted to explore the possibility of a universal trap for tsetse, *Stomoxys* and tabanids. A candidate trap adaptable for both survey and control purposes was developed and awaits validation. It crudely resembles the NG2G trap but incorporates some useful features of the Epsilon and Siamese traps (rearranged netting and blue/black panels).

Project 4

Attempts were made to find practical applications of three biocontrol agents: a virus, a bacterium and a fungus. No practical application was found for the DNA virus of tsetse. Attempts to find useful field applications for local strains of *Bacillus thuringiensis (Bt)* toxic to tsetse were partially successful. Formulations of the bacteria incorporating UV protectants and other additives killed tsetse in modest numbers for one week after application to livestock. In the case of fungi, a promising technique was developed and tested for field application of *Metarhizium anisopliae*. The technique involves the use of a simple contamination chamber that can be attached to existing control devices such as traps. The potential killing effect of this device was demonstrated in the field and now awaits more extensive trials with various tsetse species.

Project 5

Socioeconomic aspects of tsetse control at Nguruman were assessed through household surveys. These revealed numerous positive impacts on land use for grazing or agriculture as well as a reduced tsetse biting incidence. An analysis of past conflicts in tsetse control by the ranch and outside researchers revealed many problems related to resources, community participation, outside management and over-centralisation of the trapping technology. Further studies of community social organisation revealed the need for a more thorough analysis of the ability of the existing sociocultural and political institutions to adopt tsetse trapping technology.

Project 6

One PhD fellow from Zambia completed his research and is in the process of writing up his thesis. A second PhD fellow from Kenya joined the programme and completed her coursework. A month-long group training course in tsetse management was held for 8 livestock professionals from Kenya, Ethiopia, Sudan, Rwanda and Tanzania.

Exploratory studies on tsetse control with traps were conducted by ICIPE's national collaborator in Ethiopia

resulting in the development of a major project proposal for tsetse control in the southern part of the country. This proposal is in the final stage of preparation and will be submitted for funding in 1995. Negotiations for future collaborative activities were also conducted with various national and international institutes in Holland, Germany, Tanzania, Zimbabwe and Zambia. An agreement was also reached for some collaboration on tsetse behaviour with the ATTCP programme in Zimbabwe. Negotiations for a major project in Tanzania were initiated but are still in the early stages of formulation.

A. DEVELOPMENT AND IMPROVEMENT OF TRAPPING METHODOLOGIES FOR *GLOSSINA FUSCIPES FUSCIPES* USING KAIROMONES, ALLOMONES AND LARVIPOSITION PHEROMONES

Work in progress

1. DEVELOPMENT OF TRAPS FOR *GLOSSINA FUSCIPES FUSCIPES*

Participating scientist: *M. M. Mohamed-Ahmed*

Assisted by: *J. Muchiri, P. O. Ongelle, S. Mokaya*

Since the discovery of the attractiveness of kairomones from cattle to savanna tsetse, it has been possible to achieve an environmentally-safe and sustainable control of some of these open woodland tsetse. To date, no similar effective olfactory bait has been discovered for any of the species of the water-side *palpalis* group tsetse. Tsetse of this group are generally believed to be opportunistic feeders, obtaining their bloodmeals from any available sources using visual responses alone for host location. Investigations were conducted into the host preference of the water-side *G. f. fuscipes* residing along the shore of Lake Victoria, Kenya to identify preferred host(s) of this fly with the hope that host volatiles may be discovered to attract *G. f. fuscipes* and other species of the *palpalis* group.

Evaluation of catching devices

For evaluating the responses of tsetse to attractive baits it is imperative that all stimulated flies should be caught effectively. Traps and electric nets are currently the main devices in use for quantifying such responses in the field. Although some information on the efficiency of traps and electric nets is available for some savanna tsetse, nothing is known about their effectiveness for *G. f. fuscipes* and other water-side species. In this work we have found for the first time that about 48.6% and 35.4% of the populations of male and female *G. f. fuscipes* flew over the most popular 1-m electric net. Such 'over-fliers' have to be accounted for, when estimating both trap efficiency and feeding responses of flies towards a specific host. Using such information, we have also demonstrated that only about 30–55% of the males and females approaching a biconical trap were actually caught and that in addition to the over-fliers, a significant proportion of females ($P < 0.01$) avoided the vicinity when the ring of nets around the trap had a radius of 0.5 m.

Response of G. f. fuscipes *to visible baits and odour from concealed baits*

During these experiments, attracted flies were captured mainly by electric screens, though biconical traps were also used. Compared to the control (ventilated pit without cattle) the treatment (odour from concealed cattle in a pit) increased the mean catches of male and female *G. f. fuscipes* by 1.2 to 3.1 (significant) and 1.4 to 2.2 times (significant), respectively. The mean catches of muscids (*Stomoxys* spp., *Musca* spp.) and tabanids were also increased by up to 143 times and 12 times, respectively. Dominant genera of the Tabanidae were *Tabanus* spp., *Haematopota* spp. and *Ancala* spp.

To study the importance of visual and olfactory responses in *G. f. fuscipes*, three medium-sized lizards were caged in a small box of broad wire mesh that does not preclude visibility. Another similar box was left empty. The two treatments were then compared for attraction of flies by conducting 6 consecutive replicates of crossover experiments, daily from 1200 to 1600 hrs. The treatments were placed 100 m apart along the lake shore between the lake and the infested forest. It was hoped that the lake breeze would carry the volatiles from the lizards to stimulate flies inside the forest. In the first experiment the box containing the visible lizards was observed to increase the catch of flies by an electric screen over the control by a factor of 1.5 for males (ns) and 2.2 (significant) for females. In a second experiment, using concealed lizards, the catch in biconical traps was improved by 1.2 to 2.8-fold and 1.2 to 1.6 for males (ns) and females (ns), respectively. In a third experiment the lizards were concealed in an electrified model. The model containing the lizard was found to increase the catches of males by 1.8 times and females by 2.2 times (significant for both sexes). The latter findings together with those on cattle above demonstrate that both the visual and olfactory responses of *G. f. fuscipes* are important for host location.

However, the data on cattle suggest that individual components of bovine waste products identified in urine and breath and found attractive for savanna tsetse were generally not attractive for *G. f. fuscipes*. This is not surprising since in our study area flies rarely feed on cattle. The implication is that bovine metabolic waste products probably do not individually elicit host-location behaviour in *G. f. fuscipes*. Conversely, emanations from the entire cattle body are seemingly effective attractants for *G. f. fuscipes*. The latter attractive properties might have been due to synergism between the full range of tsetse-attractive volatiles of cattle including CO_2 or due to CO_2 alone. Experiments are in progress to extract CO_2 from live cattle odour using soda lime. Single components of cattle odour were also not markedly attractive to Muscidae or Tabanidae since these flies were only caught in noticeable numbers by traps or electric nets during live cattle experiments.

2. ROLE OF PHEROMONES IN LARVIPOSITION BEHAVIOUR OF *G. PALLIDIPES*

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

Assisted by: *J. Andoke, P. Ahuya, W. P. Ouma*

Preliminary behavioural studies undertaken in two choice chambers with field-caught *G. pallidipes* indicate that, as in *G. morsitans* spp., semiochemicals from larvae attract gravid females. Since regular supply of *G. pallidipes* larvae is a problem, field trips were undertaken to trap wild flies from Nguruman and to trap volatiles from larvae when they were deposited. Eight GC-EAD active peaks have been located. GC-MS studies to identify the compounds are in progress.

3. IDENTIFICATION AND EVALUATION OF POTENTIAL ALLOMONES (REPELLENTS) FOR *G. PALLIDIPES*

Participating scientists: *A. Hassanali, R. K. Saini, J. O. Davies-Cole*

Assisted by: *J. Andoke, P. Ahuya, W. P. Ouma*

In order to assist in the rapid screening of both synthetic and natural compounds for repellency, a 2-choice olfactometer was constructed and installed. Volatiles from man and phenolic analogues are being checked for possible repellency. These laboratory behaviour experiments were undertaken with *G. m. morsitans* because of lack of supply of *G. pallidipes*.

4. COMPARATIVE STUDIES ON OLFACTORY SENSITIVITIES OF DIFFERENT POPULATIONS OF *G. PALLIDIPES*

Participating scientists: *R. K.Saini, J. O. Davies-Cole*

Assisted by: *J. Andoke, P. Ahuya, W. P. Ouma*

Comparative studies on the olfactory sensitivities of different populations of *G. pallidipes* have been completed. *Glossina pallidipes* were trapped from three different agroecological zones in Kenya and EAGs recorded from them to four different phenols at various doses. Results indicate that at the receptor level the olfactory sensitivity of flies from different agroecological zones does not differ. This indicates that differences in trap responses are not due to differences in olfactory sensitivities of flies but are probably due to different behaviours under field conditions. A diagnostic behavioural approach to characterising responses of different tsetse populations may be required.

Future activities

(i) Screen domestic and wild animal hosts and humans for their attractiveness to *G. f. fuscipes* through studies of anemotactic behaviour and feeding efficiency.

(ii) Identify kairomones for *G. f. fuscipes* by trapping volatiles from monitor lizards and by undertaking GC-EAD, GC-MS and laboratory and field behavioural studies.

(iii) Establish laboratory colonies of *G. f. fuscipes* and *G. pallidipes*.

(iv) Undertake further behavioural experiments with the larviposition pheromone of *G. pallidipes*. Characterise EAG-active components by GC-EAD, GC-MS investigations. Undertake laboratory behavioural experiments with individual components and their blends. Initiate studies to field test promising compounds.

B. DEVELOPMENT OF COST-EFFECTIVE STRATEGIES FOR MAINTAINING *G. PALLIDIPES* POPULATIONS AT ULTRA-LOW LEVELS THROUGH BARRIER TRAPS AND ALLOMONES

Work in progress

1. DIGITISATION AND PRODUCTION OF STUDY AREA MAPS USING GIS TECHNIQUES

Participating scientist: *A. Odulaja*

Assisted by: *H. H. Meena*

Over 250 control traps and 23 monitoring traps were geo-positioned and integrated into the database. Monthly trap catches for 14 months were also integrated into the database. Using all this information, spatial and temporal contour maps showing relative fly densities were produced.

Coarse resolution satellite data (1989–93) were obtained for the area and are available for use. Efforts will be made to obtain seasonal high resolution satellite images of the area, if funds are available, to enable further clarification of the spatial and temporal distribution of flies.

2. ESTIMATION OF TSETSE POPULATION SIZE

Participating scientists: *C. M. Mutero, A. Odulaja*

Assisted by: *A. M. Macharia*

Background

The studies were carried out in Musenge, an area lying about 25 km to the north of the ICIPE station in Nguruman. The main objective was to determine baseline fly densities as a prerequisite to development of strategies for rationed deployment of traps. Tsetse sampling was conducted in four thickets lying alongside or nearby the permanent Uaso Ng'iro River. The thickets were about 1 km apart and reasonably isolated from each other by open grassland or scrub vegetation.

Work in progress

Sampling for baseline data involved monthly collection of tsetse in the four thickets using a total of eight NG2G traps baited with cow urine and acetone. This level of sampling was appropriate for yielding data on monthly fluctuations without the danger of depleting the fly population.

A second type of sampling was designed to provide data for estimating both relative and absolute density of tsetse in each thicket. This sampling was carried out during three distinct periods, separated by five-month intervals. On each of the three occasions, sampling was conducted for ten consecutive days. The traps were distributed proportionately according to the size of the thicket at a density of ten traps per km^2.

In order to test for possible inter-thicket movement, tsetse were marked with different colours prior to the ten-day period and released in the various thickets.

Apparent density

The total number of *G. pallidipes* caught in one trap per day between August 1993 and October 1994 ranged between zero and 200. Two major peaks were observed in May and July 1994. Analysis of variance of data obtained from three ten-day sampling sessions (Table 1) showed that certain thickets had much higher tsetse numbers than others for most of the time. Such differences could be due to presence of preferred hosts in some of the thickets and not in others. Other factors might include differences in vegetation or in availability of breeding sites. A further elucidation of such factors was considered necessary.

Table 1. Mean values (catch per trap per day) and SNK groupings of *G. pallidipes* collected in Musenge on three different occasions

		Mean values		
Thicket	Trap-days	Sep.93	Feb.94	Jul.94
1	40	3 c	32 a	38 c
2	100	7 c	18 b	39 c
3	40	101 a	21 b	63 b
4	40	76 b	28 a	117 a

Mean values with different letters for a particular occasion are significantly different.

Absolute population

Removal trapping of tsetse on a daily basis was assessed as a rapid method for determining absolute density and hence daily trapping mortality rate. Results showed that the maximum likelihood method for analysing the data was only applicable in September, 1993, but not in February or July 1994. Inapplicability of the method on two out of three occasions suggested it was inappropriate for routine use, except perhaps in completely isolated habitats.

Inter-thicket fly movement

Recapture rates of marked *G. pallidipes* in Musenge ranged between 1% and 6% among the various thickets. Overall, 4% of 5863 tsetse marked and released were recaptured. Tsetse marked with different colours were recaptured in various thickets, providing evidence of inter-thicket fly movement. Most recaptures were, however, made within the thicket of release. In ICIPE's main study area in Nguruman, results of mark-recapture experiments revealed an interchange of fly populations between the escarpment and the valley floor. Movement was also recorded in a north-south direction along the base of the escarpment.

3. SAMPLING BIAS IN TSETSE STUDIES

Participating scientist: *C. M. Mutero*

Assisted by: *A. M. Macharia*

Haematophagous Diptera are caught directly biting hosts or in a variety of traps employing visual stimuli and chemical attractants. Individual sampling methods are, however, often biased as regards species and physiological stages of the insects caught.

During 1994, tsetse samples simultaneously collected by odour-baited NG2G traps and moving vehicle were analysed in relation to species composition, sex ratio, age structure and pregnancy status. Sampling was conducted in both Musenge and the escarpment, at 690 m and 970 m above sea level, respectively. *Glossina pallidipes* comprised 93% of all tsetse collected at the two sites. The remaining 7% consisted of *G. longipennis*. More *G. longipennis* were collected in vehicle than trap samples. A complete absence of *G. longipennis* in six-month samples of tsetse collected by traps at the higher altitude was particularly intriguing (Figure 1). The sex ratio of *G. pallidipes* also varied according to location. Females were about twice the number of males at lower altitude for

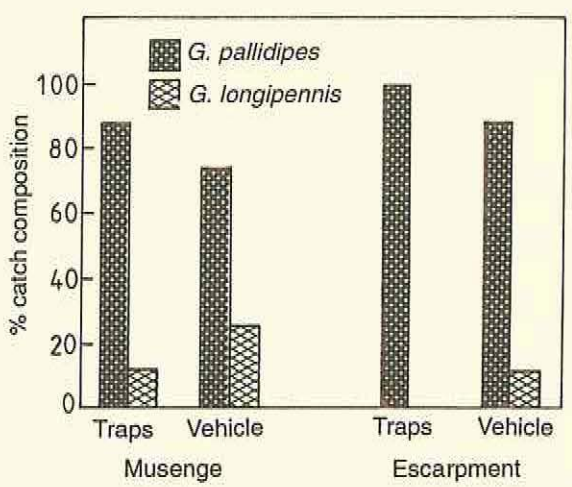


Figure 1. Percentage frequency of *Glossina pallidipes* and *G. longipennis* in NG2G trap and moving vehicle samples from Musenge and the escarpment, 690 m and 970 m above sea level, respectively.

both sampling methods while males predominated in vehicle samples from the higher site. *Glossina pallidipes* females obtained in vehicle samples at the higher site had an age distribution with a large component of young flies and progressively smaller proportions of older flies. This pattern suggested a rapidly expanding population. In contrast, trap samples of the species from the same site had a much lower proportion of young than old flies, thereby suggesting a declining population.

Observed differences in the tsetse data strongly underscore the need for using a combination of sampling methods for various population analyses, particularly those based on the population's age structure.

4. DNA STUDIES OF TSETSE POPULATIONS

Participating scientist: M. Limo

DNA-based markers for the identification of genetic relationships between different species and populations of *Glossina* spp. can contribute significantly to studies of the epidemiology and control of trypanosomiasis. The aim of the current work was to study fly populations that have been subjected to prolonged trapping for evidence of genetic differentiation. Such analysis is difficult because suitable marker probes are not available.

Use of randomly amplified polymorphic DNA (RAPD markers) has shown a complex pattern of DNA fragments within individual flies. It is, however, not easy to interpret the RAPD profiles. PCR-based diagnostic tests based on well defined and specific primers could make the interpretation of results easier. In the present work microsatellite markers were chosen. Previous experiments involve the screening of the *G. pallidipes* genomic library with $(GT)_{15}$ and $(TAAA)_6$ probes. In 1994, work on the isolation and sequence analysis of the clones containing the repeats was started. We have yet to synthesise primers to be used in typing the fly populations.

5. ISOENZYME STUDIES

Participating scientists: L. H. Otieno, N. Darji

Assisted by: E. Mpanga

G. pallidipes males and females of similar numbers were sampled between the 10th and 15th day of every month from July 1993 to December 1994 using traps at Nguruman. Flies were collected from (a) transects within the suppression zone (fixed trap positions), (b) a trap-free zone approximately 30 km north from the suppression zone (Musenge), and (c) the Nguruman escarpment (1200–1800 m). These three populations were sampled simultaneously over 17 months, ensuring that all temporary trapping positions remained unaltered, and were representative of the Nguruman biotypes.

Banding patterns and interpretations

Three PGM genotypes (pgm a/a, pgm b/b, pgm a/b) and two alleles (designated pgm-a and pgm-b) were seen on 12% starch gels. Slow or fast bands were observed in homozygous individuals and double bands in heterozygous individuals (pgm a/b). PGM appeared to be sex-linked as heterozygotes were found in females only.

For PGI, a maximum of twelve out of an expected 15 genotypes (pgi a/a, pgi b/b, pgi c/c, pgi d/d, pgi e/e, pgi a/e, pgi a/c, pgi c/e, pgi a/b, pgi b/c, pgi d/e and pgi a/e and five alleles (pgi-a-b-c-d-e) were noted.

Genetic variability in the populations

PGM allele frequencies showed no or very slight variation in the three zones. Allele b was dominant in all zones. PGI allele frequencies varied slightly among the three zones.

Overall, the various subpopulations were extremely homogeneous in both time and space. There was very little evidence from isoenzyme data of any genetic segregation of subpopulations related to the trapping suppression programme.

Future activities

(i) Establish an ultra-low density population of tsetse within a demarcated area at Nguruman through redeployment of traps and establishment of trap barriers.
(ii) Quantify sources of immigration and recruitment in the controlled area through mark-recapture studies conducted in parallel with experimentation on barrier trap configuration and density.
(iii) Elucidate environmental factors responsible for aggregation of flies at certain trap positions with a view to applying this knowledge for strategic setting of control traps.
(iv) Explore collaboration on setting up a bloodmeal identification service at ICIPE with other interested organisations.

C. CLARIFICATION OF SOME FACTORS INFLUENCING THE DYNAMICS OF TRYPANOSOMIASIS TRANSMISSION AT LOW LEVELS OF TSETSE CHALLENGE

1. TSETSE POPULATION MONITORING

Participating scientists: M. I. Abu-Zinid, L. H. Otieno

Assisted by: J. Kiilu

Starting in May, 1993, Nguruman habitat was stratified into northern, southern and riverine vegetation types. In the following months up to the end of 1994, apparent density of tsetse populations was estimated every month using NG2G traps baited with cow urine (*ca.* 100 mg/h), acetone (*ca.* 150 mg/h) and octenol (*ca.* 3.0 mg/h). Population monitoring was carried out using nine monitoring traps (M1–M9) in the southern area, five traps (M10–M14) in the riverine and five traps (M16–M20) in the northern area. In July 1994 a further three

traps were added to cover the far northern area. Monitoring traps were greased to deter ants and were emptied every 24 hours for 5–7 days each month.

Glossina pallidipes

Changes in population size of *G. pallidipes* pooled over the whole area are presented in Figure 2. The figure provides detransformed mean catch per trap per day for each month, with vertical bars showing the standard error of the mean. Females and males follow a similar trend and the females' apparent density was usually higher than the males'. Following a slight increase, the apparent density of both sexes from July 1993 decreased steadily up to November 1993. Between November and March 1994 population fluctuations were minimal and the mean catch per trap per day was 10.9 flies (F+M). During this period regression of the monthly mean catch (natural log transformation) on time reveal that the fly population decreased at a daily rate of 2.53%, $lnY = 5.499 - 0.253x$, $P=0.00011$, $r^2= 82.34$. This decline was due to a combined effect of trapping and natural mortality, evident in the age-structure of the flies. It is clear that the spatial distribution of flies was higher in the southern zone and the northern area than in the riverine area. However, temporal distribution of *G. pallidipes* in the three zones revealed seasonal shifts in the relative crowding of flies, with more clumping taking place in the southern and riverine areas during April–October, than at other times of the year. It was clear that population peaked in the dry cool spell following the long rains.

Glossina longipennis

The apparent population density of *G. longipennis* was generally lower than that of *G. pallidipes*. The ratio of *G. pallidipes* to *G. longipennis* ranged between 16:1 and 2.2:1 with a yearly average of 6.7:1. Generally, there were more males than females. In 1993, the maximum mean catch was 12 flies per trap per day (n=20) during May, but the population decreased steadily to three flies in November. The population decreased at a daily rate of 1.07% ($lnY = 2.308 - 0.1073x$, $P=0.005$, $r^2=69.2$). In 1994 the maximum was about 23 flies per trap per day in July and August, while the minimum catch was four flies per trap in March. *Glossina longipennis* population was relatively high during the cool dry season following the long rains.

The above results suggest that a strategy of varying tsetse trap densities according to location and season could be feasible in Nguruman.

2. MONITORING OF TRYPANOSOMIASIS INFECTIONS IN SENTINEL HERDS OF LIVESTOCK AND IN TSETSE

Participating scientist: *R. O. Olubayo*

Assisted by: *P. Mwamisi, C. Machika, J. Likhanga, E. N. Munyoki*

The purpose of this work was to determine the relationship between tsetse suppression using NG2G traps developed by ICIPE and the incidence of trypanosomiasis in domestic livestock kept and maintained in a tsetse suppression area.

The work was undertaken at our field station in Nguruman, southwest Kenya.

The overall objective of this work is to demonstrate to the farmers that tsetse suppression benefits the farmer since it leads to low fly challenge and hence low incidence of trypanosomiasis in domestic livestock in tsetse-infested areas.

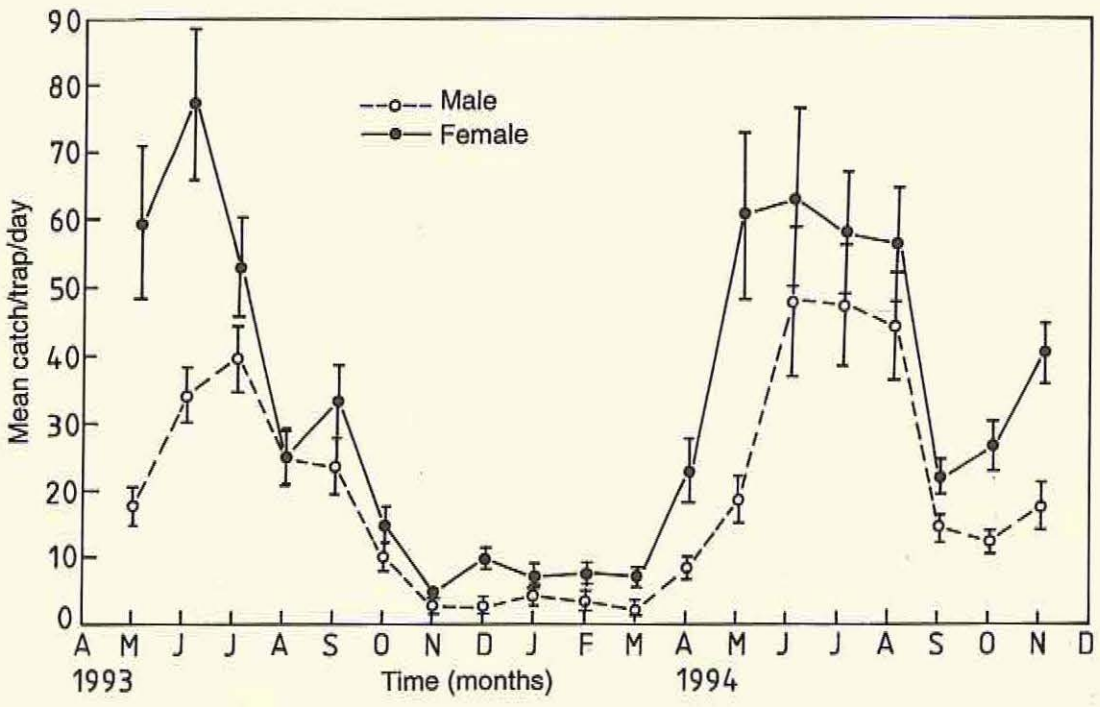


Figure 2. Monthly fluctuations in apparent density of *Glossina pallidipes* (pooled for all sites) in Nguruman.

Prevalence of Trypanosoma *infections in domestic livestock*

A sentinel herd of 30 Boran cattle and 30 goats was kept in an area where tsetse suppression is maintained by using NG2G traps developed by ICIPE scientists.

Blood samples were collected from the experimental animals once every month and examined for the presence of trypanosomes and for assessment of the level of anaemia.

There was a gradual increase in the number of animals infected with trypanosomes from 7% observed in January to 13% recorded in June, 1994. This increase is attributed to high fly density which was observed in the study area during this period. From July to December the infection rates in both cattle and goats were maintained at about 3%. During this period, there was severe drought in our study area and the animals had to move extensively from the suppression area into the escarpment in search of pastures.

Fly density

The fly density was relatively low in the first and last three months of the year with a mean fly catch of 19 flies per trap. During the months of April to October, the fly density was very high with the highest number of 415 flies caught per trap. This increase in fly density was attributed to heavy rainfall and poor trap management.

Trypanosome infection rates in flies

Wild tsetse flies were trapped in the same area where the cattle and the goats grazed. The flies were subsequently identified according to age, sex and species and thereafter dissected to determine the presence of trypanosomes. The results showed that there was a lot of variation in infection rates in both *Glossina pallidipes* and *G. longipennis*. Both *G. pallidipes* and *G. longipennis* were infected with *Trypanosoma vivax* and *T. congolense* and the percentage of these infections varied from month to month. The highest infection rates of 4% were recorded in March, whereas the lowest infection rates of 1.5% were recorded in December. In both fly species, infections of *T. vivax* were always higher (sometimes double) than *T. congolense*. Furthermore, infection rates were higher in *G. longipennis* than in *G. pallidipes*.

This study has shown that there is a direct relationship between tsetse fly density and the incidence of trypanosomiasis in cattle — an increase in tsetse fly density elicits an increase in trypanosomiasis infections in domestic livestock. The study has also shown that there is no direct correlation between trypanosome infection rates in both fly species and the incidence of trypanosomiasis in cattle since persistent trypanosome infection in tsetse had no impact in domestic livestock.

Finally, the study has shown that both *G. pallidipes* and *G. longipennis* play an important role in the epidemiology of trypanosomiasis in the Nguruman area. However, since *G. longipennis* was frequently infected with *T. vivax*, it would appear that *G. longipennis* plays a major role in the epidemiology of *T. vivax* infections in Nguruman.

Continuous tsetse trapping is therefore recommended as one of the most effective ways of controlling trypanosomiasis in domestic livestock.

3. DETERMINING FACTORS IN TSETSE AND IN BLOOD OF DOMESTIC AND WILD ANIMALS WHICH ARE RESPONSIBLE FOR MODULATING THE ESTABLISHMENT OF TRYPANOSOME INFECTIONS IN TSETSE

Participating scientists: *E. O. Osir, M. O. Imbuga*

Assisted by: *N. Ole Sitayo*

Collaborator: *Yale University*

Biochemical characterisation of a glucosamine-specific trypsin-lectin complex was basically completed during the last year. It is a chimeric molecule (MW of about 61,000) composed of two non-covalently linked subunits A (27,000) and B (33,000). The latter subunit is the lectin since it is glycosylated, whereas the other subunit is the trypsin. It is interesting that whereas the release of several trypsin-like enzymes is stimulated by a bloodmeal, only one isoform occurs in combination with the lectin. Also, the exact role of the trypsin within the complex remains a matter of conjecture. However, since agglutination of the procyclic trypanosomes by the complex appears to be unaffected by soybean trypsin inhibitor (SBTI), it is quite possible that the enzyme may act on the surface of bloodstream parasites to cleave off the surface coat, a process that may facilitate agglutination and also trigger differentiation.

The role of the trypsin-lectin in the development of bloodstream trypanosomes has now been established. Incubation of bloodstream parasites with the Mono IQ bound fraction or the isolated complex resulted in their differentiation into procyclics. This process was not stimulated by the Mono Q unbound fraction. This finding confirms our earlier observations that differentiation of bloodstream trypanosomes was inhibited by either glucosamine or SBTI.

Using polyclonal antibodies to the complex, we have shown by immunoblotting experiments that the molecule is also found in other species of *Glossina*, and that it appears to be fairly conserved from a structural viewpoint. However, the protein was not detectable in other biting flies like stable flies, mosquitoes and sandflies. This observation may explain why tsetse flies are the only known transmitters of trypanosomes. Earlier experiments carried out in this laboratory also showed that trypanosomes could not be stimulated to differentiate using midgut homogenates from previously-fed mosquitoes or sandflies.

Further characterisation of the complex in terms of nucleotide sequencing is being carried out in collaboration with Yale University. The two subunits of the complex will be microsequenced to generate probes to both of them to screen a tsetse cDNA library which is already available. Sequencing of the two genes will then follow. The Yale group led by Professor Serap Aksoy plans to

develop a specific probe to the trypsin-lectin complex which could be used in quantitative PCR assays to determine levels in field collected flies.

Efforts to set an ELISA assay using polyclonal antibodies to the complex were initiated during the last year and are still underway. Due to technical difficulties, we decided to produce fresh antibodies since the antibodies in stock were not as pure as originally assumed. This meant we had to purify more protein to be used for immunisation. However, since we do not have a colony of *G. longipennis*, we have had to rely on flies borrowed from ILRAD. We managed a few field collections of wild flies and hope to purify enough material to finish this work. The idea is to use the ELISA for quantitative determination of levels of the complex in different species or the same species in different ecological areas. Data could then be correlated with susceptibility to parasite infection.

As previously reported, blood is very important in the differentiation of bloodstream trypanosomes. In particular, the RBC fraction appears to be important for this process, since any blood fraction lacking RBCs did not stimulate parasite differentiation. In addition, the inability of eland blood to stimulate differentiation was due to an inhibitory factor(s) present in the plasma/serum fraction, since a mixture of eland RBCs and rat plasma supported the process.

The results of these studies can be summarised as follows: The inhibitory factor in eland blood is fairly unstable and appears to be readily inactivated by freeze-thawing. The factor is also inactivated by heating above 50°C for 0.5 h. It can be precipitated by between 30–50% saturated ammonium sulphate. The identification of the inhibitor is currently being attempted even though its apparent instability will be a major hindrance to this effort.

4. TO CLARIFY SOME FACTORS INFLUENCING THE DYNAMICS OF TRYPANOSOMIASIS TRANSMISSION AT LOW LEVELS OF TSETSE CHALLENGE

Collaborators: *Tanzania National Parks, Kenya Wildlife Service, Zambia Department of Veterinary and Tsetse Control Services, Zimbabwe Department of National Parks and Wildlife, Free University of Berlin, International Livestock Research Institute*

1. *Characterisation of trypanosomes from tsetse flies and animals*

Participating scientists: *S. Mihok, R. O. Olubayo*

Assisted by: *E. N. Munyoki, S. O. Maramba, F. Masaninga*, P. N. Ndegwa* (*ARPPIS PhD students)*

In order to control any disease, it is necessary to differentiate the agents causing pathology from those which are of no practical significance. Recent advances in molecular biology have shown that trypanosomiasis is caused by a bewildering variety of parasites, not just the classically-defined species such at *T. brucei, T. vivax, T. congolense*, etc. This activity is therefore focused on the identification of trypanosome diversity in tsetse flies and animals, and on the elucidation of basic principles underlying disease transmission.

In collaboration with various institutes, a wide variety of field material was collected from wildlife, tsetse flies and livestock for characterisation. DNA blots were made of infected tsetse flies and xenodiagnosis (feeding laboratory-reared tsetse flies on blood) was used to both isolate and expand trypanosome stocks from animals. Methods for the optimisation of xenodiagnosis were perfected in the field and in the laboratory with both fresh and cryopreserved blood. These studies indicated that host blood factors are critical for the success of xenodiagnosis and laboratory isolation of parasites. Although not fully understood, xenodiagnosis based on dilution of original host blood with fresh goat blood appears to be the best routine survey method. Use of tsetse midgut lectin inhibitors such as glucosamine (or other compounds such as cholesterol) as blood additives for xenodiagnosis was useful for some but not all host species. With cattle, breed effects on transmission of parasites to tsetse were also detected, complicating the choice of an optimal technique. Molecular characterisation (species and DNA subtypes) of the many stocks obtained from these studies was initiated but is not yet complete. Some of these stocks are new species or genotypes, which are difficult to characterise in the laboratory.

In collaboration with ILRI, a blind trial was done to assess the ability of the antigen-ELISA technique to properly identify trypanosome antigens in sera from a wide variety of wildlife and livestock. Results from the trial were difficult to interpret as they often contradicted parasitological diagnoses. In the absence of a 'gold standard' for pressure or absence of infection, we are continuing to develop techniques to interpret the significance of the many apparent infections detected by ELISA in animals in the field.

2. *The role of biting flies other than tsetse in trypanosomiasis*

Participating scientist: *S. Mihok*

Assisted by: *E. N. Munyoki, S. O. Maramba, K. Salih *(*FAO trainee)*

Very little is known about the biology of biting flies such as horse flies (Tabanidae) and stable flies (Stomoxyinae) in Africa. These insects are economically-important because they are thought to be responsible for the mechanical transmission of *Trypanosoma evansi* to camels. As methods for the control of tsetse are eventually perfected, it is also not clear whether biting flies will contribute to residual disease transmission where tsetse cannot be eradicated.

The initial goal of this activity was to develop sampling methods for monitoring and possibly controlling biting flies. Hence, preliminary experiments

showing the utility of Vavoua traps baited with octenol for sampling stable flies were continued with more refined tests of new trap designs. Numerous triangular designs based on the NG2G style were tested, and one particular variation was chosen as a candidate universal fly trap. This new trap is still undergoing refinement and evaluation but appears to fulfil the goal of a nearly universal trap for most biting flies, and many critical species of tsetse. These new trap designs have revealed the presence of high numbers and a wide diversity of biting flies in most localities during rainy seasons. The ability of traps to catch biting flies in large numbers has also permitted biological studies to be conducted both in the field and in the laboratory. In particular, we have now completed a survey of the ability of many species of Stomoxyinae to transmit four species of trypanosome under laboratory conditions. Our results suggest that mechanical transmission may be more prevalent in the field than previously assumed. We have also been able to show that Stomoxyinae are vectors of a variety of filaroid nematodes, probably of the genera *Habronema*, *Draschia* and *Stephanofilaria*.

Completed studies

Davies-Cole J. O. A., Olubayo R. O., Mihok S. and Mwamisi P. Reproductive performance of field-caught *Glossina pallidipes* maintained on different host bloods. *Revue Élevage Médecin véterinaire Pays tropicale* 47, 77–79.

The reproductive performance of field-caught female *Glossina pallidipes* maintained for 41 days on fresh defibrinated bloods of rabbit, buffalo, eland, waterbuck or goat was investigated in the laboratory. Mean puparial weight was highest (37.2 mg) for rabbit-fed flies and lowest (30.8 mg) for waterbuck-fed flies. Mean puparial weights for rabbit, eland and buffalo-fed flies were significantly different from goat and waterbuck-fed flies. The highest number of puparia produced per 90 females was by rabbit-fed flies (83) whereas the lowest was by goat-fed (60) flies. Mortality was high (84–99%) irrespective of the group.

Majiwa P. A. O., Maina M., Waitumbi J. N., Mihok S. and Zweygarth E. *Trypanosoma (Nannomonas) congolense:* Molecular characterization of a new genotype from Tsavo, Kenya. *Parasitology* 106, 152–161.

Trypanosoma (Nannomonas) congolense comprises morphologically identical but genetically heterogeneous parasites infective to livestock and other mammalian hosts; three different genotypes of this parasite have been described previously. Restriction enzyme fragment length polymorphisms (RFLPs) in both kinetoplast DNA minicircle and nuclear DNA sequences, and randomly amplified polymorphic deoxyribonucleic acid (RAPD) patterns have been used here to demonstrate the existence of another type of *T. (N.) congolense* that is genotypically distinct from those that have so far been characterised at the molecular level. A highly repetitive, tandemly arranged DNA sequence and oligonucleotide primers, for use in polymerase chain reaction (PCR) amplification are described, which can be used for specific identification of the trypanosome and its distinction from others within the *Nannomonas* subgenus.

Mihok S., Munyoki E. N., Masaninga F., Ndegwa P. N. and Olubayo R. O. Isolation of *Trypanosoma* spp. from wild tsetse flies through procyclic expansion in *Glossina morsitans centralis*. *Acta Tropica* 56, 25–37.

Procyclic trypanosomes from wild tsetse flies were membrane-fed to *Glossina morsitans centralis* in order to develop an optimal technique for propagating field isolates. A 70% success rate was achieved in isolating *Trypanosoma simiae* and a variety of genotypes of *T. congolense* originating from *G. pallidipes*, *G. brevipalpis* and *G. swynnertoni*. Parasites matured into forms infective for mammals, and could be maintained by passage of gut forms to new groups of flies. In experiments with laboratory stocks, we also passaged immature gut infections of *T. congolense* and *T. brucei* from various tsetse species to *G. m. centralis*. The optimal technique was investigated for procyclic *T. congolense* through addition of various compounds to goat blood using *G. m. centralis* and *G. m. morsitans* as recipients. From these experiments, many approaches to procyclic expansion appeared possible. However, a simple and practical method based on the use of fresh goat blood for rapid feeding of *G. m. centralis* is recommended. Application of this technique should aid in the resolution of questions relating to the cryptic diversity of *Nannomonas* trypanosomes in diverse host and vector communities.

Mihok S., Stiles J. K., Mpanga E. and Olubayo R. O. Relationships between protease activity, host blood and infection rates in *Glossina morsitans* sspp. infected with *Trypanosoma congolense*, *T. brucei* and *T. simiae*. *Medical and Veterinary Entomology* 8, 47–50.

Midgut protease activity in *Glossina morsitans centralis* and *G. m. morsitans*, at 48 h post bloodmeal averaged 1.8 IU of trypsin-like activity. These two tsetse subspecies differ in their susceptibility to trypanosome infection. Except for low levels in flies fed on waterbuck blood (0.7 IU), activity did not differ in flies fed a variety of host bloods (goat, pig, cow, buffalo, eland) and trypanosome species (*Trypanosoma congolense*, *T. brucei*, *T. simiae*). Protease activity was also not correlated with infection rates, despite large differences in infection rates among experiments. Nevertheless, addition of 0.06 M D(+)-glucosamine to parasitaemic blood resulted in a three fold reduction in protease activity, coincident with a large increase in infection rate. This effect did not occur when parasites or D(+)-glucosamine were added alone to the bloodmeal, suggesting that the effect was due to metabolism of D(+)-glucosamine by parasites.

Mihok S., Zweygarth E., Munyoki W. N. Wambua J. and Kock R. *Trypanosoma simiae* in the white rhinoceros (*Ceratotherium simum*) and the dromedary camel (*Camelus dromedarius*). *Veterinary Parasitology* 53, 191–196.

Trypanosoma simiae was identified as the cause of a disease outbreak in dromedary camels (*Camelus dromedarius*) introduced to Tsavo East National Park, confirming the susceptibility of camels to this pathogen. *Trypanosoma simiae* was also isolated from a new host, the white rhinoceros (*Ceratotherium simum*) through xenodiagnosis with a susceptible tsetse species (*Glossina morsitans centralis*). A white rhinoceros showed some evidence of anaemia and lymphopaenia when harbouring *T. simiae*, but did not suffer any long-term health effects.

Olubayo R. O., Mihok S., Munyoki E. N. and Otieno L. H. Dynamics of host blood effects in *Glossina morsitans* sspp. infected with *Trypanosoma congolense* and *T. brucei*. *Parasitology Research* 80, 177–181.

The pattern of infection in *Glossina morsitans morsitans* and *G. m. centralis* membrane-fed on eland, buffalo or goat blood mixed with *Trypanosoma congolense* or *T. brucei* was studied from day 1 to day 10. Tsetse were initially permissive vectors, with most flies harbouring infections of 10^4–10^5 parasites on

day 3. However, after a second bloodmeal on day 3, flies cleared many infections, with *G. m. morsitans* clearing more infections than *G. m. centralis*. Infective feeds of goat blood consistently increased final infection rates by limiting the number of infections lost between days 3 and 6. In further experiments with *G. m. morsitans* only, this effect was replicated by feeding flies on erythrocytes but not on serum. These results suggest that compounds from some mammalian erythrocytes match the target specificity of *G. m. morsitans* midgut lectins and, hence, have a protective effect on trypanosome establishment in the fly.

Reduth D., Grootenhuis J. G., Olubayo R. O.*, Muranjan M., Otieno-Omondi F. P., Morgan G. A., Brun R., Williams D. J. L. and Black S. J. African buffalo serum contains novel trypanocidal protein. *Journal of Eukaryotic Microbiology*, 41, 95–103.

The high ability of African buffalo, as compared to domestic cattle, to control infections with *Trypanosoma brucei brucei* ILTat 1.4 organisms did not correlate with the timing or magnitude of parasite surface coat-specific antibody responses and may have resulted from the constitutive presence in buffalo blood of a novel trypanocidal factor. Buffalo plasma and serum contained material that killed bloodstream stage *T. b. brucei*, *T. B. rhodesiense*, *T. b. gambiense*, *T. evansi*, *T. congolense*, and *T. vivax* organisms during 4 h of incubation at 37°C *in vitro*. Serum from eland was also trypanocidal whereas serum from oryx, waterbuck, yellow-buck duiker, cattle, horse, sheep, goat, mouse, rat and rabbit was not trypanocidal. The buffalo serum trypanocidal material was not lipoprotein, or IgG, and had the following properties: (1) a density of > 1.24 g/ml determined by flotation ultracentrifugation; (2) insolubility in 50% saturated ammonium sulphate; (3) non-reactivity with anti-bovine IgM, and anti-bovine IgG; (4) non-reactivity with protein G, and protein A; (5) a relative molecular mass of 152 kDa determined by chromatography on Sephacryl S 300, and of 133 kDa determined by chromatography of the 50% SAS cut of IgG-depleted buffalo serum on Superose 12; (6) no associated cholesterol; and (7) inactivation by digestion with proteinase K that was immobilised on agarose.

*(*ICIPE Staff)*

Future activities

(i) Characterise the host responses and preferences of *G. pallidipes* and *G. longipennis* at Nguruman through the use of electric screens as bait animals. Study daily and seasonal movements of cattle in relation to suppressed and non-suppressed tsetse populations.
(ii) Continue with characterisation studies on the trypsin-lectin complex in tsetse and evaluate the potential of a practical application.
(iii) Assess xenodiagnosis in conjunction with molecular and biochemical techniques as methods for characterising trypanosome infections in tsetse flies and in wildlife.
(iv) Assess the prevalence of trypanosomes in biting flies at Nguruman using PCR techniques.
(v) Conduct field trials at Nguruman in one wet season to validate the usefulness of the trap developed in 1994 as a sampling/control device for both tsetse and biting flies.

D. EVALUATION OF THE POTENTIAL OF CERTAIN BIOLOGICAL ORGANISMS AS BIOCONTROL AGENTS OF TSETSE

Participating scientist: *N. K. Maniania*

Assisted by: *J. Opere*

Work in progress

1. DEVELOPMENT OF AN APPLICATION TECHNIQUE FOR USE WITH FUNGAL PATHOGENS

Evidence of tarsal contamination

Tarsal contamination by entomopathogenic fungi was brought to the fore by developing a laboratory technique that uses nitrocellulose filter membrane (Millipore) as substrate for retaining conidia. Tsetse flies are therefore allowed to walk freely on the contaminated substrate. It is through tarsal contact that flies would pick up a fungus in nature, from contaminated targets and chambers, or resting sites such as tree bark.

Experiments were carried out by exposing non-fed and fed teneral *G. m. centralis* adults to fungus. Fed flies were more susceptible to fungal infection than were non-fed flies, suggesting that bloated abdomen of fed insects increased the surface of contact with the contaminated substrate.

This technique allows also accurate estimation of inoculum on the substrate, thereby permitting comparison of virulence during the screening of entomopathogenic fungi against tsetse flies. For example, when *G. m. centralis* adults were exposed to different concentrations of the fungus *Metarhizium anisopliae*, mortalities were dose dependent.

Following this finding, an 'infecting chamber' device is being developed, whereby flies get infected with entomogenous fungus before they return to the environment.

Effect of fungal infection on bloodmeal intake

It was observed in the laboratory that fungus-infected *G. m. centralis* adults became sluggish and ceased feeding before dying. Experiments were therefore undertaken to study the effect of fungal infection on bloodmeal intake of *G. m. centralis* and *G. m. morsitans*.

Male and female teneral flies of both species were exposed for 24 h to different concentrations of *M. anisopliae*: 3×10^4, 3×10^5 and 3×10^6 conidia cm^{-2}. Flies were then transferred individually into a cylindrical plastic tube (40 x 30 mm) with the top cover bored and replaced by white plastic netting. Flies were fed on rabbits at 2, 5, 7 and 9 days after treatment. The weight was taken before and after feeding.

Bloodmeal intake was generally reduced with a conidia concentration of 3×10^6 cm^{-2} as compared to controls and other concentrations, except in case of male

of *G. m. morsitans*. However, the implication of this reduction on trypanosome transmission has to be established.

Host age and sex as factors in the susceptibility of tsetse

Since flies entering the trap are of different age and sex, their susceptibility to fungal infection may vary. Therefore, experiments were carried out to determine the effect of the fungus *M. anisopliae* on age and sex of *G. m. centralis* and *G. m. morsitans*. Females and males of different ages, 0–1, 19–20, 39–40 and 59–60 days, were exposed to concentration of 2×10^7 conidia cm^{-2} for 2 h.

Both sexes and different ages of the two species were susceptible to *M. anisopliae*. However, male and female teneral *G. m. centralis* were less susceptible than old flies. Moreover, development of fungal infection appeared to take longer in teneral flies. On the other hand, teneral male and female *G. m. morsitans* were equally susceptible to fungal infection.

Completed studies

Maniania N. K. A laboratory technique for infecting adult tsetse with a fungal pathogen. *Insect Science and its Application* (in press).

A technique for infecting adult tsetse with an entomopathogenic fungus was developed and tested in the laboratory. A nitrocellulose filter membrane (millipore) was used as substrate for retaining conidia after filtration, and a cylindrical plastic tube served as a chamber for the flies. The technique was designed to allow accurate estimation of inoculum on the substrate, thereby permitting comparison of virulence during the screening of fungal pathogens against tsetse flies. *Glossina morsitans centralis* adults were susceptible to *Metarhizium anisopliae* at all doses tested, and mortalities were dose dependent. No significant differences in mortalities were observed when flies were exposed for different lengths of times to the pathogen. The number of conidia picked up by flies varied considerably with exposure time and concentration.

Future activities

Evaluate the potential field application of a fungal contamination chamber for the control of tsetse flies *G. pallidipes*, *G. longipennis* and *G. f. fuscipes*.

E. THE SOCIOECONOMIC ASPECTS OF ICIPE'S NGU TRAP FOR TSETSE CONTROL AND ITS COST-EFFECTIVENESS AND SUSTAINABILITY

Participating scientist: *G. T. Lako*

Assisted by: *G. G. O. Nyambane, D. K. Kahuria*

Collaborators: *Kenya Ministry of Agriculture, Livestock Development and Marketing; Kajiado District Development Committee*

Background

The rationale for this activity emanates from the fact that the development of livestock production in Africa is beset by a complex of technical, social and institutional constraints.

The ICIPE has chosen to tackle the control of tsetse-transmitted trypanosomiasis through concentrating on the control of the tsetse vector. To ensure adoption and sustainability of the technologies developed, socio-economic and cultural considerations have to be incorporated into R&D as well as into other phases of technology development.

Work in progress

1. IMPACT OF TSETSE TRAPPING TECHNOLOGY ON THE LOCAL COMMUNITY AND LAND USE IN NGURUMAN

The study sought to assess the impact of the tsetse control programme set up in Nguruman from the point of view of the people themselves. A random sample of 210 (35%) households was selected and interviewed, focusing on how they perceived the land for cultivation/grazing. In their replies, over 90% of the respondents regarded the tsetse menace as having been significantly reduced to the extent that people could now access areas which were otherwise inaccessible prior to the control of tsetse in the area.

All the respondents in Nguruman proper, Oloibortoto East and West, Ndarkalali and Konei areas reported that they had been able to increase their land under cultivation, although gradually and in small sizes, since the introduction of tsetse control in 1987. The majority of the respondents described how prior to tsetse control they were not able to graze their animals in areas higher up the escarpment. It is now possible to do so, and in their opinion this is due to the reduction in the tsetse population in the area.

As mentioned above, the increase in agricultural activity in the area has resulted in a number of beneficial effects for pastoralists during the dry season. For example, farmers who also own livestock now graze them on their farms after harvesting. They also allow other pastoralists with no agricultural residues to have access to their farms. The above impacts have occurred mainly due to ICIPE's trapping activities.

2. COMMUNITY SOCIAL ORGANISATION

This study is based on the assumption that if a community is to adopt and sustain the tsetse trapping technology, then it could perhaps do so best using its own existing social and political structures and capacities. Given appropriate goals, objectives and activities for the management of the tsetse trapping technology, such a community could use any of its existing organisations or create a new one for the purpose. The aim of this study therefore is to assess the community social organisation and the capacity of existing leadership structures to adopt and manage the tsetse trapping technology in Nguruman, Kajiado District.

The data and information gathered for the study were largely based on a household survey covering 210

(35%) households and guided interviews and discussions.

The following are highlights of some of the findings obtained from this study.

1. At the household level, decision making on the following decisions and activities belongs to the household head:
   - where animals should graze;
   - locating sites for new 'manyattas' (huts) and when movement should actually take place;
   - deciding on who does what within the household and at what time;
   - deciding on when and which animals should be slaughtered;
   - when and how to dispose of or acquire animals, e.g. through sale or exchanging for cereals or exchanging goats for sheep or cattle, etc.
2. Milking, processing, storage and decision regarding consumption of milk are made by each wife given that each has a number of animals allocated for her use.
3. Construction and maintenance of 'manyattas' is entirely a job for women, including their dismantling when the household has to move to a new site.
4. At the village level, the Group Ranch consists of a leadership structure which is elected by the community directly. The chiefs and sub-chiefs are appointed by the local government authorities. The significant difference between these two organs in terms of decision making is that the chiefs and sub-chiefs are empowered to implement government decrees regarding the community, while in the case of the Group Ranch, decisions are reached after consultations and discussions by the elected officials of the Group Ranch or through a 'Baraza' or public meeting.

At the community levels of authority there are a number of levels with varying degrees of influence in community decision making. The first level of authority emanates from the age-group. An *Olaiguenani* (chief councillor) is selected from each age group of boys before being circumcised and given a wooden club (*Okiuka*) which symbolises his authority.

Next is *Olobolosi - Olkiteng*, selected also before the boys are circumcised. He provides the big bullock which is slaughtered after the boys have wrestled with it.

Third is *Olotuno* who is selected during the *Eunoto* ritual when the warriors graduate to become elders. In fact, he becomes the leader of the elders with all the responsibilities connected with this position. He is the first to marry from among his age-group. However, his authority is superseded by the Chief Councillor, and *Oloberu - Enkeene* does not fall under his authority.

The fourth, *Oloberu - Enkeene*, shares the same degree of authority as *Olotuno* as far as particular matters are concerned, though *Olotuno* commands more respect both within the age-group and within the tribe.

The fifth man is *Oloiboni* (Chief Seer), whose respect emanates from the whole tribe and not only from sub-divisions within it. Unlike the others, he is not *selected*, but *grows up* as a seer. The reputation and respect given to him depends on his perceived abilities. He controls warfare and raids, and no war may be undertaken against an enemy before he is consulted, lest disaster strike and the enemies win.

Custom among the Maasai is controlled by the above five men. However, with more and more government intervention and influence of outsiders through trade, commerce, migration and education etc., the authority of the above persons may have declined somewhat.

Further investigation is yet to be made into assessing the potential of the above sociocultural and political institutions for the management of tsetse trapping technology. The roles of external governmental and non-governmental bodies in the adoption of the tsetse trapping technology also need to be assessed.

3. COST OF TSETSE TRAPPING

This study aimed at assessing the costs of the trap in terms of materials needed and labour used, based on ICIPE's experience at its Nguruman Field Station. More specifically, the study aimed at:

(a) determining the cost of making a single trap and maintaining it for a period of one year;
(b) establishing the labour requirements/costs of making a trap;
(c) establishing the labour requirements of servicing one trap for a year; and
(d) assessing the servicing activities of the traps.

The study started in November, 1990 and lasted 20 months through July, 1992. A total of 246 traps were observed through the stages of production, installation, operation and servicing/replacement. Technical staff from the Tsetse Research Programme visited each trap an average of once a month for purposes of repair and maintenance, and to replenish odour baits. In all, 4164 visits were made to the traps, i.e., an average of 17 visits to each trap over the study period.

The analysis of the data gathered has depended largely on descriptive statistical tools (e.g. frequencies, cumulative frequencies and percentages) as well as simple accounting procedures and probability theory concepts.

Table 2 summarises the various elements that have been considered in the determination of the total cost of making a single trap, setting it up ready for operation and maintaining it for a year.

Table 2. Total cost of a tsetse trap in a year

Materials and services for trap	Cost in KSh.
Material in making the trap	817.15
Labour in trap making (ICIPE rate)	24.10
Labour for setting up the trap	8.85
Labour in servicing the trap	86.70
Transportation (fuel cost) in servicing	17.30
Trap replacement materials	45.80
Servicing of acetone	33.30
Servicing of octenol	16.55
Servicing of the cage	0.20
Servicing of the shelf	0.60
Servicing of the target	0.80
Servicing of the cone	3.00
Servicing of the trap body	17.60
Total cost	1071.95

The above figure of the cost of one trap for a year is based on the cost prices of the various items as at the time of the study, when these prices were fairly stable. At the exchange rate of the US dollar to the Kenya Shilling at 1 US $ = KSh. 35, the cost of constructing and servicing one trap for a year is US $ 30.65.

Although the above costing is based on ICIPE's experience, it is not expected to vary significantly in the case of the community producing and maintaining the traps. The reason for this is that the community will have to carry out the control using similar materials from similar sources of supply, and managing the technology in much the same way as ICIPE, since both would enjoy similar economies of scale.

It is difficult to determine whether, at the cost of KSh. 1071.95 per trap per year (or KSh. 263,699.70 total cost per year for making and servicing 246 traps), the community could manage the technology as was done by ICIPE during the study period. However, it is possible for the community to do so if it is organised well enough to raise all the necessary resources, presuming that it has a high level of willingness to control tsetse.

Furthermore, the above cost should be assessed in terms of the benefits that would accrue to the community from tsetse trapping, which will enhance their willingness to pay for the technology.

Finally, it is obvious that further studies have to be made with regard to comparability of the above costs to those incurred elsewhere, where similar traps are used, or even where other control methods are employed. Studies of the management requirements of the trapping technology have yet to be done in order to ensure its long-term sustainability.

Future activities

(i) Assess households' incomes and expenditures and the affordability of the tsetse trapping technology to sedentary and pastoralist populations in Nguruman.
(ii) Study the potential of the Nguruman community to sustain the tsetse trapping technology.

F. REARING OF *GLOSSINA* FOR TSETSE RESEARCH PROJECTS

1. PRODUCTION OF *GLOSSINA MORSITANS MORSITANS* AND *G. M. CENTRALIS*

Participating Staff: *J. P. R. Ochieng'-Odero, G. W. Oloo, L. H. Otieno*

Assisted by: *J. U. Wanyonje, H. K. Banda*

Glossina morsitans morsitans and *G. m. centralis* accounted for most of the tsetse production in the reporting period. A total of 157,821 *G. m. morsitans* and 130,773 *G. m. centralis* were produced during this period. Of these, 63,899 G. *m. m.* and 67,704 *G. m. c.* adults were supplied to various users, respectively. Table 3 summarises the supply of these two species to various users.

Table 3. Production and supply of *Glossina morsitans morsitans* and *G. m. centralis*

Programme/ Department	*G. m. morsitans*	*G. m. centralis*	Total
Behavioural and Chemical Ecology	11,915	10,796	22,711
Molecular Biology	45,831	14,488	60,319
Livestock Ticks	6153	34,267	40,420
Biotechnology	–	8153	8153
Total	63,899	67,704	131,603

2. EXPERIMENTAL REARING OF *G. F. FUSCIPES* AND *G. PALLIDIPES*

Participating scientist: *L. H. Otieno*

Assisted by: *H. Banda, J. Wanyonje*

Experimental rearing of *G. pallidipes* was done to investigate the effects of possible contaminants in rabbit feed obtained from a local supplier. Low insemination rates (e.g. 30%) as well as survival problems have always been associated with past attempts to rear this fly, possibly as a result of blood quality. Initially, 94 mated females of *G. pallidipes* (Nguruman strain) were randomly selected to form two comparative groups. One group was maintained on rabbits fed on diet from 'special diet services' (SDS) in UK while the other group was maintained on rabbits fed on local diet, prepared specially for ICIPE to be free from coccidiostat.

The feeding regime for both groups was the same, i.e., five days per week. Flies were not fed during weekends. Female flies were mated when 7 days old with males 10 or more days old and were allowed to stay together for 7 days. Their performance was monitored through survival rate, fecundity and pupal weight. Flies maintained on imported diet produced more than double the number of pupae, of higher weights as well, than flies maintained on local diet (Table 4). Fly survival did not appear to be affected, but was lower than desirable on either diet.

Table 4. Performance of *G. pallidipes* maintained on rabbits fed on imported (SDS) and local diet

Parameters investigated	SDS diet	Local diet
Total number of repr.cycles	461	419
Repr.cycles per original female	4.9	4
Total pupae produced	82	34
Pupae/original female	0.87	0.36
Pupae/reproductive cycle	0.18	0.08
Mean pupal weight	34.9	31.6

Training activities

Two ARPPIS PhD scholars were trained under the EU-funded tsetse research projects:

F. Masaninga, Zambia
S. Akinyi, Kenya

An International Group Training Course was also held:

Title: Integrated Tsetse Management for the Tropical Developing World

Date: 14 February–12 March 1994

Venue: ICIPE Headquarters at Duduville and Mbita Point Field Station

Participants: 8 livestock professionals from Kenya, Ethiopia, Sudan, Rwanda and Tanzania.

Future training activities will include carrying out a one-month group training course on integrated tsetse management towards the end of 1995, and carrying out a short-term training course on tsetse control methodologies for Maasai pastoralists.

II. Development of Efficient and Environmentally Acceptable Tsetse and Tick Control Strategies for the Tropical Developing World: Tsetse Research

Background

Project coordinators: *L. H. Otieno, R. K. Saini, 1994*

Donor: *UNDP*

Tsetse and ticks continue to be a major constraint to livestock production and agricultural development in Africa. The overall objective of the project is to develop sustainable, cost-effective, environmentally-friendly and culturally-acceptable tsetse and tick management technologies. The project also proposes to continue with human resource development through interactive research and training programmes.

Work in progress

1. IMPROVING TRAP EFFICIENCY TO MAKE THEM BROAD SPECTRUM WITH RESPECT TO TSETSE SPECIES IN VARIOUS PHYSIOLOGICAL STATES

Participating scientists: *R. K. Saini*, A. Hassanali*
*(*Project Coordinator, 1995)*

Assisted by: *J. Andoke, P. Ahuya, W. P. Ouma*

Trapping of host body volatiles

The technique for selective trapping of host body volatiles was used to trap volatiles from cattle and an attempt was made to collect odour from warthogs. In the case of cattle, volatiles were collected from various body parts and GC-EAD and GC-MS studies undertaken with the collected volatiles (Figures 1, 2).

Seven GC-EAD active peaks have been located from volatiles collected from the head and body of cattle using *G. m. centralis* as test insects, while nine active peaks have been located using *G. m. morsitans*. These findings are very encouraging, as they, for the first time, allow identification of compounds emanating from host animals and also open up the possibilities of investigating their role in attraction/close range behaviour of different species of tsetse flies.

2. LARVIPOSITION PHEROMONES OF *G. MORSITANS* GROUP OF FLIES

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

Assisted by: *J. Andoke, P. Ahuya, W. P. Ouma*

Two compounds, *n*-pentadecane and *n*-dodecane have been identified as 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 trapped larval volatiles (Figures 3, 4). Preliminary results indicate that these compounds attract gravid females to larviposition sites in laboratory bioassays. In both species minor EAD active components could not be clearly separated and located. Identification of these components is being done by micropreparation of blends corresponding to these regions followed by re-chromatrography under different sets of conditions.

Completed studies

Saini R. K., Hassanali A., Andoke J., Ahuya P. and Ouma E. O. Olfactory sensitivity of tsetse flies to phenolic kairomones (submitted).

Laboratory studies have been completed on the olfactory sensitivity of *G. m. morsitans* and *G. pallidipes* to various phenolic analogues. Results clearly indicate that in the case of *G. pallidipes*, activity of 4-cresol and 3-*n*-propylphenol cannot be increased. However, in the case of *G. m. morsitans*, three new phenolic analogues propylbenzene, 5-indanol and methylaniline have been shown to have high activity at the receptor level. Field testing of these compounds especially for *G. m. morsitans* is being initiated.

Saini R. K., Andoke J. and Ahuya P. Responses of gravid females to larviposition pheromones and phenolic kairomones (submitted).

Electroantennogram sensitivity was determined of *G. m. morsitans* and *G. m. centralis* gravid females to their respective larviposition pheromones and to five different phenolic analogues. Peak sensitivity of *G. m. morsitans* flies to the larviposition pheromone occurred prior to ovulation and

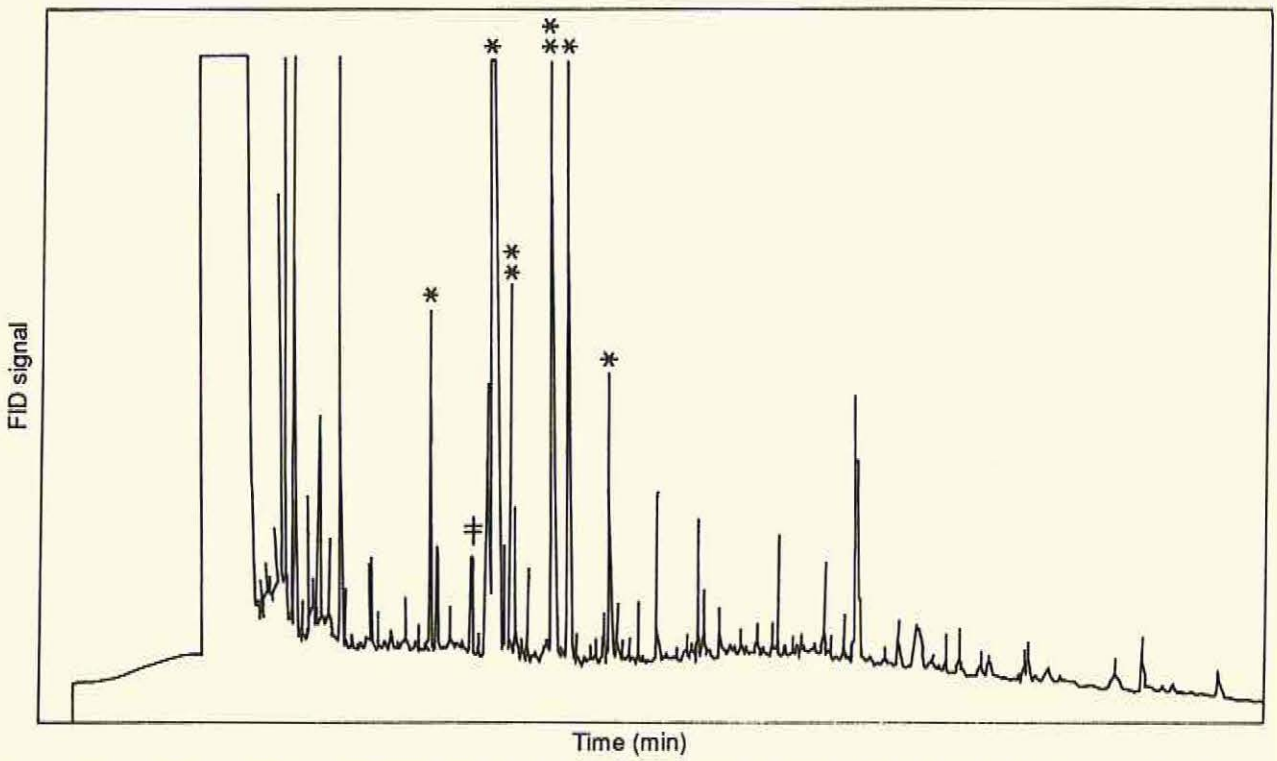


Figure 1. GC profile of volatiles collected from the head of a cow using a selective trapping technique. The many peaks indicate the very high sensitivity of the technique. EAD-active peaks are indicated. (*Active to *G. m. centralis* and *G. m. morsitans*, *active to *G. m. centralis* only, **active to *G. m. morsitans* only.)

prior to larviposition (Figure 5). Peak sensitivity to all kairomones tested was during ovulation and about two days prior to larviposition. These observations on receptor sensitivity agree with the known observations on the physiology and behaviour of gravid *G. m. morsitans* females. It is interesting to note that olfactory sensitivity of flies is governed by the physiological state of the flies. Similar results were obtained with *G. m. centralis* gravid females.

Kaaya G. P. and Munyinyi D. Biocontrol potential of the entomogenous fungi *Beauveria bassiana* and *Metarrhizium anisopliae* for tsetse flies (*Glossina* spp.) at developmental sites. *Journal of Invertebrate Pathology* (in press).

Spores of two entomogenous fungi, *Beauveria bassiana* and *Metarhizium anisopliae*, were mixed with sterile sand at two different concentrations (1.0 and 0.5 g/litre) and larvae of tsetse flies *Glossina morsitans morsitans* allowed to pupate in it,

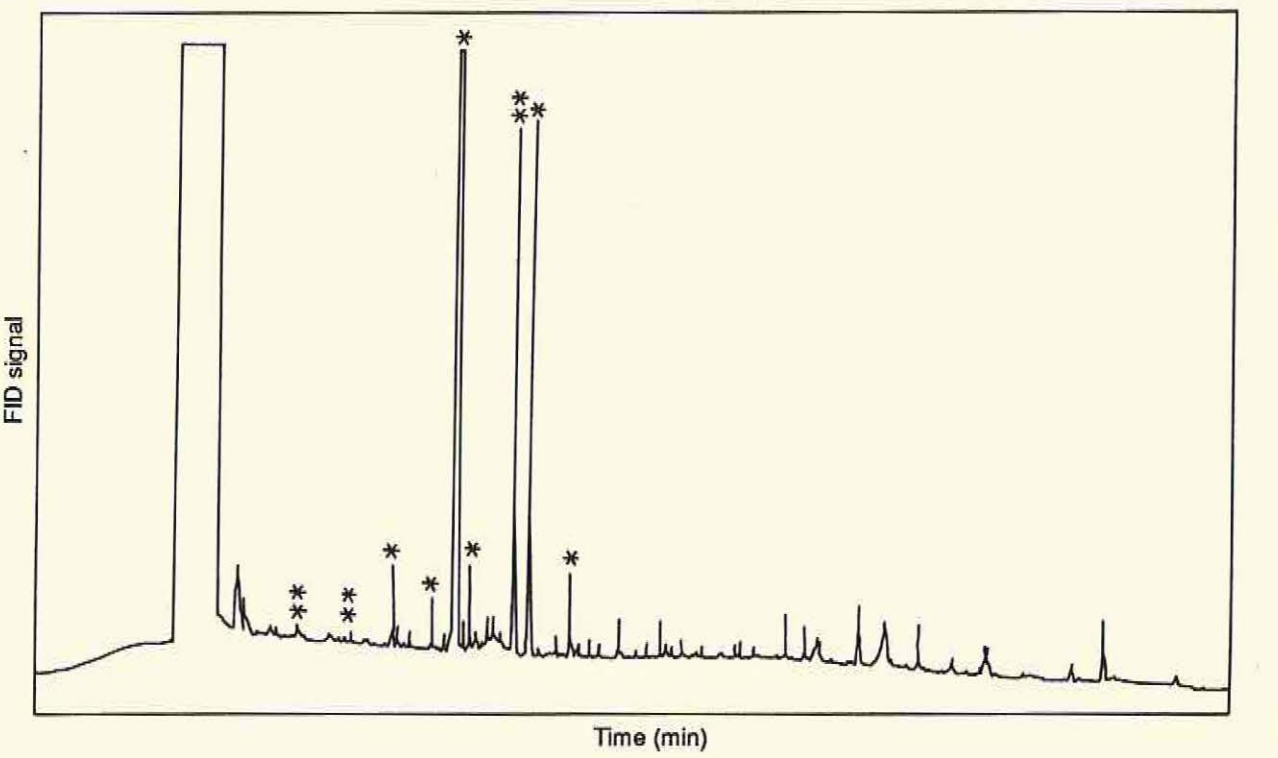


Figure 2. GC profile of volatiles collected from the body of a cow using a selective trapping technique. Key is as for Figure 1.

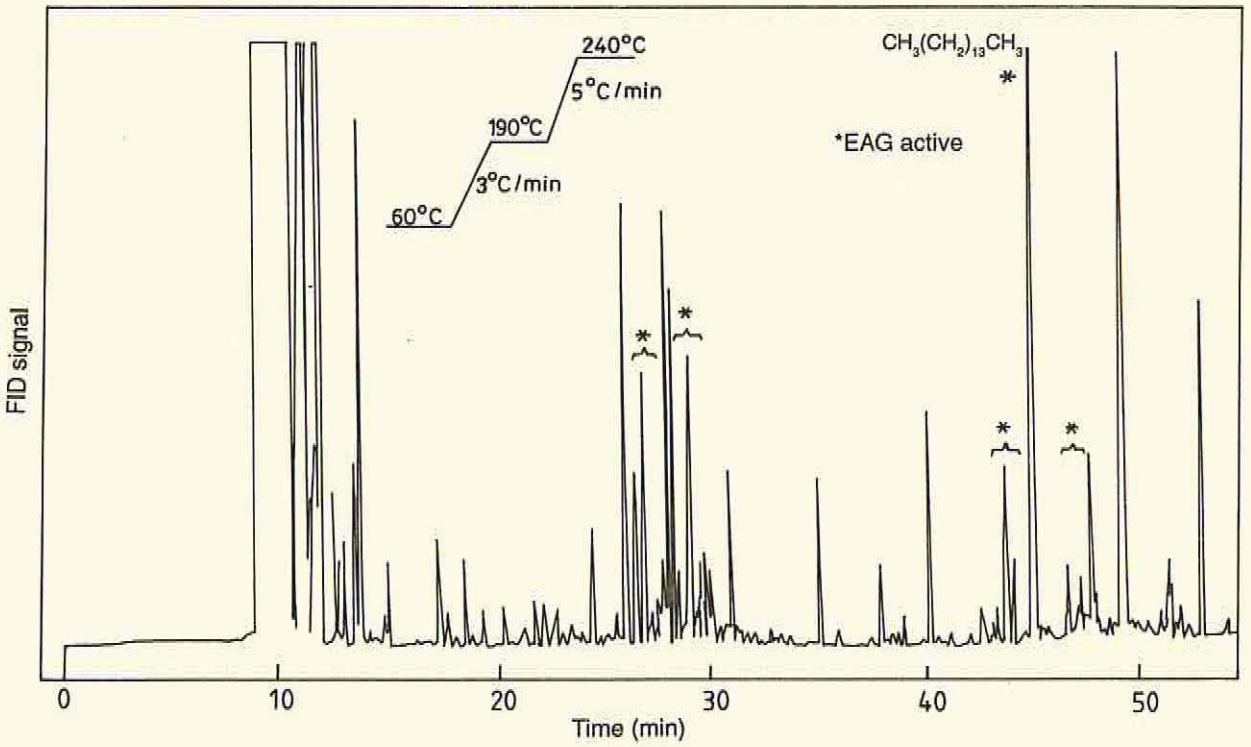


Figure 3. GC profile of *G. m. morsitans* larval volatiles. The predominant EAD-active peak has been identified as *n*-pentadecane. EAD-active peaks are starred.

simulating field larviposition sites. One gram weight of *B. bassiana*-sand mixture was estimated to contain 1.4 x 10^6 spores/g and that of *M. anisopliae*-sand mixture 2.3 x 10^6 spores/g. Adult tsetse emerging from pupae in sand-spore mixtures suffered heavy mortalities 2–10 days post-emergence. The highest mortality recorded at 1.0 g/litre was 97% for *B. bassiana* and 80% for *M. anisopliae*. Lower spore concentrations produced lower mortalities. Possibilities of biocontrol of tsetse in the field using mycopesticides at breeding sites are discussed.

Future activities

(i) Continue studies on the role of body volatiles from wild preferred hosts and investigate their role in attraction/close range behaviour of tsetse flies.
(ii) Field test the promising phenolic analogues.
(iii) Complete identification of larviposition pheromones of *G. morsitans* flies. Develop control release dispensers and initiate field testing.

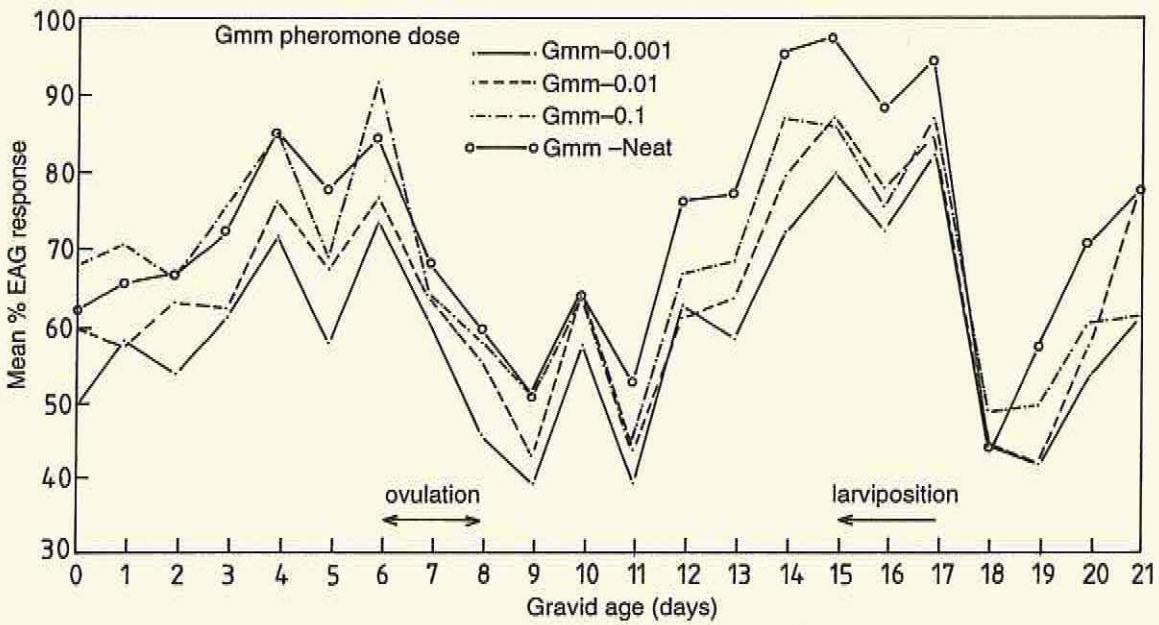


Figure 4. EAD responses of *G. m. morsitans* gravid females to four different dilutions of the larviposition pheromone over a 3-week period.

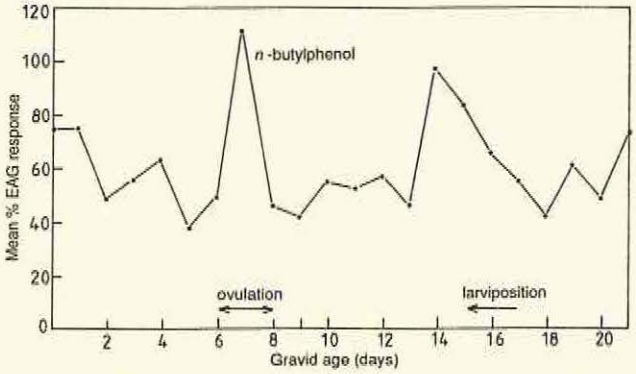


Figure 5. Trends in EAG responses of *G. m. morsitans* gravid females to *n*-butylphenol (a phenolic analogue) over a 3-week period. Response indicated is a mean of 4 different doses tested. Responses to other phenolic analogues (4-cresol, 3-*n*-propylphenol, propylbenzene and 5-indanol) show a similar trend.

3. TSETSE-HABITAT ASSOCIATION AT THE KENYA COAST

Participating scientist: *M. L. A. Owaga*

Assisted by: *S. S. Wakape, H. Simba*

Background

Three tsetse fly species, *Glossina austeni, G. pallidipes* and *G. brevipalpis* occur in the humid and sub-humid climatic belt of eastern Africa. Any management strategy of the vector tsetse in relation to the transmission of nagana in that area must consider all of them if an impact is to be made. The effective trap-odour system developed for *G. pallidipes* by ICIPE scientists in the semi-arid south-western Kenya could not be used successfully in the management of three species of tsetse in the humid habitats of the coastal region. Due to differences in fly behaviour, habitat preferences and climatic and vegetational parameters in various habitats, tsetse traps tend to be species-specific.

Work in progress

1. *Utilisation of micro- and macro-habitat for host seeking and breeding*

As part of an ongoing study to develop a 'compromise' trapping system for the above species in the humid coastal habitat, and particularly a device for *G. austeni*, an analysis was made of the utilisation of micro- and macro- habitats by the three co-existing *Glossina* species, and of their specific association with such macro habitats, for host seeking and breeding activities. In two sites, Muhaka and Marenge forest areas, *G. austeni* showed significantly greater association with the forest floor for breeding and host seeking activities than with ecotone and open woodland. However, there is evidence that ecotone is used under certain conditions. *Glossina pallidipes* showed strong preference for ecotone habitat, both for breeding and host seeking activities, while *G. brevipalpis*, was strongly associated with the forest floor during its daytime resting period, and for breeding activity, but showed significant association with the ecotone, paths and open woodland at dusk, during its peak host seeking activity time.

2. *Modification in trap size and colour*

Subsequent experimental trapping of each species in the relevant macro-habitats strongly indicates that effective trap size and colour for each of them may be influenced by conditions of the macro-habitat with which the fly is associated. For example, experimental, comparative work conducted under forest and open woodland conditions revealed that designs smaller than that of NG2G by as much as a third were more effective for both *G. austeni* and *G. brevipalpis*. Furthermore blue was not necessarily the best colour for those two species as they responded as well, and sometimes better, to colours other than the usual royal blue.

Continuing investigations into effective trapping system for *G. austeni* are incorporating these results in redesigning and testing different promising devices for the species that might also work for the sympatrics.

4. SOCIOECONOMIC ASPECTS OF TSETSE AND TICK CONTROL STRATEGIES AND THEIR COST-EFFECTIVENESS AND SUSTAINABILITY

Participating scientist: *G. T. Lako*

Assisted by: *G. G. O. Nyambane, O. Wambua*

Collaborators: *Kenya Ministry of Agriculture, Livestock Development and Marketing; Kwale/Kilifi Adaptive Research Project; Kenya Agricultural Research Institute (KARI, Mtwapa); Kwale District Development Committee*

Donor: *UNDP through the World Bank*

Background

The overall goal of the project is to develop technologies for the control of tsetse and ticks which are both socially and environmentally acceptable and sustainable. It is imperative therefore, that socioeconomic and cultural considerations be included in the process of the development of these technologies in order to ensure their adoption and sustainability by the end-users, i.e. rural communities.

Work in progress

Study the community social organisation and the capacity of existing leadership structures to adopt and manage the tsetse trapping technology

ICIPE, under the Kwale/Kilifi Adaptive Research Project, set up a 50 km^2 tsetse control zone in Shimba Hills area, Kwale District, Coast Province, Kenya in 1993. One hundred and twenty (120) Siamese version tsetse traps were deployed in the area. The aim of this study was to assess the extent to which the existing community social organisations and leadership structures could be mobilised and organised for managing the tsetse trapping technology. The data were collected in 1993, based on a sample of 191 out of a total of 564 (about 34%) of households in Lukore Location which falls within the above mentioned tsetse control zone. The analysis of data was done using descriptive statistical tools.

The findings show that at the household level, the household head alone decides on a number of activities, e.g. how much land is to be cultivated in a particular season/year; what crop(s) are to be grown on this land; who should use the available oxen for ploughing and when and how to dispose of crop harvests.

Decisions regarding allocation of family as well as hired labour are made by the household head including the timing of every agricultural operation during the season or year.

At the village level the first order of authority is the local government representatives such as the chief and sub-chiefs. These are empowered to implement government decrees regarding the community. In addition there are a number of other organisations in the villages which carry out different functions as shown in Table 1.

In the case of the village committees, decisions made are usually sanctioned by the chief who quite often uses this committee to ensure that his directives are followed. The women's groups are voluntary associations formed largely through encouragement from the Ministry of Culture and Social Services. Office bearers are elected democratically.

In terms of mobilisation and organisation of the community for tsetse control, 53% of the persons interviewed suggested that the existing village committees and women's groups, guided by village elders, should form the basis for community management of tsetse control. Most interviewees also suggested that the funeral groups should be charged with the task of raising funds from the community for tsetse control. This is because everyone recognises them as being more active and efficient in raising funds from the people.

Table 1. Activities of village organisations

Name	Main function
Village committee	– General overseer of village affairs
Women's groups	– Merry-go-round (revolving fund) – Farming – Cottage industries
Self-help groups	– Various development activities
Funeral groups	– Assisting bereaved member families

Assessment of the social division of labour and its implications for the adoption of the tsetse trapping technology

The main objective of this study emanates from the widely accepted view that the control of tsetse using traps can be best sustained over the long term if it is managed by the community itself. Ideally, all the resources should be provided by the community, i.e. types of cloths used, trap supports and poles, urine odour baits, etc. However, the critical input is labour for making the traps, setting them up, and servicing them.

Lukore location was selected for the study based on the fact that the area has a severe tsetse problem. However, both livestock and agricultural activities are widely practised apart from other activities. From a census of all household heads in the area (564) a random sample (191, about 34%) was selected for the interviews.

A wide variety of data has been gathered under this study. However, only a summary of the main findings is presented here:

1. At the level of individual households, according to 70.6% of the sample, there is shortage of labour for crop and livestock activities.
2. Individual households may not have time to manage the tsetse control technology, but they may be able to do so at the community level. Each household may be able to allocate a proportion of its labour time, however small, to community control activities.
3. The main reason for the above conclusion is that the community is willing to make sacrifices, as shown by the readiness of 68.6% to make their own traps or even to buy them.
4. About 52.6% of the individuals interviewed suggested that the existing village committees and women's groups, guided by village elders, should form the basis for community management of tsetse control.

Finally, it is obvious that further studies have to be made with regards to comparability of the above costs to those incurred elsewhere, where similar traps are used or even where other control methods are employed. Studies of the management requirements of the trapping technology have yet to be done also in order to ensure its long-term sustainability.

Future activities

(i) Assess households' incomes and expenditures and affordability of the tsetse trapping technology to a local community in Kwale District.

(ii) Study the impact of introduction of trapping technology on the role of livestock in the community, farmers' perceptions, effectiveness of community social organisation in the introduction of this technology.

Completed studies

Lako G. T., Cost of tsetse trapping using the NG2G tsetse trap: A case study in Kenya. ***Insect Science and its Application*** **(in press).**

5. POPULATION DYNAMICS AND MOVEMENT OF TSETSE FLIES, *GLOSSINA* SPP. AT THE KENYA COAST

Participating scientists: *J. B. Okeyo-Owuor, L. H. Otieno*

Assisted by: *C. Ogutu, J. Mwandandu*

Donor: *UNDP*

Collaborators: *W. Ogana, University of Nairobi; O. Macharia, Kenya Wildlife Service; T. O. Adede, Ministry of Agriculture, Livestock Development and Marketing, Kenya*

Background

The tsetse, *Glossina* spp. is a well known taxonomic group within the order Diptera, belonging to the Glossinidae, a family formerly assigned to Muscidae to which, though separate, they are closely related. The *Glossina* species are restricted to tropical Africa, within 15°N–20°S but extending more southerly along the coastal area. The fly is a well known biological vector of *Trypanosoma* spp., pathogenic microorganisms responsible for causing the disease trypanosomiasis (or sleeping sickness) in humans and nagana in livestock. Some 36 countries in Africa are infested by the fly, putting about 50 million people at risk of contracting the disease, while 23,000 new cases are reported annually from endemic areas. Similarly, nagana is a major constraint in agricultural development, especially in livestock production leading to shortages of meat and milk over a belt of 10,000 km^2 in Africa.

In tropical Africa, 30 or so *Glossina* spp. have a diverse distribution and habitat preferences whose limits are determined by climate through its effect on vegetation. The abundance and distribution of tsetse flies are determined by both vegetative cover and microclimate. But where rainfall is high and desert conditions are intensive, the limit of *Glossina* distribution is related to seasonal low temperatures which accordingly hinder adult activities (less than 23°C) and pupal development (less than 18°C).

The major ecological factors influencing tsetse population dynamics, distribution and movements are still a matter of speculation, since even within a limited geographical area there are unexplainable diversities in different sites. Further, little is known about the factors influencing relative abundance, movement and dispersal. This report provides information on some factors responsible for changes in population abundance, movement and dispersal of three *Glossina* species, *G. pallidipes*, *G. austeni* and *G. brevipalpis* at Muhaka Forest and Shimba Hills Game Park at the south coast of Kenya.

Muhaka Field Station, one of the ICIPE's research stations, is located some 50 km on the south coast along the Mombasa–Lunga Lunga road, Kwale District, on the south coast of Kenya. The station is sited on 300 hectares of land, nearly half of which is covered by indigenous forest, the Muhaka. Muhaka is a gazetted protected area and is inhabited by numerous species of small mammals and reptiles as well as a wide diversity of insect fauna, including the three species of tsetse flies. The rest of the station is set in an agroecosystem within typical coastal trees and food crops, part of which is cleared for research on annual food crops. The whole station is surrounded by human settlement (peridomestic) areas.

The studies were also conducted in Shimba Hills Game Park in Kwale District. The park is located near the equator and covers an area of about 150 km^2. It lies between three settled divisions, namely Matuga (north-east), Msambweni (south-west) and Kinango (west). The park's main features are the *nyika* plateau with an altitude of about 420 m above sea level and a comparatively cooler climate than the rest of the coastal region, with an annual rainfall of 1200 mm falling in a bi-model fashion. The vegetation cover of the park is typical savanna grassland intercepted by secondary and primary forests and thickets along the valley bottoms. A small portion of the park is covered by a plantation of pines (*Pinus patula* L.). Lantana weed (*Lantana camara* L.) covers the open areas along the main paths of the park.

Several species of wildlife occur in the park and the surrounding areas. These include buffalo, warthog, elephant, sable antelope, wild pigs, rodents and different species of reptiles. Recently, the Kenya Wildlife Service introduced a small number of giraffes. While some wildlife species are relatively sedentary in their habits, others such as wild pigs, elephant, buffalo, sable antelope, and baboons are quite mobile. These animals move extensively within the park and even into the settled areas, carrying variable populations of Muscidae and Glossinidae with them. Three species of tsetse flies, *G. pallidipes*, *G. austeni* and *G. brevipalpis* inhabit the park as well as other parts of the coastal region.

Work in progress

1. *Seasonal abundance of tsetse flies in Muhaka Forest and peridomestic areas*

Studies were started in November, 1993 and terminated in December, 1994. The ICIPE-designed tsetse traps, NG2B, baited and unbaited with cow urine were used for the study. The traps were checked daily and the flies trapped collected for laboratory examination. To determine the diurnal activities of tsetse flies, daily collections of trapped flies were made every two hours between 0800–1600 hrs.

Diurnal changes in trap catches show that the activity of tsetse flies is dynamic throughout the day. There were two peak catches observed, one at 0700–0800 hrs and the other at 1600–1800 hrs. The other times were characterised by a trough in fly catches when the catch was low and more or less uniform (Figure 6). At the experimental sites, *G. pallidipes* was the most abundant species, accounting for 95.5% of the total catch per trap. The other species occurred in low numbers, 2.5% and 2.0% for *G. austeni* and *G. brevipalpis*, respectively. Data obtained from trap catches show that those baited with cow urine

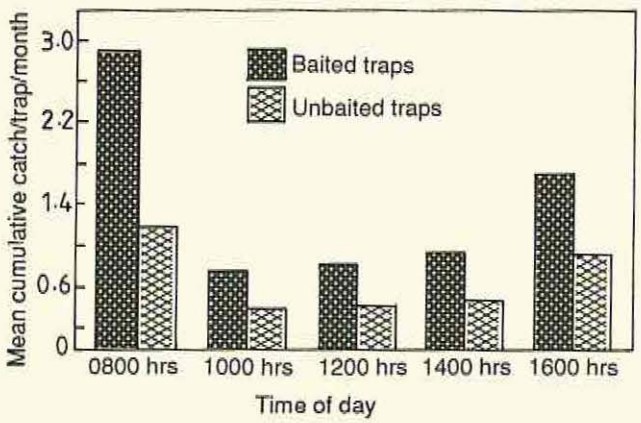


Figure 6. Monthly tsetse catches at different times of the day at Muhaka, Kwale District, Kenya.

caught significantly ($P > 0.5$) more flies than unbaited (Figure 6). These results confirm earlier observations at ICIPE that baiting traps with cow urine does improve the fly catches and may enhance trap performance when used for monitoring low fly populations in settled areas within endemic tsetse-infested areas. The presence or absence of baits did not influence the sex ratio or age groups in the traps.

This study covered two rainy seasons (March–July and November–January) and one dry season (August–October). During this period the highest catch was realised in March 1994 and the lowest in October 1994 (Figure 7). Another peak, but lower than that of March, was in December 1994. This population cycle appears to synchronise with the rainy seasons and the vegetative growth in the area. The role of climatic factors in determining tsetse population fluctuations has not been well studied but our studies suggest the possible role of these factors, especially rainfall, in patterns influencing tsetse abundance. Rainfall may be a factor which is instrumental in creating seasonal outbreaks of the flies and nagana in peridomestic situations in the Kwale area, as reported by the veterinary division (MOALDM *Annual Reports*).

Data from comparative studies on fly catches in forest and settled areas in the Muhaka area show that the highest (150 flies) catch was from traps located 500 m into the forest (Trap 2), followed by traps at the forest edge (132 flies, Trap 3). Traps located in the forest centre (Trap 1) gave low catches (37 flies). The catches declined to 16 flies in traps 5 and 6 located further away (1.0 and 1.5 km, respectively) from the forest edge. Data obtained from this brief study was inadequate for a reasonable comparative analysis on fly population abundance in the two situations.

2. *Vertical distribution patterns of* Glossina *spp. at Shimba Hills Game Park*

In studying and monitoring tsetse populations, dispersal and movements, as well as for control, the present strategy is based on horizontally deployed traps at ground level. No studies have been conducted on the vertical distribution patterns and responses to traps deployed at different heights above ground level on the three tsetse fly species occurring at the Kenya coast. The importance of vertical distribution has been shown in sandflies, where studies have revealed that flies highly infected with promastigotes were caught at 39 m above the ground and none at ground level in forests in Honduras. In Baringo, Kenya, it has been shown by

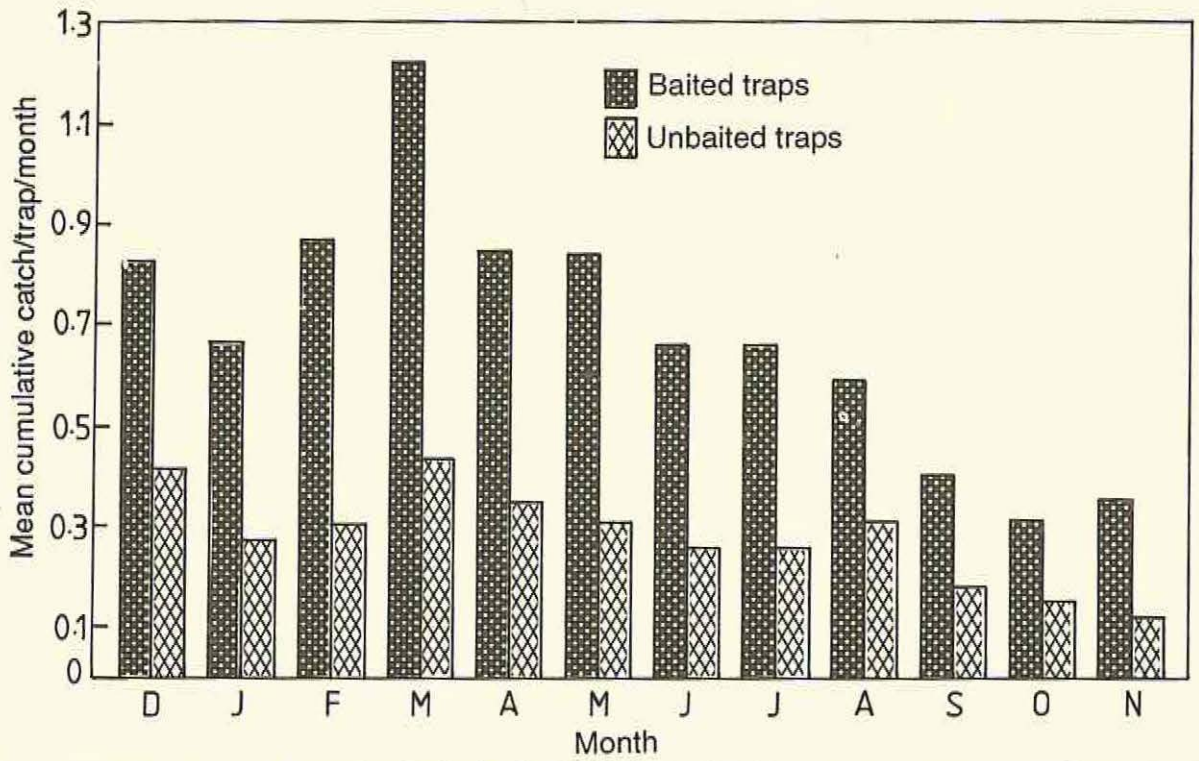


Figure 7. Total tsetse catches in baited and unbaited traps at Muhaka Forest on the Kenya coast from December, 1993 to November, 1994.

ICIPE that different species of phlebotomine sandflies are vertically distributed at heights 0–11 m in wooded areas and 0–9 m in open fields and that the largest number of flies were caught at 0–7 m and 0–4 m, respectively.

This report provides data from studies on tsetse conducted at Shimba Hills Game Park. The studies were conducted during April–August, 1994. Different trap deployment patterns, between heights zero to 4 m above the ground level were used: In pattern A, traps were deployed at 1-m vertical intervals placed directly above each other, while in pattern B, traps were deployed vertically but staggered at distances of 3 m from each other. The study was repeated five times between March–June, 1994 and the data pooled for analysis. The studies aimed at,

(i) determining the optimum trap deployment patterns and heights for population monitoring and other studies;
(ii) understanding the tsetse vertical distribution patterns leading to determining how other factors such as wind speed, host odour plume, vertical variations in microclimate, etc., may influence tsetse movement and dispersal;
(iii) relating fly movement and behaviour patterns to possible host animals resting and moving above the ground level;
(iv) determining the relative abundance of and trap attractancy to the three tsetse species occurring in the Park.

The results show that tsetse catches per trap per day (CTD) vary with trap deployment levels above the ground. The ratios of CTD in the two trap deployment patterns (B:A) for males, females and total flies are 4.41, 4.06 and 4.2, indicating that all the traps deployed in pattern B caught four times as many flies as A. The proportions were similar in both sexes indicating that the patterns did not discriminate between fly sexes (Figure 8) nor was there any variation with vertical deployment of the traps. Data from two other patterns were inconsistent and not considered in this analysis. Comparison between patterns A and B show that the latter caught four times more flies than A and proved more useful in satisfying the objectives of the study. For instance the mean number of flies caught per trap per day in pattern B was 51.8 at 0–1 m, 18.7 at 1–2 m and 7.5 at 2–3 m, while the respective numbers for A are only 12.1, 5.1 and 1.4, respectively. The mean number of flies caught by all traps in pattern B per site was 78.0 compared to only 18.6 in pattern A.

Considering the number of flies caught per site in each deployment pattern, *G. pallidipes* was predominant, at an average percentage of 71.8% flies in B and 17.5% in A. These constituted 92.0% and 94.4% respectively of the total fly population in both cases. In all cases, the data show that *G. pallidipes* constitutes more than 90% of the total tsetse fly populations in Shimba Hills Game Park. This species could accurately be used to estimate and study both horizontal and vertical population patterns of *Glossina* spp. in this area. The other species numbered on average only 4.89 flies for *G. austeni* and 1.33 for *G. brevipalpis* in B and 0.79 and 0.25 flies in A, respectively. The numbers of *G. brevipalpis* were too low for a meaningful comparison of the vertical distribution patterns of this species.

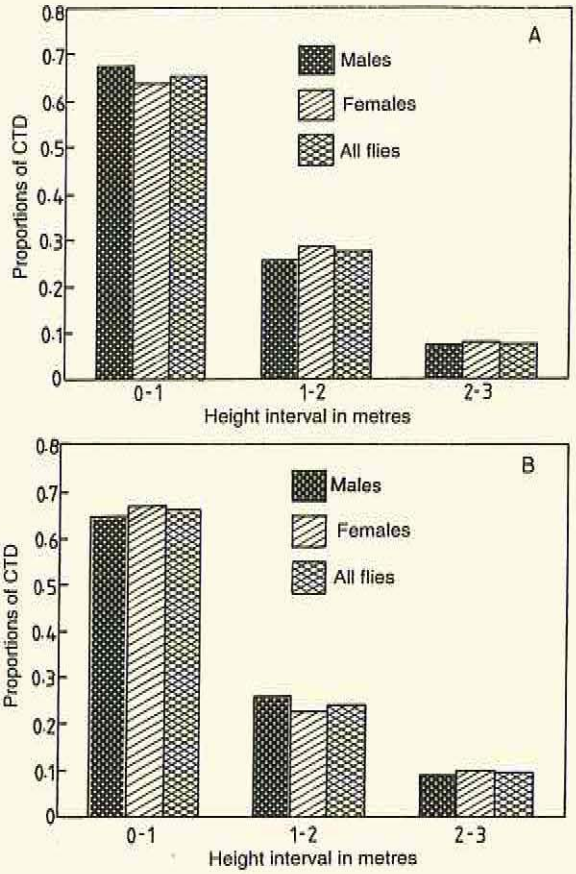


Figure 8. Proportion of all *Glossina* species in catches using two different trap deployment patterns. A, Traps deployed at 1 m vertical intervals above each other; B, traps deployed vertically but staggered at distances of 3 m from each other.

The results suggest that *G. pallidipes* populations estimates followed closely the trend in distribution patterns in total fly populations. A similar trend but to a lesser extent was observed in the case of *G. austeni* in pattern B.

It was observed that when traps were placed at ground level, they caught only 65–66.4% of all trapable tsetse flies in each site, while the rest (35%) were caught at higher levels. This reveals that in designing traps, an optimum trap deployment height must be in-built for improving trapping efficiency. When traps were placed at levels above 3 m, i.e. at 3–7 m, very few flies were caught, the number being inconsistent and not analysable. However, this indicated that tsetse flies were attracted to objects such as traps at higher elevations (>3 m) which might to some extent influence their feeding, resting and dispersal behaviour. A model for optimal trap deployment height was developed from the field data; these results are reported elsewhere.

3. *Role of wild host animals in abundance, movement and dispersal of tsetse*

Previous studies have shown wide variations in tsetse populations, even within similar ecological areas in

close-by areas. These variations do occur in time and space, making the data difficult to analyse, interpret and predict. Little information is available on factors responsible for tsetse population changes, movement and dispersal within and between different ecological areas. This information is important in understanding the phenomenon of tsetse infestation and re-invasion into respective new and 'control' areas and the subsequent disease epidemiology. Of particular interest is the fact that natural tsetse habitats are closely associated with natural vegetation, game reserves, or secondary woodlands where human interference is minimal. However, such areas usually border human settlements and agricultural areas, a situation characteristic of the coastal region of Kenya.

The objective of this study was to determine the influence of movement of wild animals on tsetse fly abundance, movement and dispersal within the natural habitat and their potential in causing re-invasion and disease epidemiology into the neighbouring domestic areas. Several study sites were selected in different parts of Shimba Hills Game Park, i.e. grazing sites, watering points, animal tracks and resting sites. Detailed observations were made on three animal species: elephant, buffalo and sable antelope. Other animal species found in association with these three were recorded. The studies were conducted between July and November, 1994 using NG2B traps.

The results showed high variations in trap catches between different sites (Figure 9). Daily trap catches were also variable. Three sites at buffalo resting sites (B), elephant track (F) and watering sites (W) gave consistently high fly catches. Other sites (G, FL1, and FL2) gave lower trap catches. Site G was the common grazing site in open grassland, while FL1 and FL2 (located in thickets) did not show any animal activities. Site F gave the highest fly yields, followed by W and then B.

At site B, located in open grassland as was G, the results showed that fly abundance was closely related to the absence or presence of buffalo at the site. The number of flies attracted to the traps was high when the buffalo were at the site but minimal during their absence (Figure 10). It was also observed that the fly abundance was not influenced by the mere number of buffalo, but by their presence or absence at the site.

Data from elephant track sites reflected a similar trend, as the fly numbers were highest whenever there were fresh elephant track marks near the sites. In the case of water points, the numbers of flies remained reasonably high throughout the study period, but the trap catches increased significantly whenever animals visited the site. Even though the study sites were frequented by many wild animals, the proportions of fed flies to the traps were extremely low (0.3–4.5%) suggesting that the traps were not suitable for catching fed flies.

These studies show that wildlife are major factors influencing tsetse fly abundance as well as movement and dispersal. In the case of buffalo and elephant, their absence even for only a short time resulted in low fly numbers and *vice versa*. Visual observations on the two animal species also showed that they were followed by large numbers of flies. In the case of sable antelope, these animals, although moving in herds, were too mobile for any reasonable data to be obtained. Their grazing and resting sites were inconsistent. However casual observations showed that they were followed by tsetse flies during their movement. Information available from the Kenya Wildlife Service (KWS) officers in the park show that the sudden influx of a large number of flies at a site is an indication of the presence of wild animals, especially buffalo and elephant within the vicinity. Thus, it is common practice to use tsetse flies as indicators of animal movement or approach in the park and peridomestic areas.

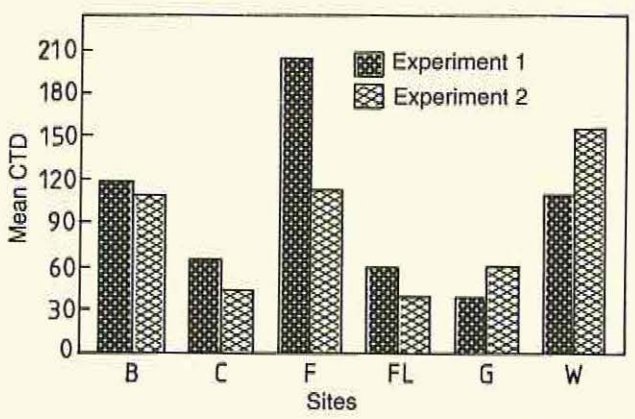


Figure 9. Mean fly catches at different trapping sites in Shimba Hills Park in relation to wild animal movement. Sites: B, buffalo resting in open grassland; C and F, elephant tracks; FL, thickets with no animal activity; G, buffalo grazing site in open grassland; W, buffalo watering site.

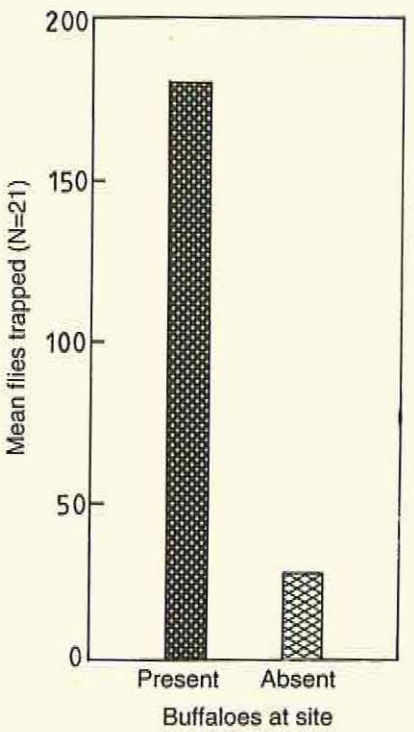


Figure 10. Mean number of tsetse trapped at buffalo resting sites with or without buffaloes (data from 21 traps).

4. *Use of mark-release-recapture technique (MRRT) to determine movement and dispersal in tsetse flies in the game park and peridomestic areas*

To date, little is known about the mechanisms of tsetse movement and dispersal and the relationship between the populations in the forest vegetation and peridomestic sites. Further, it is important to evolve suitable methodologies for investigating the phenomenon of tsetse movement and dispersal for better understanding of invasion/re-invasion behaviour of the flies into new or control areas. This report gives the results of preliminary investigations using the mark-release-recapture technique (MRRT) to determine patterns of tsetse movement and dispersal as a prerequisite for understanding mechanisms and factors influencing these activities.

NG2B tsetse traps were set at various sites known to contain high fly numbers in order to collect flies for the mark-release-recapture studies. Winton oil colour paints were used to mark flies. Small quantities of the paint diluted carefully with linseed oil was applied using the round end of an insect pin onto the prothoracic segment to give a colour dot. Flies (10,950) marked using cream colour paint were released at Longomwagandi Forest, while those (12,800) marked with bright green paint were released at Makadara forest. Marking for this study was done for a period of three (3) days in each case.

To determine fly movement and dispersal from the release point, NG2B traps baited with cow urine were set at different sites and distances at least 500 m from the release sites. In the case of flies released at Longomwagandi Forest, traps located at various sites such as buffalo resting sites (B1, B2 and B3), elephant tracks (C1 and F1), water points (W1, W2 and W3) and open grassland (G3) were set to monitor the fly movement. In Makadara Forest, traps were set between the release site (MF1, 500 m from release site) and the Kidingo gate (MF8, 5 km from release site) bordering settled areas. Initially the traps were left at the sites for a period of 10 days while being checked daily, when flies were collected for examination. After this period traps were set at weekly intervals for five days for a period of 2 months. The whole experiment lasted from 27 November, 1994 to 15 February, 1995.

Data obtained from both studies, though preliminary, yielded some interesting information on tsetse fly movement and dispersal patterns. Other experiments designed to give more detailed data were discontinued due to staff transfer, lack of funding and inadequate time.

In the first experiment in Longomwagandi, a total of 7161 flies were collected from all the traps in 10 days, of which 70 flies marked with cream paint were recaptured. There was a wide variation in trap catches at different sites, with the maximum number of flies (1533) being recorded at B1 and the lowest (161) at G3. No marked flies were recaptured at sites B2, FL3 and G3. Site G3 is open grassland, FL3 is a forest with no sign of animal activity and B2 is a buffalo site rarely visited by the buffaloes.

High fly catches were found at buffalo site B1 (1533 flies) of which 31 flies were marked; the elephant track site, F1, gave 1475 flies, out of which 6 were marked; the water pool site, W1, had 1445 flies, with 15 marked flies recaptured. At sites W2 and W3 with 487 and 705 flies, respectively, seven marked flies were recaptured at each site, while at site B3, with 309 flies, only one (1) fly was recaptured. Sites W1, W2 and W3 were located to the north of the release site, while G3, B3 and W3 were to the southern side. Sites C1 and FL3 were to the west, while sites B2 and W2 were to the east. The furthest sites to the release site were F1, B2 and B3, out of which F1 had the highest recaptures of marked flies. In general, the sites to the north gave relatively higher recoveries of marked flies compared to the other directions. All the water points gave good recaptures of marked flies with W1 leading with 15 marked flies and the others having 7 each. The two elephant track sites yielded 6 marked flies at F1, compared to only 3 at C1. In general the marked flies were recorded in all four directions from release site.

Data from studies at Makadara forest showed that after only five days, flies could be recovered at Kidongo gate (MF7) some 5 km from the release site. The highest recoveries were made at MF3 followed by MF6 which were 2 km and 3.5 km away from release site, respectively. MF8 did not yield any marked flies, but being only 500 m from MF7, at the park border, where the last marked flies were recorded, indications are that some flies might have crossed into the settlement areas bordering the park.

It was found that tsetse flies have a high mobility and dispersal capacity. The results suggest that fly movement and dispersal are closely associated with those of wildlife, especially elephant, buffalo, sable antelope and warthog. Both buffaloes and warthogs were often found together at B1, B2, and B3 as well as at common resting sites. During the study both animals were predominantly present at B1 and found only occasionally at the other sites. Similarly, all the animals listed above were frequent at the water point, W1. Both B1 and W1 gave the highest proportion of the recaptured marked flies, 44.3 and 20%, respectively. Site F1 was only 2 km from the main Kwale gate and located on the elephant track leading to the Marere river, the main water point for wildlife and domestic animals to the west of the park. Although traps were not set at the river, the fact that 8.8% of the recaptured flies were trapped on the track suggest the possibilities of flies following the elephants or other animals using the track to the river.

Studies at Makadara-Kidongo route suggest that flies were carried by some mechanism and within 5 days could be found at the gate (MF5) some 5 km away. These results suggest continuous invasion by the flies into the neighbouring settled area from the park, facilitated possibly by wildlife movements. Detailed studies are required to elucidate the tsetse fly dispersal and movements from natural habitats to peridomestic areas, a phenomenon which may suitably be investigated using MRRT.

6. TSETSE LONGEVITY VERSUS BLOODMEAL SOURCE/SIZE

Participating scientists: *A. Odulaja, J.O.A. Davies-Cole*

Background

Tsetse flies are known to have specific host preferences. The need to establish tsetse laboratory colonies for research purposes makes it imperative to understand the various factors which influence the longevity of flies. However, difficulties have been faced in establishing colonies for some species of the tsetse. Observation is usually made on a cohort on insects kept under monitored environmental conditions to study the rate of development. In such studies, the problem of premature death (drop-out) is prevalent. This results in incomplete data sets.

Reasons for drop-out may include environmental conditions, bloodmeal source, bloodmeal size, bloodmeal frequency, and feeding method. We investigated the dropout mechanism in a set of bloodmeal size data obtained from a laboratory colony of tsetse. The aim was to examine the nature of premature death (drop-out) of flies as related to the size of bloodmeal taken.

Work in progress

A cohort of female tsetse (*Glossina morsitans centralis*) was kept under controlled laboratory conditions (25 ± 1°C, L:D 12:12, and 70–80% relative humidity). The flies were allowed to mate and later randomly divided into five groups of 30 flies. Each group was fed through silicon membranes at 2-day intervals on fresh defibrinated blood of one of the hosts—buffalo, eland, goat, rabbit and waterbuck. The size of bloodmeal intake was recorded for each fly at each feeding opportunity for four gonotrophic cycles. The gonotrophic cycle of each fly was recorded at drop-out time. The experiment was terminated after 52 days. Two questions were to be answered: (1) Is the drop-out process dependent on bloodmeal size and/or the fly's gonotrophic cycle? (2) Does the present bloodmeal size at drop-out influence the drop-out process more than the previous meal?

Method

Given C groups of flies, each fed on different bloodmeal sources, let M_i, i=1,..,C, be the number of flies in group i. A complete sequence of n longitudinal bloodmeal size measurements may be represented as:

$$(Y_{ij1}, \ldots, Y_{ijn});$$
$$i=1,..,C;\ j=1,..,M_i.$$

The drop-out indicator for each fly is defined as

$$R_{ij} = \begin{cases} d & \text{if fly j in group i drops out at time d,} \\ n+1 & \text{if fly is completely observed.} \end{cases}$$

If $R_{ij} = d \leq n$, then a sequence of bloodmeals (Y_{ijd},.., Y_{ijn}) are missing while (Y_{ij1},.., $Y_{ij,d-1}$) are observed. Hence, bloodmeal history of fly j in group i at time d is

$$H_d = (Y_{ij1}, .., Y_{ij,d-1})$$

The general model for drop-out process assumes

$$\text{Prob}\ (R=d/H_d, Y_d) = P_d(H_d, Y_d/\beta)$$ where β is a vector of unknown parameters. The joint distribution of Y and R has been described and parametised in the literature.

Three possible drop-out mechanisms have been defined. These are: (i) complete random drop-out (CRD)—fly's drop-out independent of bloodmeal size, (ii) random drop-out (RD)—drop-out process depends on H_d, (iii) Informative drop-out (ID)—drop-out process depends on unobserved bloodmeal.

We employed a logistic linear model to investigate these drop-out processes. The model is represented as

$$\text{Logit}\ \{P_d\ (H_d, Y_d/\beta\} = \gamma$$

where γ is a linear predictor made up of the bloodmeal size history, current bloodmeal size, and gonotrophic cycle. This is spelt out for each bloodmeal source data set and combined as

$$\text{Logit}\ \{P_k(H_k, Y_k/\beta)\} = \beta_0 + \beta_1 Y_{k-1} + \beta_2 Y_k.$$

A re-parameterisation of the drop-out parameters for easier interpretation of the ID process gives

$$\text{Logit}\ \{P_k(H_k, Y_k/\beta)\} = \beta_0 + \theta_1(Y_k+Y_{k-1}) + \theta_2(Y_k-Y_{k-1}).$$

Hence, $\theta_1 = (\beta_2+\beta_1)/2$ and $\theta_2 = (\beta_2-\beta_1)/2$. The maximum likelihood estimates of all the parameters were obtained.

Results

The probability of drop-out was found to depend more on previous rather than current bloodmeal size before drop-out. This probability, however, decreased with increase in both previous and current bloodmeal size. The risk of drop-out increased when the current bloodmeal size was higher than the previous one while the risk decreased with increase in the mean of the two bloodmeals.

Both the ID (Informative Drop-out) and the RD (Random Drop-out) models fit the data better than the CRD (Completely Random Drop-out) model, but the ID model is not significantly better than the RD model. The implication is that the drop-out process depended more on the observed bloodmeal size preceding the drop-out.

Differences in drop-out mechanism were obtained between the host sources.

7. TSETSE INTERLARVAL PERIOD

Participating scientist: A. Odulaja

Background

Growth rate is central to the modelling of any population. One of the important components of growth rate in tsetse population is the natality rate, which in turn is a function of the interlarval period. Hence, an understanding of the distribution of female tsetse interlarval period is crucial to modelling the population.

Female tsetse kept under identical conditions larviposit at different intervals of time during any gonotrophic cycle, probably due to inherent differences between individuals in the population. This is the stochastic aspect of tsetse larviposition which is very important for predictive purposes.

Work on modelling of tsetse interlarval period, among individual flies as well as their frequency distributions, is rare. Tsetse population models are often developed incorporating the interlarval period as a fixed value without provision for its stochastic nature. This work provides some preliminary exercises aimed at modelling tsetse interlarval period, which takes into consideration its stochastic variability. Such models may then be incorporated into existing tsetse population models for higher accuracy in predicting population growth rates.

Work in progress

Description of data

Data used for this exercise were obtained from a cohort of female *Glossina morsitans centralis* maintained at 25 ± 1° C, L:D 12:12 and 70–80 % relative humidity. The flies were divided into six groups, and each group was membrane-fed on alternate days on fresh defibrinated buffalo, eland, waterbuck, rabbit, cow or goat blood (N between 30 and 37 flies per group). The flies were allowed to mate singly when 3 days old with 7-day-old males in transparent plastic vials (4 x 3 cm) with black nylon netting. Each fly was observed up to the fourth gonotrophic cycle or death before the experiment was terminated. The first cycle was eliminated from the analysis of the data.

Preliminary analysis

Since the exact larviposition time for a particular fly was unknown, it was assumed to be uniformly distributed within the interval just before the larviposition was observed. The central value of each class (class mark) was therefore taken as a reasonable estimate of the interlarval period for the flies in that class when constructing the frequency distribution table.

All the frequency histograms of interlarval period for each of the three cycles (over all hosts) separately as well as combined, were skewed toward the longer periods. Hence, the central values (median) were used to calculate the mean interlarval period of the distribution. The median interlarval periods were respectively 11.675, 11.464, and 11.423 days for the second, third and fourth cycles.

Model

Our approach was to model the cumulative density function (CDF) of the frequency distribution of the interlarval period data by applying a probability function directly to the measured distributions. The variability in these distributions for the different cycles was assumed to be relatively independent of hosts, while the distributions for the hosts were likewise relatively independent of the cycles. Hence, a single host-independent and cycle-independent distribution of normalised interlarval period was used to describe the distributions for all cycles and hosts.

We used the median interlarval period as the norming constant because the median was less sensitive to outliers which were very prominent in the usually skewed interlarval period data. Using the median period also forced all the distributions to coincide at least at their midpoints. We then obtained by linear interpolation the period after which given percentages of the flies would have larviposited. These were then divided by the median period to give the normalised distributions. A three-parameter Weibull function of the form

$$F(x) = 1 - \exp(-[(x-\gamma)/\eta]^{\beta})$$

was then fitted to the normalised distribution, where F(x) is the probability of larviposition at normalised time x and γ, β and η are parameters to be estimated.

Model evaluation

The shapes of the normalised distributions were found to be similar but not identical for all the cycles.

The coefficient of variation between the normalised distributions obtained for each cycle was computed at various points (0.01 to 0.95) along the cumulative frequency values to obtain the extent of similarity of shapes of the distributions. These ranged between 0 and 12.52%; hence, the distributions are sufficiently similar to be represented by a single function. The observed differences could be due to small sample sizes in some cycles (n=119, 95 and 64 for cycles 2, 3 and 4, respectively). The goodness-of-fit of the Weibull function applied to the weighted normalised distribution was 99.59% as measured by the R-square.

The function proposed in this study can be used to predict the interlarval period of individual flies in a population at different cycles using a rate-summation approach.

8. KWALE/KILIFI ADAPTIVE RESEARCH PROJECT ON SUSTAINABLE MANAGEMENT OF INSECT PESTS AND TSETSE IN COASTAL KENYA: TSETSE TRAPPING COMPONENT

(See the report of this project under Project X of Plant Pests Research Programme for the project background and other information.)

Participating staff: *C. Kyorku*

Collaborators: *KARI staff*

This year marked two major activities (1) completion of bench mark data collection on the incidence of tsetse and trypanosomiasis at the target sites chosen for mass trap deployment, and (2) launching of pilot mass trap deployment in a 50 km^2 area involving these sites in Shimba Hills of Kwale District.

Work in progress

1. Bench mark data collection

Monthly sampling of tsetse populations for a 12 month continuum, by installing the improved design (NGU2B) of tsetse trap at the chosen sites was completed. Concurrent monitoring of the disease incidence on about 1000 head of cattle was also completed, by blood sampling and scanning for trypanosomiasis infection. In addition, indicative data were also collected on cattle productivity, especially on milk yields for enabling long term comparisons.

2. Mass deployment of traps

The mass deployment of traps, although delayed due to resource flow constraints, was launched during July–September. This involved sensitising the local community, training of farmers, training of frontline extension and farmers leaders on the principles and practices governing the mass deployment of tsetse traps. Groups were formed at each site for selecting the locations for the traps as well as to undertake periodical servicing of the traps including replenishing the materials for odour source (acetone and cow urine).

*(*See under Project V, page 113 for the ticks research component of this project.)*

III. Adaptive Research to Assess the Sustainability of the ICIPE NGU Tsetse Trap for Community-Based Management of Tsetse and Trypanosomiasis in Lambwe Valley, Kenya

Participating scientists: *J. W. Ssennyonga*, F. G. Kiros* (adoption studies), M. M. Mohammed (biological studies), G. T. Lako, A. N. Ngugi (economic analysis), N. K. Ndirangu, E. O. Omolo (land use)* (*Project Coordinators)

Assisted by: *P. O. Agutu, T. Anode, M. W. Were, R. O. Tumba, J. O. Obinga*

Donor: *Natural Resources Institute (NRI), UK*

Collaborators: *Lambwe Valley Community, Nyanza, Kenya; Natural Resources Institute (NRI), UK; Ministry of Agriculture, Livestock Development and Marketing, Kenya*

Background

After the technical success of ICIPE's NGU trap at Nguruman, S.W. Kenya was achieved, a project was launched in the mid-1980s to evaluate its efficiency in Lambwe Valley, western Kenya. Within 8 months, apparent fly density was reduced from 200 flies/trap/day to below 1 fly/trap/day. Noting these results, the Lambwe Valley community began to press for the widespread deployment of traps. ICIPE used this opportunity to develop a community-based project aiming to assess aspects that had not been determined at Nguruman.

Project objectives

The most important objective is to demonstrate that the community can, relying on its own resources, manage tsetse and trypanosomiasis, using the NGU trap. Other objectives are to:

- provide a framework for the widespread dissemination of tsetse trapping technology (TTT);
- identify options for community management of TTT;
- prepare a monitoring plan to assess the impact of TTT on tsetse population, trypanosome infection, cattle productivity, land use and the environment;
- train extension workers and to develop extension tools.

Implementation strategy

A three-pronged approach was taken. First, researchers would train a catalytic group of 42 farmers (CGF), who would, in turn train and mobilise their community. Second, the adoption process would be based on a sound understanding of tsetse, nagana, how traps work, organisation and management principles. Third, the community would be wholly responsible for managing and financing the technology; other agencies would provide facilitative services.

Activities were planned to follow a logical sequence as follows: (i) baseline studies; (ii) community mobilisation; (iii) formation of effective organisation and management; (iv) mobilisation of resources; (v) trap deployment; (vi) impact assessment; (vii) monitoring and evaluation.

Work in progress

1. TRAP DEPLOYMENT

January 1994 marked the beginning of trap deployment. Community trap managers selected 493 trap sites in January–February following which a three-phase trap deployment plan was developed: 64 traps in Nyaboro thicket (phase I), 120 barrier traps along Ruma National Park (phase II) and 309 traps at the foothills (phase III). Traps were made in March–June. In May, 16 criss-crossing transects were cut in Nyaboro thicket. Finally, 64 traps were placed and serviced between July and December.

2. IMPACT ASSESSMENT

Trap placement set the stage for assessing the impact of TTT on tsetse population, trypanosome infection, cattle productivity, land use, and human welfare. Although these activities are technical tasks, farmers have been trained to participate in performing them to enable them grasp the benefits of TTT. However, it is too early to assess the impact on cattle productivity, land use and human welfare.

3. REDUCTION IN TSETSE POPULATION

The apparent densities of male and female *G. pallidipes* in April to June ranged between 0.8–1.4 and 2.1–2.8/trap/day respectively. After trap deployment in July, the density dropped gradually to 0.2/trap/day. In addition the population became younger as trapping gained momentum. This is remarkable because density was already low.

4. REDUCTION IN TRYPANOSOME INFECTION

The trypanosome infection rate in tsetse and cattle also declined as a result of trap deployment. For example, *Trypanosoma brucei* infection was not detected by December and overall, infection declined by 25-fold compared to 1993 levels. Similarly, the disease incidence in cattle fell by 80-fold in high challenge areas.

5. ORGANISATION AND MANAGEMENT

The above results could only be achieved with a high degree of organisation and management efficiency. The community is managing three major tasks simultaneously, namely: (i) the community organisation, (ii) resource mobilisation, and (iii) trapping.

Management of the organisation

This is achieved through meetings in which all activities are planned and controlled. Accordingly, a total of 115 meetings were held, 89 and 26 at block (unit of 2–5 villages) and Kisabe (central unit coordinating activities of blocks) levels. Two trends emerged. The number of meetings at Kisabe level have risen steadily, mainly because it is responsible for trap deployment in phase I. Meetings per quarter have declined slightly, mainly because of the inception of trapping activities. Leaders have also recognised weaknesses in management and are taking remedial measures.

Resource mobilisation

Four different kinds of resources are being mobilised and managed on a continuous basis. These are: money, materials, labour, and premises for storage, holding meetings, etc. The first task was to put in place a sustainable mechanism for mobilising these resources.

Management of funds is one area that still poses problems, mainly because of the lack of education in financial management. Plans are underway to organise a short training course on this topic.

Management of trapping activities

Each block recruits four persons on each Wednesday and Saturday, to work on trap placement and servicing. Traps are made by a group of 'trap managers' selected from all the blocks. Data collected so far reveal that trap deployment is far more labour intensive than is commonly believed. The nature of plant cover is an important factor. For example, Nyaboro thicket is covered for the most part by thorny shrubs and becomes waterlogged in wet months. Thus, it took 65 men (952 man-days) to cut 16 transects while trap servicing has taken 66% of the 569 man-days spent on trap deployment, with women contributing 42% of this.

Future activities

Monitoring and evaluation (M&E) will be the major activities for all the project components. The impact of TTT will be monitored and evaluated. Community management and organisation, resource mobilisation, and trapping activities will be monitored.

It should be noted, however, that the achievements of the community are already beginning to attract attention as evidenced by the number of visitors and requests for collaboration. ICIPE and ILRI will launch a joint research project in January 1995, funded by IFAD, aiming to assess tsetse control technologies and their impact on agricultural production, the environment and human welfare. The World Resources Institute (WRI) is exploring the feasibility of including this project in a global network of eight case studies of projects showing built-in collaboration and use of IPM strategies for pest management. The Nairobi Cluster, an informal organisation of researchers on livestock development in Kenya, sent a delegation of 17 members to familiarise themselves with the implementation of community-based TTT in Lambwe Valley, 17–19 November 1994.

IV. PESTNET Community-Based Disease Vector Control Programmes in Ethiopia

Participating scientists: *Getachew Tikubet, M. Makayoto, L. Otieno*

Assisted by: *B. M. Muiia and field staff from Ministry of Health, Ethiopia*

Donors: *EU, UNHCR*

Collaborators: National: *Ethiopian Science and Technology Commission (ESTC), Ministry of Agriculture, Ministry of Health, Ministry of Education through Addis Ababa University, Region Twelve Administration, Southern Ethiopian Peoples Regional Administration through Agricultural Bureau.* ***International:*** *Oxford University, UK, University of California, USA, University of the North, South Africa, Howard University, USA, The Regional Centre for Services in Surveying, Mapping and Remote Sensing (RCSSMRS), Nairobi, Kenya*

Background

Following the signing of a country agreement between the ICIPE and the Government of Ethiopia in January, 1993, the ICIPE/Ethiopia Collaborative Programme has mounted a pilot project for control of disease vectors in Bonga, Gambela, in collaboration with the Transitional Government of Ethiopia and with the United Nations High Commissioner for Refugees (UNHCR) and the communities in Bonga and Bedessa at large. The project validates simple cost-effective and sustainable technologies developed by ICIPE for the control of mosquitoes, tsetse flies and filthflies.

Work in progress

1. TSETSE AND TRYPANOSOMIASIS

The high incidence of tsetse and trypanosomiasis in the Bonga, Gambela area is surprising because previous reports and observations do not reflect the current situation. As a result, the study was focused to establish the vector and disease situation and to develop a feasible control strategy for the area. The initial survey conducted showed that the fly infestation is very high: 1200 *Glossina tachinoides* and 410 *G. fuscipes* were collected in three sampling periods with 15 traps. The NGU trap gave the highest catch for *G. tachinoides*, but this requires further investigation. Over 366 animals were tagged and bled in Bonga (108), Fugnido (160) and Itang (98) and the proportion of *T. congolense* infection was found to be 15.8%, *T. vivax* (4.6%) and *T. brucei brucei* (0.27%).

The pilot study has therefore demonstrated the relative abundance of the vectors and the existence of the disease in the area. Hence, an intervention package has been submitted to the Ethiopian Government and UNHCR for consideration.

The Ethiopian Science and Technology Commission (ESTC), the Southern Peoples Regional Government and the International Centre of Insect Physiology and Ecology (ICIPE) mounted a joint community based tsetse control project in Bedessa, Wollayta Sodo. This was reported to be a high challenge area, with reports of cattle dying because of trypanosomiasis and the people of the area suffering from chronic shortages of milk, meat and animal power for traction.

The prevalence of trypanosomes was found to vary from 24–31% in different peasant associations. *Trypanosoma congolense* and *T. vivax* were the dominant parasites in the area.

Nine hundred eighty (980) NG2B traps were used covering 200 km^2 of fertile land. Currently, the fly population has declined from 100 flies/trap/day to 2–3 flies/trap/day, and the trypanosome prevalence has declined from 30% to as low as 10%.

In addition to tsetse, several thousands of biting insects (i.e. *Tabanus* spp., *Stomoxys*, etc.) were caught. The disease and economic implications of these flies is being examined.

2. MOSQUITOES AND MALARIA

The World Health Organisation (WHO) has acknowledged that "health today in Africa has reached a state of emergency". The Laboratory of Malaria Research at the United States National Institutes of Health (NIH) has denounced malaria as a "microscopic

murderer that remains the clearest single target for scientists interested in helping Africa". ICIPE believes that an effective malaria control programme must emphasise general public health rather than sickness treatment and therefore focuses on the management of the vector through ecological approaches and adequate sanitation.

The pilot project conducted data collection on the relative density of mosquitoes and species composition of malaria vectors. Although the relative density of mosquitoes was low, as expected, because of spraying and due to the season, the malaria incidence was 10.9%. The most dominant parasite was *Plasmodium falciparum*, which accounted for 83.3% of infections. This was followed by *P. vivax* and *P. malarae* which together contributed to 16.7% of infections. *Anopheles gambiae* and *An. funestus* were the most dominant malaria vectors incriminated during the study period.

About 1800 houses in the settlement have been fitted with the *Mbu Cloth* which is a large cloth impregnated with permethrin (pyrethroid) EC20. The remaining houses in the settlement are slated to be fitted with the Mbu Cloth and impact assessment and cost-benefit analysis will be conducted for future application of this technology elsewhere in Ethiopia. This study is continuing.

3. FILTHFLY CONTROL

The pilot field trials of the insect pathogen, *Bacillus thuringiensis (Bt)* or *Dudustop* in Bonga Refugee Settlement has shown a long lasting effect. Over 400 latrines were treated with *Dudustop*, which practically eliminated the larval population of flies in the pit-toilets, resulting in a notable decrease in adult flies. It is anticipated that a substantial decrease in transmission of infectious diseases such as diarrhoea and trachoma will follow. Cost element analysis indicates that the *Bt* can easily be produced using cheap and locally available raw materials such as molasses and protein sources such as soybeans. The cost of the treatment per toilet per year is estimated at US$ 1.0 which is far cheaper than chemical application. The establishment of *Bt* fermentation facilities in Ethiopia would facilitate the large-scale application of this technology.

(See also Project IX, page 129.)

TICKS RESEARCH

V. Development of Efficient and Environmentally Acceptable Tsetse and Tick Control Strategies for the Tropical Developing World: Ticks Research

Donor: UNDP, through the World Bank

Project rationale

Project Coordinator: G. P. Kaaya

Global losses due to ticks and tick-borne diseases have been estimated as US$ 7 billion and over 800 million cattle worldwide are constantly exposed to ticks and tick-borne diseases. Unfortunately, over half of the estimated global losses occur in Africa where 1 million cattle die annually. The major tick-borne diseases of livestock are theileriosis, babesiosis, anaplasmosis, heartwater and toxicosis (tick paralysis and sweating sickness). African swine fever is also transmitted by soft ticks. Dermatophilosis, associated with *Amblyomma* infestations, is also an important livestock disease. Economic losses due to East Coast fever alone have been estimated at US$ 168 million annually. Apart from mortality, tick infestation causes serious economic losses in cattle, e.g. reductions in growth rates, reduction in milk production, damaged skins and hides, etc.

The control of ticks in Africa, as on other continents, has relied mainly on commercial acaricides since their introduction in South Africa in 1890. The intensive use of these imported chemicals has led to various problems, e.g. tick resistance, environmental pollution including residues in meat and milk, and escalating costs. Several acaricides have been withdrawn from the market due to toxicity and tick resistance and currently there is no acaricide in use to which ticks are not at least partially resistant. It is estimated that Africa spends about US$ 720 million annually to import acaricides and since acaricides are purchased with foreign currencies, some countries are finding it increasingly difficult to afford them. Even when purchased, other logistical, economic and social problems make their use in communal dips very inefficient. In some countries, it has been estimated that only 3% of cattle dips are functional at any time.

In view of the above-mentioned tick control problems, ICIPE livestock ticks research section undertook to develop integrated tick control strategies that will utilise little or no acaricides and are therefore environmentally-friendly, and affordable by resource poor farmers who possess over 90% of the African cattle population. The current UNDP/World Bank project was therefore initiated in January 1991 to run for 5 years to conduct research on development of the alternative methods of tick control. The work has also received strong support from other ICIPE departments and units, especially from social science and biomathematics.

1. IMMUNOLOGICAL CONTROL OF *RHIPICEPHALUS APPENDICULATUS*: IMMUNE INTERVENTION AND ITS EFFECTS ON TICK POPULATIONS IN THE FIELD

Participating scientists: S. Essuman, A. Odulaja

Assisted by: P. Muteria

Background

Tick burden, the number of ticks infesting livestock at any given time, is one of the major causes of under-productivity and mortality among cattle and other livestock. It is therefore one of the major causes of the high economic losses in the livestock industry. The burden can only be effectively reduced to an economically tolerable level by reducing the tick population in the environment. The use of acaricides, with all its attendant problems, has been the main practice for controlling tick populations. There has therefore been a need for alternative control strategies. One such strategy could involve an immunological approach whereby the immune system of the bovine host is manipulated (by vaccination) such that cattle resist subsequent tick infestations. Briefly, this approach involves identification, isolation, purification and characterisation of immunologically potent antigens from either the whole tick or specific tissue of the tick. At ICIPE we have been concentrating on the midgut of the brown ear tick,

Rhipicephalus appendiculatus as the source of potential anti-tick vaccine antigens. We have particularly been interested in the membrane-bound proteins of the midgut (SMP-Gut).

Work in progress

Previous laboratory studies in rabbits and cattle (Zebu, Boran and Friesian) showed that the immune response due to immunisation with SMP-Gut (crude preparations, semi-purified and enriched glycoprotein fraction) could protect the animals to an appreciable degree against subsequent tick infestations. The studies also showed that the immune response induced by these immunogens augments immunity to infestation acquired naturally by the host through exposure to tick infestations. Another effect documented is that the immune response enhances anti-tick effects and drastically reduces the lethal dose of systematically applied ivermectin. In order to evaluate their impact on tick population in the field, three different intervention regimes are being tried in the field at the Kuja River field site. The interventions are: (1) immunisation of Zebu cattle with semi-purified SMP-Gut, (2) immunisation of Zebu cattle with 'purer' fraction F2 (enriched glycoprotein fraction), and (3) combined (synergistic) effects of immunity induced by semi-purified SMP-Gut and the systemic anti-tick compound, ivermectin.

At the start of the experiments, proportional numbers of cattle were put in four paddocks and the paddocks seeded with nymphs and adult *R. appendiculatus*. The fourth paddock served as the control. The on- and off-host populations of the ticks were monitored. At the end of the six months the cattle were reshuffled and proportionally equal numbers of resistant and susceptible animals redistributed in the paddocks. When the on- and off-host populations of the ticks reached that of the surroundings the interventions were started. The interventions are still going on.

For the evaluation of the effects of intervention, the data collected before the intervention will be used as covariates in the analysis of the data collected after intervention. The dynamics of tick populations being monitored in the surrounding areas will be compared with those in each of the trial paddocks using the intrinsic growth rates. These growth rates will also be compared between the trial paddocks.

Completed studies

Essuman S., Latif A. A. and Muteria P. Immunological reactivity of sera from cattle in the field against tick-salivary gland antigens. *Journal of African Zoology* 108 (3), 261–265.

Sera from high and low tick resistant cattle from different ecological zones were used in immunoblotting in an attempt to correlate the differences in acquired host's immune resistance to specific salivary gland antigens. One of the two antigens with very close relative mobilities (M_r about 25Kd) were prominently recognised by sera from high resistant cattle. Sera from susceptible cattle strongly recognised antigens with the molecular weights of about 20 Kd and 30 Kd.

2. DEVELOPMENT OF IMPROVED METHODS FOR THE PRODUCTION OF 'TARGET' TICK ANTIGENS FOR ANTI-TICK STUDIES

Participating scientists: *N. N. Massamba, S. Essuman*

Assisted by: *R. K. Rotich*

Background

The antigen fractions (tick midgut proteins) when used as an immunogen and administered to laboratory animals and cattle as a vaccine result in the production by the animals of an immune response which is capable of producing anti-tick effects on vaccinated animals (e.g. reduction in tick engorgement weights, feeding period, egg masses and egg viability).

There has been considerable interest in the characterisation and isolation of tick antigens from various tick tissues that may be useful on the artificial induction of resistance. Progress has, however, been limited by the small amount of purified material for effective immunisation trials. This problem can be circumvented through the use of recombinant DNA technique to purify the antigens. The production and purification of recombinant proteins can result in large yields of pure and homogeneous molecules.

Work in progress

Experiments were initiated to characterise polypeptides produced by clones in expression libraries constructed from tick gut tissues. Poly (A) + mRNA was isolated from gut tissues of partially fed *R. appendiculatus* ticks using LiCl double precipitation procedure followed by phenol extraction and chromatography over oligo (dT) cellulose. Purified mRNA was then translated *in vitro* with a rabbit reticulocyte translation system in presence of ^{35}S- methionine. The *in vitro* synthesised proteins were immunoprecipitated and analysed on sodium dodecylsulfate polyacrylamide gel electrophoresis and identified by autoradiography.

Double stranded cDNA was synthesised and an expression library constructed in lambda gt 11 vector. Screening of the library is being done using sera from animals immunised with antigens fraction F2.

Future activities

Future work will focus on the characterisation of positive clones, isolation and the cloning of the genes in appropriate and efficient expression vector for the production of recombinant antigens to be used as potential anti-tick vaccines in laboratory and field trials.

3. TICK MIDGUT HAEMOLYSIN

Participating scientists: *W. R. M. Vundla, E. O. Osir, S. Essuman*

Assisted by: *R. Chesang'*

Background

Red cell haemolysin is a prerequisite for digestion, as the process releases haemoglobin, the major blood protein, thus facilitating its digestion by proteolytic digestive enzymes. However, in addition to its importance in tick physiology, the midgut haemolysin is likely to be important in disease transmission by ticks, as most pathogens transmitted by ticks enter the tick gut within erythrocytes. Previously, we reported the presence of a haemolysin in the midgut of the tick, *Rhipicephalus appendiculatus*.

Work in progress

The molecular mechanisms for inducing haemolysis are varied and include the combined action of proteinases and phospholipases, lipids and polypeptides without apparent enzymatic activity. It was, therefore, necessary to establish the nature of the *R. appendiculatus* midgut haemolysin. The experiments summarised below were designed to determine the nature of the midgut haemolysin through biochemical characterisation.

We studied the effects of temperature, boiling, substrate concentration, haemolysin concentration, as well as the effects of various inhibitors on haemolysis.

(i) The activity of the midgut haemolysin increased with temperature up to 40°C, after which there was progressive loss in activity. Boiling for 10 minutes completely abolished haemolysis, but the activity was restored to original level after 90 minutes at 4°C. These results indicate the involvement of a polypeptide, having at least a tertiary structure.

(ii) Haemolysis increased with an increase in substrate concentration in a typical Michaelis/Menten relationship. Such data are typical of enzyme activities.

(iii) Haemolysis increased with an increase in haemolysin concentration, and showed saturation kinetics. These results are also typical of enzyme activities.

(iv) The haemolysin was inhibited by calcium ions in a typical concentration-dependent manner. Dixon transformations of the inhibition data indicated a K_I of 7.9 mM for the inhibition of the haemolysin by Ca^{2+}. Other inhibitors studied were aprotinin, which had no effect on the haemolysin, and palmitic acid which inhibited the enzyme. The lack of inhibition by aprotinin suggests that the midgut haemolysin has no proteolytic component. The inhibition by Ca^{2+} and palmitic acid, as well as the positive modulation by EDTA (*1993 ICIPE Annual Research Highlights*) indicated the possible involvement of a phospholipase. In summary, our data show that the *R. appendiculatus* midgut haemolysin is an enzyme, and that it has a phospholipase component.

Future activities

The midgut haemolysin will be purified to homogeneity. Monospecific anti-serum to the haemolysin will be raised in rabbits, and its effects on the activity of midgut haemolysin will be assessed *in vitro* and *in vivo*.

4. BIOLOGICAL METHODS OF TICK CONTROL: TICK PARASITOIDS

Participating scientist: *E. Mwangi*

Assisted by: *J. Mugane, E. Njogu*

Background

Tick parasitoid work was started in 1990 when *Ixodiphagus hookeri*, a parasitoid of *Amblyomma variegatum* was reported from Trans-Mara area, Kenya. It has since been reported in two other areas, the Kuja River basin and Busia. A method of rearing parasitoids in the laboratory which has a 90% parasitisation rate when the ratio of parasitoid/ticks is 1:1 has been developed. Other completed studies in the laboratories include a study of its biology, and the development profile of the parasitoid in the tick. The main objective of this study is to adequately study and investigate the best ways of using the parasitoid for control of *A. variegatum*.

Parasitic wasps such as *Trichogramma* and *Cotesia* have been used for control of other pests in the field. Parasitoids of ticks were released in the USA and Russia and were found to have an impact on ticks. In Martha's Island, Massachussets, over 30% of ticks were found to be parasitised by *I. hookeri*, which had been released there in 1928. It is envisaged that *I. hookeri* would be used either inundatively or in classical biological control in areas where it does not occur naturally.

Work in progress

An experiment was conducted to assess the impact of *I. hookeri* on tick numbers on animals in a field at Mbita Point Field Station, using 10 cattle which had a mean pre-parasitoid infestation of 44 and 47 ticks per animal for *A. variegatum* and *Rhipicephalus appendiculatus*, respectively. After a release of 150,000 parasitoids over a period of 1 year, the level of *A. variegatum* was reduced to 2 ticks per animal while that of *R. appendiculatus* had increased to 75 ticks per animal (*R. appendiculatus*, not parasitised by *I. hookeri*, was unaffected). The recovery of parasitoids from engorged nymphs of *A. variegatum* was about 51%. This experiment has helped determine numbers of parasitoids required to bring tick loads down, and has shown that *I. hookeri* could be used for management of *A. variegatum* given the right climatic conditions.

In the laboratory, experiments were done on infectivity of *I. hookeri* to other ticks of the genera *Hyalomma* and *Boophilus*. No positive parasitisations were recorded.

Completed studies

Mwangi E. N., Kaaya G. P. and Essuman S. Experimental and natural infections of the tick *Rhipicephalus appendiculatus* with entomogenous fungi, *Beauveria bassiana* and *Metarhizium anisopliae*. *Journal of African Zoology* (in press).

Two strains of the entomogenous fungus, *Beauveria bassiana*, were found to be pathogenic to all stages of the tick *Rhipicephalus appendiculatus* in the laboratory. A mortality of up to 73% of unfed adults was recorded, while the entomogenous fungus *Metahizium anisopliae* was found to be only slightly pathogenic killing only 35% of unfed adults. Unfed ticks immersed in suspensions of *B. bassiana* spores engorged normally on rabbits, but 74% of them failed to lay eggs. The fecundity of those which laid eggs was reduced to 10% compared to controls in natural infections. 9.77% and 1.7% of 423 adult engorged *R. appendiculatus* females which have stayed in grass plot for 8 days died due to bacterial and fungal infections respectively. The isolated bacteria were *Enterobacter cloacae*, *Serratia marcesens* and *Proteus mirabilis*. The isolated fungi were from the genera *Aspergillus*, *Fusarium* and *Mucor* but their species were not determined. Large numbers of a laboratory colony of *Boophilus decoloratus* were found to be infected with *Staphylococcus aureus* and *Escherichia coli*. The possibility of using pathogens for control of ticks is discussed.

Mwangi E. N., Essuman S. and Kaaya G. P. Repellence of the tick *Rhipicephalus appendiculatus* by the grass *Melinis minutiflora*. *Tropical Animal Health and Production* (submitted).

In a study to develop anti-tick pastures, the climbing behaviour of *Rhipicephalus appendiculatus* on *Melinis minutiflora* (molasses grass) was investigated. Experiments were done with cut green stems of grass, grass dried in the shade, grass dried in the sunshine, grass washed in solvent and grass growing in a study plot. In all cases, a common pasture grass, *Pennisetum clandestinum* (Kikuyu grass) was used as a control.

All instars of the tick completely avoided climbing on the green molasses grass, as compared to 86%, 77% and 83% of larvae, nymphs and adults, respectively, which climbed on the control green Kikuyu grass. More ticks climbed on the stems dried in the sunshine than those which climbed on air-dried grass. Acetone was found to be the best of five solvents used to extract the tick-repellent substance. Possibilities of using *M. minutiflora* as a part of an integrated tick control package is discussed.

Mwangi E. N. Biological methods of tick control. In *Community Based and Sustainable Pest and Vector Management for Rural Development* (Edited by Otieno L. H. and Bugembe M.), pp. 29–32. ICIPE Science Press.

Mwangi E. N., Kaaya G. P. and Essuman S. Parasitism of *Amblyomma variegatum* by a hymenopteran parasitoid, and some aspects of its basic biology. *Biocontrol* 4, 101–104.

Unfed *Amblyomma variegatum* F. nymphs were experimentally infected in the laboratory with a hymenopteran parasitoid, *Ixodiphagus hookeri* (Howard). The parasitoid was originally obtained from ticks collected from cattle in the Trans-Mara area of Kenya where it naturally infects 50% of *A. variegatum* nymphs. In the field, nymphs collected from cattle were found to be infected, but not those collected from grass. The optimum temperature for emergence of parasitoids from the nymphs in the laboratory was 28°C, but emerged parasitoids were more active and survived longer at 22°C. There was a higher proportion of parasitoid non-emergence from the laboratory-infected than from the field-infected nymphs. This study is the first record of infection of *A. variegatum* in the laboratory with a parasitoid. Possibilities of mass rearing and use of the parasitoid as a biocontrol agent for ticks are discussed.

Future activities

(i) The second part of the experiment described above on assessing the impact of *I. hookeri* on tick numbers on animals will be carried out, after the parasitoid release is stopped. This part will show whether the parasitoid will have established itself in the environment, how long it will take for ticks *(A. variegatum)* to reinfest the cattle, and therefore will give an indication of how often *I. hookeri* should be released in a strategic release regime for management of *A. variegatum*.

(ii) An attempt will be made to develop better methods of rearing parasitoids by developing a method of storing parasitised ticks in the laboratory.

(iii) A study will be initiated to investigate the physical and chemical cues involved in host finding by *I. hookeri*, as well as field studies of flight range and host finding behaviour of *I. hookeri*.

5. EVALUATION OF ENTOMOGENOUS FUNGI, *BEAUVERIA BASSIANA* AND *METARHIZIUM ANISOPLIAE* FOR BIOLOGICAL CONTROL OF TICKS

Participating scientist: *G. P. Kaaya*

Assisted by: *E. A. Ouna*

Background

Tick control in Africa has relied heavily on chemical acaricides since their introduction in South Africa in 1890 resulting in problems such as environmental pollution, tick resistance and high costs. The use of entomogenous fungi, when fully developed, will be more environmentally-friendly, will reduce development of tick resistance and will be cheaper since the fungi will be mass-cultured in cheap local raw materials. It will also be more effective than commercial acaricides since it will not only be applied on ticks feeding on cattle but also on those questing in vegetation where ticks spend up to 95 percent of their lifetime.

Work in progress

Two entomogenous fungi, *Beauveria bassiana* and *Metarhizium anisopliae* in aqueous and powder spore formulations were tested in the field for their biocontrol potentials against two livestock ticks, *Rhipicephalus appendiculatus* and *Amblyomma variegatum*. The aqueous

spore suspensions (10^9 sp/ml) were tested on adult *R. appendiculatus* feeding on Zebu cattle in the field and on unfed larvae, nymphs and adult stages of *R. appendiculatus* and *A. variegatum* seeded in vegetation. For the adult *R. appendiculatus* feeding on cattle, half of the infected ticks were maintained in the laboratory after detachment from cattle, while the other half were maintained in the grass in the field in nylon tetrapacks. Tick mortality, fecundity and egg hatchability were then recorded and compared between the two groups. The powder spore formulations (starch, maize flour, sorghum flour and millet flour) were tested on adult *R. appendiculatus* feeding on cattle in the field.

When sprayed as aqueous spore suspensions, *B. bassiana* and *M. anisopliae* induced high mortalities (63–77%), reductions in fecundity (32–60%) and egg hatchability (42–55%) in adult *R. appendiculatus* fed on cattle, and incubated in the laboratory after detachment. Mortalities occurred between 7–12 days post-infection. In ticks maintained in the field in the grass after detachment, similar observations were made. Mortalities (62–71%), reductions in fecundity (44–48%) and egg hatchability (72–75%) were observed. Control mortalities were normally less than 10% of experimental levels.

Spores of *B. bassiana* and *M. anisopliae* in dry powder formulations (10% w/w spore-powder) were also effective in killing adult *R. appendiculatus* feeding on cattle. With the starch formulation, mortalities were 65% *(B. bassiana)* and 53% *(M. anisopliae)*. With the other powder formulations, i.e. maize, sorghum and millet flours, mortalities with *B. bassiana* were 82, 85 and 82% respectively, while those induced by *M. anisopliae* were 79, 64 and 100%, respectively.

When sprayed on unfed larvae, nymphs and adults of *R. appendiculatus* and *A. variegatum* seeded in vegetation, both *B. bassiana* and *M. anisopliae* induced high mortalities, especially in larvae where *M. anisopliae* induced 100% mortality in both tick species. Mortalities induced in nymphs and adults normally ranged between 60–80%.

From the above results, it is clear that the entomogenous fungi, *B. bassiana* and *M. anisopliae* are promising biocontrol agents for livestock ticks and therefore merit further study. Although these fungi have been used to control agricultural pests, e.g. sugarcane pests, where spores are sprayed over extensive areas, to our knowledge, this is the first attempt to control livestock ticks using entomogenous fungi.

Completed studies

Kaaya G. P., Mwangi E. N. and Ouna E. Prospects for biological control of livestock ticks, *Rhipicephalus appendiculatus* and *Amblyomma variegatum* using the entomogenous fungi, *Beauveria bassiana* and *Metarhizium anisopliae*. *Journal of Invertebrate Pathology* (in press).

Both *Beauveria bassiana* and *Metarhizium anisopliae* induced approximately 30% mortalities in adult *Rhipicephalus appendiculatus* feeding on rabbits while *M. anisopliae* induced a mortality of 37% in adult *Amblyomma variegatum*. Both fungal species induced reductions in engorgment weights, fecundity, and egg hatchability in adult *A. variegatum*. *Metarhizium anisopliae* reduced fecundity by 94% in *A. variegatum*. Furthermore, *B. bassiana* reduced egg hatchability to 0%, while 11% of the infected females failed to lay eggs. In Zebu cattle naturally infested with *R. appendiculatus* in the field, both *B. bassiana* and *A. anisopliae* induced high mortalities ranging from 76–85%, a remarkable reduction in fecundity (85–99%), and a significant reduction in egg hatchability (94–100%). When incubated in organophosphate acaricides for up to 120 h, both fungi retained their normal growth and morphological characteristics. *Beauveria bassiana* and *A. anisopliae* persisted on cattle ears for 1 and 3 weeks, respectively, after application. Both *B. bassiana* and *A. anisopliae* induced a mortality of approximately 100%, 76–95% and 36–64% in larvae, nymphs, and adults, respectively, of *R. appendiculatus* seeded in grass in the field. Spores of *B. bassiana* and *A. anisopliae* mixed with sterilised sand and maintained at 0 and 25°C maintained good viability for over 12 months (*B. bassiana*) and for 8 months (*A. anisopliae*) and no significant difference was observed in spores stored in the two different temperatures.

Future activities

(i) Compatibility of entomogenous fungi, *B. bassiana* and *M. anisopliae* with various commonly used acaricides will be determined, and
(ii) The effectiveness of oil formulations on ticks feeding on cattle and those in vegetation will be studied.

6. SOCIOECONOMIC FEASIBILITY OF USING FUNGI AS BIOLOGICAL CONTROL AGENTS OF TICKS

Participating scientists: *J. W. Ssenmyonga, G. P. Kaaya*

Assisted by: *E. Ouna*

Background

Two entomopathogenic fungi, *Beauveria bassiana* and *Metarhizium anisopliae* are being tested for their efficiency as biological control agents (BCA) of ticks on Zebu cattle under traditional livestock husbandry in Muhaka, Kenya coast. Results obtained so far show that the fungi reduce egg hatchability to 0–4%, fecundity to 1–20% while inducing a mortality of 78% (*1993 ICIPE Annual Research Highlights*). Research designed to assess the socioeconomic feasibility of using the two fungi as BCA of ticks has been undertaken.

Work in progress

Research was carried out in four homesteads made up of 17 families in Muhaka, Kenya coast. The objectives were to identify the major socioeconomic factors determining the feasibility of using fungi as BCA of ticks (FBCAT) and to undertake research on identified factors. The major factors identified are:

(a) Social factors: Farmers' knowledge of ticks, their role in disease transmission, tick-borne diseases, and economic losses caused by tick-borne diseases; land ownership and use; grazing patterns,

ownership and management of livestock; organisation and management requirements of FBCAT; extension requirements of FBCAT.

(b) Economic factors: Costs, benefits, cost-benefit ratios and affordability of FBCAT.

(c) Environmental factors: Safety of users of FBCAT and the environment.

Results of the investigation on the above factors show the following:

Social factors: Farmers' understanding of ticks and tick-borne diseases is very poor. Although most of the land has been surveyed, few people have title deeds. Free range grazing is the norm especially in communal grazing areas making it unsuitable to use FBCAT. Livestock, owned by men, is reared in large herds kept at homesteads of senior male elders. A small herd is about 19 head of cattle while a large one is 66–78. All livestock species, dominated by cattle with a share of 98% of SSU, are indigenous. Cattle are dominated by females (83%).

Economic factors: Costs and benefits of FBCAT are not yet fully known. As a result, affordability and cost/benefit ratios have not been estimated. However, the collection of baseline data for estimating increase in benefits has started. Cattle productivity is very low. For example, mean life time fertility of cattle is 3 calves; age of a cow at first calving is 4–7 years; calf mortality is about 70%. Milk yield is 0.64 litre/day/cow. Custom prohibits the use of cattle for traction.

The methodology for assessing the use of FBCAT has been developed. Provisional results show that use of FBCAT would not be feasible under current livestock husbandry. Collection of data on other economic parameters will be undertaken in 1995.

7. EVALUATION OF BOTANICAL EXTRACTS FOR THE CONTROL OF TICKS

Participating scientist: *G. P. Kaaya*

Assisted by: *M. M. Malonza*

Background

Control of livestock ticks in Africa depends almost entirely on imported acaricides which cost governments millions of dollars each year. Africa is one of the richest continents in plant biodiversity not yet exploited for their medicinal and pesticide potentials. Indigenous plants possessing anti-tick activities, when identified, can be used as local sources of acaricides. Botanical extracts will also be less toxic to the environment since they are more easily biodegradable.

Work in progress

A water soluble extract of a local plant named *Margaritaria discoidea* induced high mortalities in nymphs of *Rhipicephalus appendiculatus* and *Amblyomma variegatum* and in adult *R. appendiculatus*. Furthermore, an oily extract from the dry wood of this plant was highly acaricidal; a 6.25% extract induced 100% mortality in nymphs and adult of *R. appendiculatus* and adult of *A. variegatum* in the laboratory. When applied on adult ticks feeding on rabbits, it induced mortalities of 70% and 97% in *A. variegatum* and *R. appendiculatus*, respectively. A 50% concentrated oil extract induced mortalities of 100% and 50%, respectively, in adult *R. appendiculatus* and *A. variegatum* feeding on cattle in the field. At this concentration, the extract was found to be as effective as a commercial acaricide, Steladone (0.05%) used in the field to control ticks.

Completed studies

Hassan S. M., Dipeolu O. O. and Malonza M. M. Natural attraction of livestock ticks by the leaves of a shrub. *Tropical Animal Health Production* 26, 87–91.

During examination of leaves of different plants on Rusinga Island, Kenya, ticks were commonly found on the leaves of a plant identified as *Acalypha fruticosa* Forsk. var *villosa* Hutch (Euphorbiaceae). Larvae of *Rhipicephalus appendiculatus* were the predominant ticks encountered, found quiescent on the undersurface of the leaves. Laboratory investigations showed that significant numbers of ticks were attracted by odours from this plant. It was concluded that the leaves of *A. fruticosa* are attractive to this tick and have potential for use as a trap to control ticks.

Kaaya G. P., Mwangi E. N. and Malonza M. M. Acaricidal activity of *Margaritaria discoidea* (Euphorbiaceae) plant extracts against the ticks, *Rhipicephalus appendiculatus* and *Amblyomma variegatum* (Ixodidae). *International Journal of Acarology* (in press).

A water-soluble extract of *M. discoidea*, an African indigenous plant induced high mortalities in nymphs of both *Rhipicephalus appendiculatus* and *Amblyomma variegatum* and in adult *R. appendiculatus*, but not in adult *A. variegatum*. An oil hexane extract from dry wood of this plant was found to be more acaricidal and a 6.25% concentrated extract killed 100% nymphal *R. appendiculatus*, 100% adult *R. appendiculatus* and 100% *A. variegatum* when exposed to the extract for 10 min. Application of a 50% concentrated oil extract on rabbit ears caused a complete inhibition of attachment by adult *R. appendiculatus* and *A. variegatum* for at least 4 days, and when applied on adult ticks engorging on rabbits, it induced mortalities of 70% and 97% in *A. variegatum* and *R. appendiculatus*, respectively. When applied on ticks naturally infesting cattle in the field, the 50% oil extract induced 100% and 50% mortalities in adult *R. appendiculatus* and *A. variegatum*, respectively, by 2 days post-application. In adult *R. appendiculatus* feeding on cattle the 50% oil extract was found to be as effective as the standard concentration (0.05%) of Steladone, a commercial acaricide.

Mwangi E. N., Hassanali A., Essuman S., Nyandat E., Moreka L. and Kimondo M. Repellent and acaricidal properties of *Ocimum suave* against *Rhipicephalus appendiculatus* ticks. *Experimental and Applied Acarology* (in press).

An oil extracted from the leaves of a tropical shrub *Ocimum suave* was found to repel as well as kill all stages of the tick *Rhipicephalus appendiculatus*. In an *in vitro* bioassay for the larvae, the LC_{50} of the oil in liquid paraffin was 0.024%. A 10% solution was found to kill all immatures and more than 70% of adults feeding on rabbits. Rabbits were protected for 5 days against attaching larvae using a 10% solution. Preliminary experiments undertaken with cattle kept in the field suggest that the oil may have potential in tick control, and a role in integrated tick management.

Future activities

(i) Conducting biochemical characterisation of active acaricidal compounds.
(ii) Screening of more indigenous plants for anti-tick activities.
(iii) Developing simple but effective extraction and storage methods that can be adopted by farmers.

8. DROP-OFF RHYTHMS, DEVELOPMENT AND SURVIVAL OF *R. APPENDICULATUS* AND *A. VARIEGATUM* UNDER FIELD CONDITIONS

Participating scientists: *S. M. Hassan, A. Odulaja, J. W. Ssennyonga, S. Essuman, E. Mwangi*

Assisted by: *P. O. Ngoko, J. O. Odhiambo*

Background

Ecological research helps us understand tick population activity and behaviour under field conditions and provides a basis for the use of specific or integrated population management methods. Such studies aim to explore weak points in ticks' life cycle, and will provide information needed to build tick population models and to devise tick control strategies. Despite the fact that *A. variegatum* and *R. appendiculatus* are the most economically important ticks in Africa, and are most prevalent in western Kenya, no ecological studies on these ticks have hitherto been conducted in this area.

Following engorgement in each of their stages, ticks drop from their hosts. The cessation of feeding, withdrawal of mouthparts and dropping is not random but follows a regular pattern. Timing of drop-off has a dual ecological purpose: engorged ticks tend to drop in an area where conditions are favourable for their development and subsequently where they are likely to encounter a new host. Thus, with alteration of animal grazing, the drop-off could be allowed to occur where conditions are unfavourable for tick development and survival. However, scanty information is available in this field, particularly about *A. variegatum*.

Work in progress

1. Circadian rhythms of drop-off of engorged ticks

The objective was to determine the diurnal drop-off rhythms of *R. appendiculatus* and *A. variegatum* from Zebu cattle kept under traditional husbandry practice for the purpose of improving tick control methods.

Using white cotton ear sleeves, larvae and nymphs of *R. appendiculatus* and *A. variegatum* and adults of *R. appendiculatus* were placed separately on each ear of 12 adult Zebu cattle kept under a traditional husbandry regime. The drop-off of engorged ticks was monitored by opening the bags and removing detached ticks at 2-hour intervals between 0600 and 2200 hours. Partially engorged *A. variegatum* females attached on 12 cattle were marked using artist's oil paints dissolved in linseed oil. The marked ticks were also visually monitored at 2-hour intervals. The experiment was conducted every two months.

Diurnal drop-off rhythms were exhibited by the three stages of both tick species (Table 1). The period of maximum drop-off of engorged *R. appendiculatus* females, nymphs, and larvae occurred between 1400 and 1600 hours. Similar results were obtained for *A. variegatum*. However, their adults and nymphs detached from the hosts towards the end of the day. This diurnal rhythm was consistent over the seasons.

2. Development and survival of ticks

On the day engorged ticks detached, 1000 larvae, 100 nymphs and one female of *R. appendiculatus* and *A. variegatum* were placed in glass tubes covered with nylon mesh (Grade 70 GG, mesh size 236 µm). The ticks were put in the field under a thick layer of litter and were checked daily for oviposition and twice a week for egg hatching, larval-nymphal, and nymphal-adult moulting. Number of eggs laid by the females and those which hatched were estimated and premoulting periods of larvae and nymphs were recorded. The experiment was conducted at 2-month intervals both in Kuja River and Mbita.

The results for preoviposition, prehatching periods, and percentage of hatchability of eggs are summarised in Table 2. Development of these ticks took significantly longer periods in Kuja River ($P < 0.05$). Percentage hatching of eggs was higher in Kuja with marked seasonal effects. Eggs failed to hatch in the dry season, particularly those of *A. variegatum*. Results on premoulting periods of nymphs and adults and pre-eclosion were also similar. These periods were significantly longer in Kuja River ($P < 0.05$).

At the point of their transformation in the development rate study, the three stages of the two tick species were transferred into nylon mesh tubes (Grade 70 GG, mesh size 236 µm) measuring 30 cm long and 1 cm in diameter and sealed using a heavy duty stapler. The tubes were exposed vertically among the grass which was regularly mowed to a level of 15 cm. Live and dead ticks were counted every two weeks in the case of larvae and once a month in the case of both nymphs and adults. The experiment was carried out at 2-month intervals.

Larvae of *R. appendiculatus* released in January survived between 2 to 2.5 months whereas those ones released in March survived one month longer. Their nymphs released in Mbita in February survived for 8 months. *Amblyomma variegatum* larvae survived in Mbita for 3 and 4 months when released in January and April, respectively. However, in Kuja their survival was one month longer. Interestingly, nymphs and adults of *A. variegatum* survived considerable shorter periods than those of *R. appendiculatus*. The season had marked effects as ticks survived considerably shorter periods in the dry seasons.

Completed studies

Latif A. A., Rowlands G. J., Punyua D. K., Hassan S. M. and Capstick P. B. An epidemiological study of tick-borne

Table 1. Drop-off rhythms of engorged *Rhipicephalus appendiculatus* and *Amblyomma variegatum* under field conditions

Time of day	*R. appendiculatus*			*A. variegatum*		
	Females	Nymphs	Larvae	Females	Nymphs	Larvae
0600	1.1 c	1.3 c	7.3 c	0	2.4 c	7.9 c
0800	0.3 c	0.9 c	6.1 c	2.2	1.4 c	1.3 c
1000	0.1 c	0.7 c	2.3 c	5.6	0.6 c	0.9 c
1200	0.6 c	13.1 bc	105.4 bc	5.6	3.9 c	8.5 c
1400	3.6 ab	84.9 a	387.4 a	7.4	9.1 b	109.3 ab
1600	5.4 a	81.3 a	164.4 b	17.7	21.0 a	184.2 a
1800	3.0 b	27.5 b	69.7 bc	39.4	15.3 ab	68.6 b
2000	0.7 c	3.9 bc	12.1 c	15.2	3.8 c	33.4 c
2200	0.1 c	0.03 c	0 c	0.4	0.1 c	0 c

Means followed by the same letter in each column are not significantly different at the 5% level. Analysis is based on values transformed to $\sqrt{(x + 0.5)}$.

Table 2. Development periods, preoviposition, prehatching (days) and hatchability (%) of *R. appendiculatus* and *A. variegatum* at Mbita and Kuja River in 1994

Month		*R. appendiculatus*			*A. variegatum*		
		Preovi.	Prehatch.	% Hatch	Preovi.	Prehatch.	% Hatch*
Kuja	1	9.0 b	47.4 b	55.3 b	20.3 b	79.3 c	76.9 a
	3	7.0 c	46.2 b	75.2 a	17.8 b	84.7 b	69.6 a
	5	NR	NR	NR	18.3 b	73.1 d	14.0 b
	7	10.2 a	50.6 a	49.7 b	19.3 b	91.0 a	10.8 b
	9	7.1 c	42.5 c	76.1 a	25.8 a	75.7 d	63.8 a
	11	7.8 c	39.3 d	48.4 b	14.6 c	88.2 ab	12.0 b
Mbita							
	1	7.1 bc	36.4 c	64.9 a	15.7 ab	68.3 b	42.2 b
	3	6.5 bc	37.4 c	56.9 a	14.4 b	74.5 a	66.4 a
	5	8.4 a	38.3 c	62.4 a	15.8 ab	75.0 a	9.8 c
	7	8.8 a	52.7 a	2.0 c	18.5 a	NH	0 c
	9	6.3 c	44.3 b	32.6 b	15.7 ab	67.3 b	79.4 a
	11	7.3 c	37.0 c	58.4 ab	15.4 ab	NH	0 c

Means followed by the same letter in each column are not significantly different at 5% level.
*Analysis based on values transformed to $\sqrt{(x + 0.5)}$.
NR = No release, NH = No hatching.

diseases and their effects on productivity of Zebu cattle traditionally managed on Rusinga Island, western Kenya. *Preventive Veterinary Medicine* (in press).

Ten farmers on Rusinga Island, Lake Victoria, Kenya were selected to study the epidemiology of tick-borne diseases (TBDs) and their possible effects on calf performance. During the years 1986–88 a total of 162 calves were ear-tagged, weighed monthly and monitored closely for TBDs and endoparasitism. The mean (±SD) body weights at 4 months, 8 months and 12 months were 35 ± 7 kg, 47 ± 10 kg and 61 ± 12 kg, respectively. The average growth rate from birth to 12 months of age was 120 g day^{-1}, but there were significant effects of year, season of birth and farm on calf liveweight gain. Calf mortality from birth to 12 months of age was high, ranging from 17 to 56% among farms, and averaging 33%. Twenty-one percent of the mortalities were diagnosed as due to East Coast fever (ECF) and 14% as due to endoparasites. The annual average ECF incidence rate was 22% and the ECF case fatality rate 21%, but these deaths were recorded on only two of the ten monitored farms. Forty-nine percent of dams had one or more damaged teats due to the tick species *Amblyomma variegatum*. Attempts were made using this small data set to analyse for effects of ECF and number of damaged teats on calf performance but no statistically significant effects could be demonstrated.

Future activities

(i) Factors initiating the drop-off of the engorged ticks from their hosts which include physiological status, photoperiodism, and the effect of the grazing area will be investigated.
(ii) Effect of season on the feeding performance of ticks and seasonal drop -off pattern will be established.
(iii) Fecundity of females, rate of development of engorged ticks and duration of survival of unfed ticks under open and shade sites will be investigated.
(iv) Effect of climatic factors such as rainfall, temperature, and relative humidity on fecundity, development rate of engorged ticks and duration of survival of unfed ticks will be determined.

VI. Chemical Ecology of Ticks

Participating scientists: *W. Lwande*, A. Hassanali, S. Fra Kutua (*Project Coordinator)*

Donor: *ICIPE Core Funds*

Background

Semiochemicals, the chemicals that are derived from organisms that help to control various interactions among organisms, play an important role in mediating aggregation, mate finding and host and host site location by the brown ear tick, *Rhipicephalus appendiculatus* and the red legged tick, *R. evertsi*. In addition, some plants exhibit anti-tick properties due to repellent volatile chemical constituents in the plants. If the function of tick semiochemicals is known and the chemicals that are involved are identified, it is possible to develop highly selective methods of control of these ticks that are not harmful to the environment, such as is the case with acaricides. In 1994, the chemical ecology department continued with research on the identification of semiochemicals for *R. appendiculatus* and *Amblyomma variegatum*.

Work in progress

1. IDENTIFICATION OF PHEROMONES OF THE BROWN EAR TICK, *RHIPICEPHALUS APPENDICULATUS*

Analysis of airborne volatiles of male and female adult brown ear ticks (*R. appendiculatus*) led to the isolation of six phenolic compounds: phenol, salicylaldehyde, *p*-cresol, 2,6-dichlorophenol, 2,6-dibromophenol and 2-bromo-6-chlorophenol from both sexes (Figure 1). Although 2,6-dichlorophenol had previously been suggested to be a female sex pheromone for *R. appendiculatus*, the fact that this compound and the other phenols were found from both sexes in our study indicated that these compounds were functioning as aggregation rather than sex pheromones. Previous workers had employed less efficient methods of extraction of the tick-derived compounds.

2. CHEMICAL AND BIOACTIVITY STUDIES OF ANTI-TICK PASTURE PLANTS

We previously reported on tick repellent properties of volatile oils and constituents of the oils of two tick

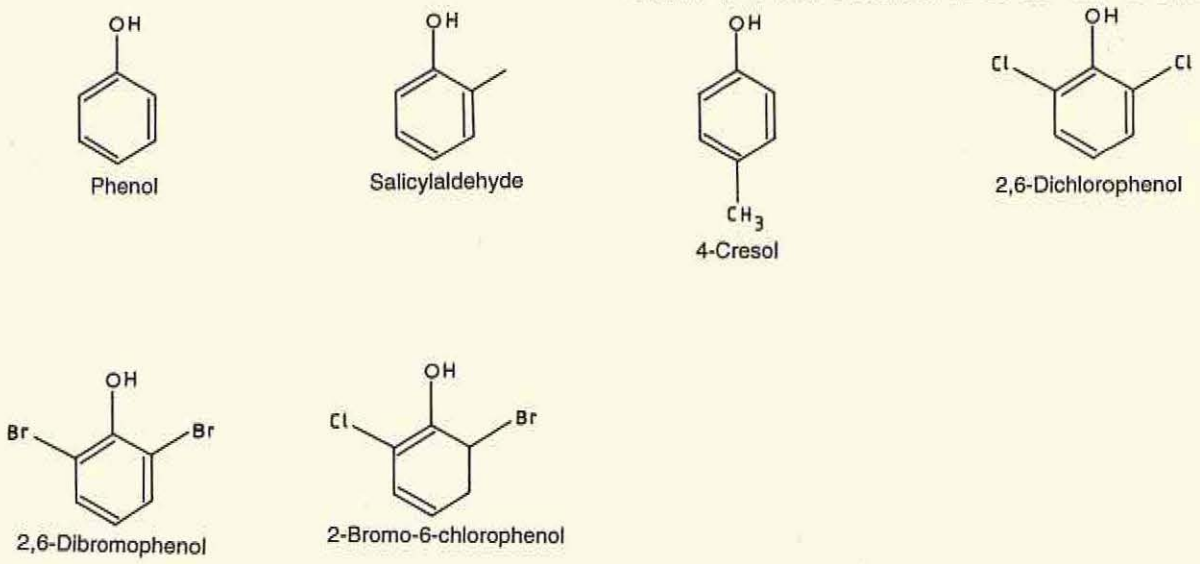


Figure 1. Compounds identified from airborne volatiles of male and female brown ear ticks, *Rhipicephalus appendiculatus*.

repellent plants, *Gynandropsis gynandra* and *Cleome monophylla*, both belonging to the family Capparidaceae (*ICIPE Annual Reports, 1990, 1991, 1993*). During this year, we examined the tick repellency properties of volatile oils and constituents of four more plant species of the Capparidaceae family: *Boscia angustifolia, B. mossambicensis, Cabada farinosa*, and *Thylachium africanum*. All the oils of the four plants exhibited repellency to the brown ear tick, *R. appendiculatus*, with *B. mossambicensis* being most repellent. The most repellent constituents were *m*-cymene, nonanal, 1-α-terpeneol, β-cyclocitral, nerol, *trans*-geraniol, carvacrol, α-ionone, *trans*-geranyl acetone, nerolidol and α-cedrene (Figure 2).

3. STUDIES ON THE ROLE OF KAIROMONES IN THE MEDIATION OF FEEDING SITE LOCATION ON CATTLE

The preferred feeding sites on animals for the brown ear tick, *R. appendiculatus* and the red legged tick, *R. evertsi* are the inner parts of the ears and the perianal region, respectively. Studies in our department revealed that host odours played a key role in the location of the preferred sites by the two species of ticks. Extracts from the ear were attractive to *R. appendiculatus* and repellent to *R. evertsi* while the effect was reversed with extracts from the perianal region. Work is in progress on the isolation of semiochemicals that play a role in mediating this behaviour.

Completed studies

Mwangi E. N. Biological methods of tick control. In *Community-based and Sustainable Pest and Vector Management for Rural Development* (Edited by Otieno L. H. and Bugembe M.), pages 29–32. ICIPE Science Press.

Mwangi J. W., Achola K. J., Lwande W.* and Hassanali A.* Volatile components of *Heteromorpha trifoliata* (Wendl.) Eckl. & Zey. *Flavour and Fragrance Journal* 9, 241–243.

Mwangi J. W., Achola K. J., Lwande W.*, Hassanali A.* and Laurent R. Volatile constituents of essential oil of *Tarconanthus camphoratus* L. *Journal of Essential Oil Research* 6, 183–185.

Mwangi J. W., Achola K. J., Lwande W., Hassanali A. and Laurent R. Constituents of the essential oil of *Blumea brevipes* (Oliv. & Hiern) Willd. *Flavour and Fragrance Journal* 9, 233–235.

Mwangi J. W., Lwande W.* and Hassanali A.* Composition of the leaf essential oil of *Ocimum keniense* Ayobangira. *Flavour and Fragrance Journal* 9, 75–76.

Ndungu M., Lwande W.*, Hassanali A.*, Moreka L., Chhabra S. C., Amiani H. and Achieng G. *Cleome monophylla* essential oil and its constituents as livestock tick (*Rhipicephalus appendiculatus*) and maize weevil (*Sitophilus zeamais*) repellents. *Entomologia Experimentalis et Applicata* (in press).

*(*ICIPE staff)*

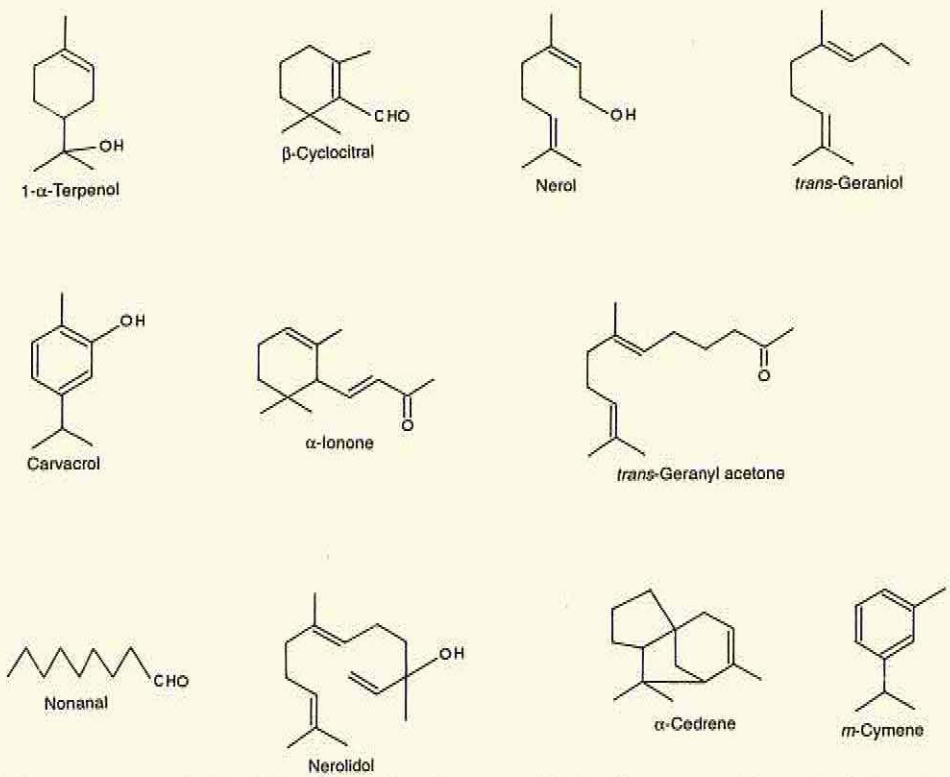


Figure 2. A few of the compounds identified from *Boscia angustifolia, B. mossambicensis, Cabada farinosa* and *Thylachium africanum* that are most repellent to the tick *Rhipicephalus appendiculatus*.

MEDICAL VECTORS RESEARCH

VII. Effects of Natural Diet of Sandflies (Diptera: Psychodidae) on their Vector Competence for *Leishmania*

Participating scientists: *M. Muhinda*, M. J. Mutinga, M. Basimike (*Project Coordinator)*

Assisted by: *M. P. Nyamori, D. M. Omogo*

Donors: *USAID through the Hebrew University of Jerusalem*

Collaborators: *Yosef Schlein, Principal Investigator and Raymond L. Jacobson, Research Associate, Hebrew University of Jerusalem*

Background

Leishmaniasis is a disease caused by parasites of the genus *Leishmania*, transmitted to man by different species of phlebotomine sandflies. Leishmaniasis is prevalent worldwide in rural as well as urban areas of temperate and tropical regions. Its growing importance, especially in developing countries, prompted the World Health Organisation to include it into the six major tropical diseases along with malaria, African trypanosomiasis/ Chagas disease, filariasis, schistosomiasis and leprosy.

The intensity of transmission is a function of the vectorial capacity, which is affected by, among other factors, the density and longevity of the vector. Studies in the Jordan Valley show that, while blood is taken according to the gonotrophic cycle, plant tissues are the common diet of sandflies, amounting to nearly half of the sugar meals of *P. papatasi*. These meals were also found to contain carbohydrates, lectins and proteins which can compete with the pathogens on binding sites and affect the establishment of infection.

Since the life cycle of *Leishmania* takes place in the sandfly gut, the parasites are exposed to the vector gut environment including food, digestive enzymes and products.

The analysis of natural diets of vectors as factors in the vector competence is a novel approach to the epidemiology of leishmaniasis developed by Schlein and co-workers. This approach contributes to the basic understanding of vector-pathogen interactions and provides methods for the control of leishmaniasis.

Some of the field methods can be used for monitoring the behaviour of sandfly vectors in the field that will help in designing control programmes. They can also be used as cost effective means for selective control of sandflies. The results of the study would be of interest to entomologists, parasitologists, and health professionals concerned with tropical vector-borne diseases.

Work in progress

1. PHYTOPHAGY AND EFFECTS OF PLANT DIETS ON FECUNDITY AND LONGEVITY IN KENYAN PHLEBOTOMINE SANDFLIES

The present report is an account of experiments designed to contribute more evidence on phytophagy and evaluate its effect on fecundity and longevity of Kenyan phlebotomine sandflies, with reference to *Sergentomyia ingrami* Newstead and *Phlebotomus duboscqi* Neveu-Lemaire. The first was suspected to harbour uncharacterised *Leishmania* parasites while the second is a confirmed vector of *Leishmania major*, the causative agent of cutaneous leishmaniasis in the Old World in general and in the Kenyan focus of Baringo District in particular.

Phytophagy

Both sandfly species were offered overnight (1800–0600 hrs) in a feeding cage maintained in an incubator at 28.5°C and 60–70% relative humidity, each of the seven test plants: *Azadirachta indica, Melia azedarach, Ocimum kenyense, Ocimum suave, Rumex usambarensis, Solanum incanum* and *Tagetes minuta*. Each plant was tested with a sample of 24 flies in 12 replicates. After the feeding period, phytophagy was assessed using anthrone reagent which in the presence of fructose changes the colour from yellow to green/blue within 60 minutes.

Sergentomyia ingrami (Figure 1A) and *P. duboscqi* (Figure 1B) were observed to be highly selective towards the different test plants with the highest preference for *R. usambarensis* and *M. azedarach*; however, *S. ingrami*

showed more preference for *R. usambarensis* than did *P. duboscqi* which in turn preferred *M. azedarach*. The two plants along with sucrose proved more suitable with a feeding rate of > 50% while *A. indica* and *S. incanum* showed an intermediate feeding rate (between 25 and 50%). *Ocimum kenyense*, *O. suave* and *T. minuta* elicited the poorest feeding response in both sandfly species, being just better than water for which the only one positive out of 288 flies may be attributed to a possible contamination. This confirms the selective phytophagy observed by Schlein and Warburg working with *P. papatasi* in the Jordan Valley, Israel.

Fecundity

Twenty-four hours after the bloodmeal (hamster for *P. duboscqi* or geconid lizard for *S. ingrami*) gravid females were subdivided into four groups; these were kept for 24 hours with a nearly equal number of males in different feeding cages containing different diets, i.e. *R. usambarensis*, *S. incanum*, sucrose and water, respectively. After a 24-hour exposure to the respective diets, flies were transferred by couple into individual oviposition vials provided with respective diets and the vials kept in a moisture retention container. Oviposition was checked and eggs counted (under a dissecting microscope) on a daily basis until the last female had laid or died. Each experiment was run in 5 replicates of 25 ± 4 flies.

The highest average number of eggs in *S. ingrami* (Table 1) was recorded from females maintained on *R. usambarensis* and the lowest from those given *S. incanum*. The maxima per diet were 163, 160, 161, and 137 eggs in females offered *R. usambarensis*, *S. incanum*, sucrose and water, respectively.

The series of experiments with *P. duboscqi* (Table 2) showed that the highest mean number of eggs per female was observed in the flies maintained on *R. usambarensis* and the lowest in those given water, while *S. incanum* and sucrose showed an intermediate fecundity level. The maxima recorded were 101, 85, 127 and 85 eggs with flies offered *R. usambarensis*, *S. incanum*, sucrose and water, respectively.

A significant difference in fecundity due to the difference in diets was observed in females of both *S. ingrami* and *P. duboscqi*: *Rumex usambarensis* was associated with the highest number of eggs per female in the two sandfly species but the lowest fecundity was associated with *S. incanum* in *S. ingrami*, while water yielded the lowest number of eggs in *P. duboscqi*.

Longevity

Flies emerging from the same batch (equal numbers of males and females) were put into one cage and kept for 24 hours in the incubator under the same conditions of temperature and humidity as those described in the feeding studies; after that period the individuals found dead were discarded. The lot of surviving flies was then divided into 4 groups of 30 each of about 15 females and 15 males; these were introduced into feeding cages where they were maintained on *R. usambarensis*, *S. incanum*, sucrose and water, respectively.

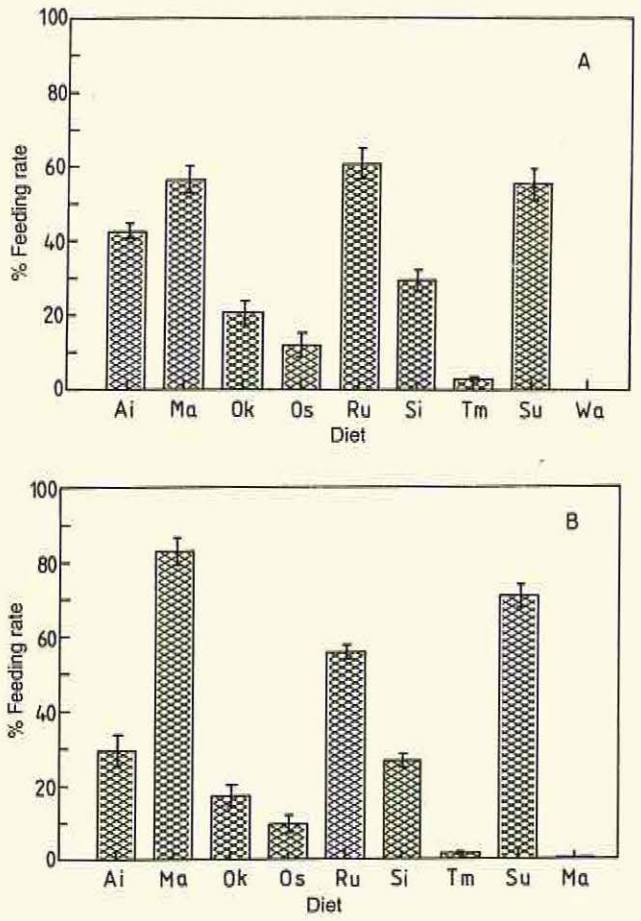


Figure 1. Feeding rate of (A) *S. ingrami* and (B) *Phlebotomus duboscqi* on various plant species, sucrose and water: Ai, *A. indica*; Ma, *M. azedarach*; Ok, *O. kenyense*; Os, *O. suave*; Ru, *R. usambarensis*; Si, *S. incanum*; Tm, *T. minuta*; Su, sucrose; Wa, water.

Table 1. Fecundity of *S. ingrami* females maintained on different diets during the preoviposition period

Diet	Number of flies laying	Number of eggs laid	Mean ± SE
Ru	100	8990	89.90 ± 3.14 a
Si	90	7128	79.20 ± 3.52 f
Su	108	9584	88.78 ± 3.00 a
Wa	106	8746	82.51 ± 2.66 ab

Ru, *R. usambarensis*; Si, *S. incanum*; Su, sucrose; Wa, water. Means followed by the same letter are not significantly different at $P \geq 0.05$.

Table 2. Fecundity of *P. duboscqi* females maintained on different diets during the preoviposition period

Diet	Number of flies laying	Number of eggs laid	Mean ± SE
Ru	108	5835	54.03 ± 1.89 a
Si	106	5291	49.92 ± 1.63 ab
Su	115	5959	51.82 ± 1.93 ab
Wa	109	5103	46.82 ± 1.70 b

Ru, *R. usambarensis*; Si, *S. incanum*; Su, sucrose; Wa, water. Means followed by the same letter are not significantly different at $P \geq 0.05$.

Diets were replenished and mortality recorded daily until the death of the last fly in each cage. The experiment was done in 5 replicates.

The maximum longevity in *S. ingrami* (Figure 2) associated with the four diets were as follows: 28, 24, 21 and 9 days for *R. usambarensis*, sucrose, *S. incanum* and water, respectively, with their corresponding overall means, in the same order, being 12.8, 8.8, 9.8 and 4.7 days respectively.

The maximum longevity in *P. duboscqi* is presented in Figure 3 for the different diets: 41, 44, 27, and 17 days for *R. usambarensis*, sucrose, *S. incanum*, and water, respectively, the corresponding respective overall means being 15.7, 13.5, 9.3, and 7.2 days.

Among the four diets, water produced the lowest longevity for *S. ingrami* and *P. duboscqi*. And noteworthy, *S. incanum* was associated with almost the same longevity in *S. ingrami* and *P. duboscqi*, suggesting that if that plant had any effect, it would not be species-specific. For *S. ingrami*, sucrose and *S. incanum* were not significantly different but for *P. duboscqi*, sucrose produced a longevity more close to *R. usambarensis*.

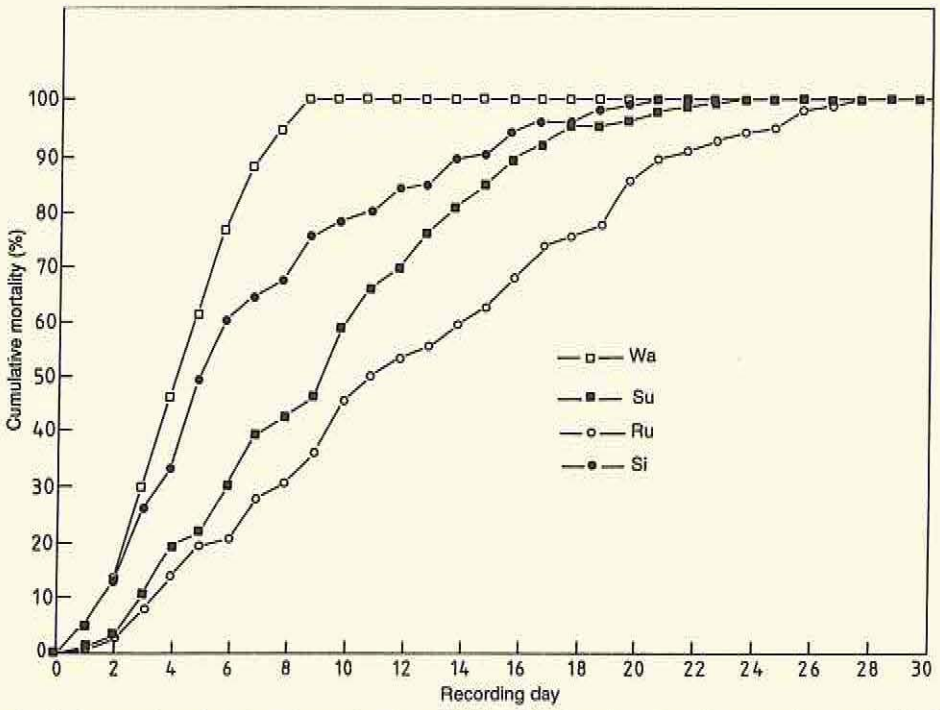


Figure 2. Mortality in *S. ingrami* maintained on plants, sucrose and water: Ru, *R. usambarensis;* Si, *S. incanum;* Su, sucrose; Wa, water.

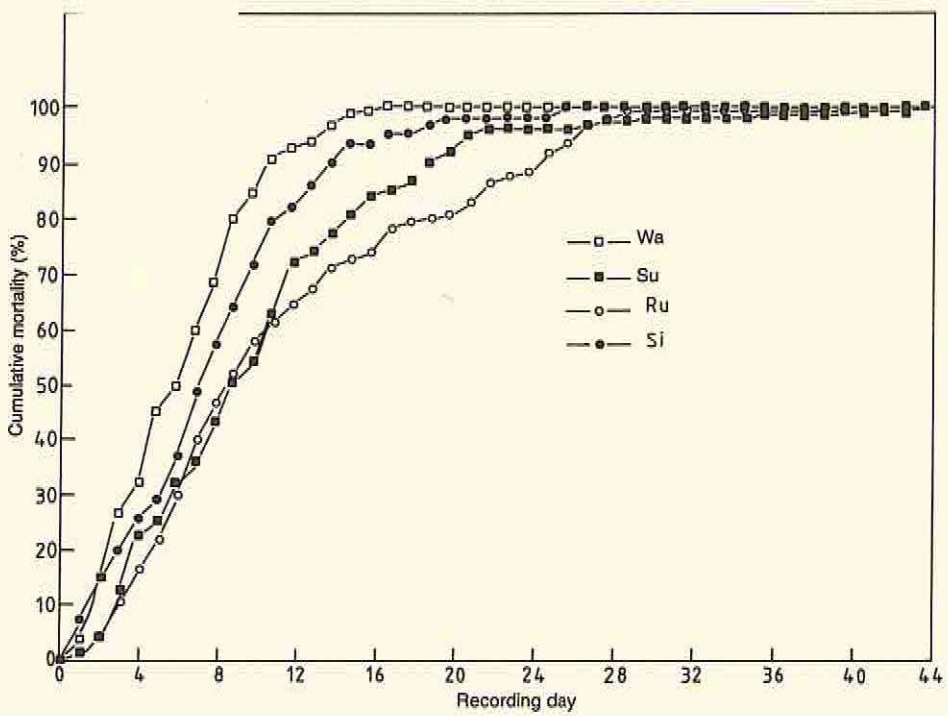


Figure 3. Mortality in *P. duboscqi* maintained on plants, sucrose and water: Ru, *R. usambarensis;* Si, *S. incanum;* Su, sucrose; Wa, water.

The results of the reported experiments show that some plants are significantly attractive to sandflies, while others are significantly repellent. On the other hand, different plant tissue meals seem to differently affect the population dynamics of the test sandflies; this has a potential implication for their vectorial capacity. One of the most important subsequent questions is how the effects of the tissue meals of the plants attractive to sandfly vectors on the suitable plants influence the *Leishmania* that the latter harbour.

VIII. Malaria Research Activities

1. STUDY OF ADOPTION AND HOUSEHOLDS' CAPACITY TO MANAGE AND SUSTAIN PERMETHRIN IMPREGNATED MBU CLOTH TECHNOLOGY IN MARIGAT AREA, KENYA

Participating scientists: *P. Chitere, F. G. Kiros*

Assisted by: *B. A. Omolo, S. Kelwon*

Donors: *ICIPE Core Funds*

Collaborators: *ICIPE Medical Vectors research staff*

Background

In 1989, the Medical Vectors Research Programme (MVRP) provided the *Mbu Cloth* technology for control of malaria to 2000 persons within the Perkerra Irrigation Scheme area of Marigat Division of Baringo District (*1989 ICIPE Annual Report*). Some of the persons who were given the cloths were at the time residing within Marigat township. A baseline study of the technical aspects of the health conditions of the area with emphasis on malaria was reported to have been carried out prior to the introduction of the cloths in the area. By distributing the cloths to a large number of persons within a smaller geographic area, a community-wide impact of the technology on malaria was expected.

The two objectives of the study were: (i) to examine the potential for widespread adoption and sustainability of the technology in the study area; and (ii) to look into the problems and potential for involvement of the community in the testing and validation of the technology.

Since a baseline study of the socioeconomic conditions of Marigat area was not done at the time of introduction of the Mbu Cloth, our study also sought to bridge this gap.

Work in progress

The following research activities were carried out:

- develop a list of households which had adopted the technology;
- sample and interview both adopter and non-adopter household heads of the technology using a structured and unstructured questionnaire;
- undertake direct observations of the manner of use of the technology within houses of sampled adopters;
- identify patterns of settlement (e.g. villages and manyattas), the number of homesteads per settlement and sample a few of them for the study;
- list all community organisations, e.g. women's groups and village health committees, which provide preventive and curative health services and assess their potential for involvement in control of malaria through the use of Mbu Cloth; and
- investigate how the community can best participate for better adoption of the technology.

Community-based approach

When the Medical Vectors field staff distributed 2000 cloths to individuals in Perkerra area, a community-wide impact of the cloths was envisaged. However, it was not possible to trace many of these persons during the period of this study. To facilitate adoption and diffusion of the technology and to ensure its sustainability, a community-based approach needs to be used in the introduction of the technology to a few delimited areas (e.g., villages). Within such pilot areas, also termed 'socioeconomic laboratories', the target units are usually households or homesteads. These should be mobilised and organised to work within the framework of an R&D project.

Baseline surveys

Whereas a baseline study of the health conditions of Marigat area is reported to have been done by the Medical Vectors team, there is need for a broad-based survey which can help in better understanding of the various conditions of the community where the R & D project is being launched.

Stages of Mbu Cloth technology development

The stages through which Mbu Cloth technology is developed are not clear. In ICIPE's Crop Pests Research Programme, the main stages through which IPM

technology is developed are: (1) on-station trials; (2) on-farm, researcher-managed trials; and (3) on-farm, farmer-managed trials. It is not clear whether a similar approach has been used in the development of Mbu Cloth technology. In the researchers' view, stages 2 and 3 in relation to the Mbu Cloth technology development are vital.

Preferences for Mbu Cloth

A majority of the respondents ranked the Mbu Cloth technology higher than other alternatives of controlling mosquitoes such as bednets, coils and sprays. The problem has to do with the observed low rate of re-impregnation of the cloths. This was being done by ICIPE staff at their station in Marigat but the response of the adopters of the cloths was low. As a result re-impregnation was not effectively carried out in nearly all cases. Similarly, the responsibility for re-impregnations was not transferred to the community. In this regard, a leaf can be borrowed from UNICEF's Barmaco project which mobilises and organises communities.

Community organisations

The local organisational base is weak in both Perkerra and Loboi areas. There is one cooperative society and a few women's groups which are active, but they seldom deal with primary health care matters. It may be possible to coordinate research efforts with an NGO such as CCF and help it to develop local capacity for handling and distributing the cloths in ways that ensure their sustainability.

Settlement patterns, types of houses and environmental factors

In both Perkerra and Loboi areas, villages appeared to have been sited at particular localities and cropped fields and livestock grazing grounds were on the outskirts. Most of the houses, especially those in Loboi area, were very small in circumference with short walls and may not fully accommodate the 9 metre cloth which is recommended by the Medical Vectors team for all houses.

Sanitary conditions are poor and are worsened by the fact that most of the houses are built of grass thatch, sticks and/or mud walls and mud floors. Other problems that contribute to the poor sanitary conditions of the houses include living and cooking in the same house, or keeping of young livestock such as calves in the house. The poor sanitary conditions of the houses have a bearing on the sustainability of the Mbu Cloth technology.

Mbu Cloth and primary health care

There is need for a detailed study of all primary health care activities carried out by households and their effectiveness in controlling mosquitoes relative to the use of Mbu Cloth.

2. PRODUCTION AND SUPPLY OF MOSQUITOES

Participating staff: *J. P. R. Ochieng'-Odero, G. W. Oloo, M. W. Gitau*

The Insect and Animal Breeding Unit works to colonise and produce selected mosquito species in order to support various vector management studies. During the period under review, the unit produced three major species: *Aedes aegypti*, *Anopheles gambiae*, and *Culex quinquefasciatus*. Of these three species, *Ae. aegypti* accounted for most of the production: 112,847 adults were produced, and 44,040 were supplied to users. *Culex quinquefasciatus* were next highest in production: 32,787 were produced out of which 4400 were supplied to users. *Anopheles gambiae* accounted for only a small level of production and supply. Most of the mosquitoes were supplied to the Medical Vectors Research Programme, Behavioural and Chemical Ecology Unit and ARPPIS scholars.

(See also Project IV, page 111 for mosquito and malaria control activities in Ethiopia under PESTNET and Project IX, page 129 on production of Bt *as a mosquito larvicide.)*

IX. Production and Application of *Bt* for Control of Disease Vectors and Plant Pests

1. INCREASING THE PERSISTENCE OF BACILLAR MOSQUITO LARVICIDES

Participating scientists: *M. Makayoto*, M. Oketch*
*(*Project Coordinator)*

Assisted by: *Z. Ngalo, A. Luyai*

Donor and collaborators: *Hebrew University, Israel: N. Sandler, A. Keynan*

Background

This Project is a collaborative one between the ICIPE and the Hebrew University. The initial planned project duration was from 27 August 1990–26 August, 1994. The project was designed to combat malaria and other mosquito-borne diseases that cause much illness and high mortality in tropical countries. Due to the difficulty of producing an effective vaccine against malaria, it is especially desirable to have a preparation to achieve control of the disease. The goal of the project is to transfer genetic material coding for one or more of the several *Bacillus thuringiensis israelensis (Bti)* toxins into *Bacillus sphaericus* in the hope of creating an improved larvicide combining the activity of *Bti* with the persistence of *Bacillus sphaericus*. The Hebrew University is involved in transformed clone growth and sporulation and immunoassays of these clones. ICIPE's role is to develop a bioassay method to determine the LD_{50} of the clones and their persistence by simulating laboratory field testing conditions to decide on the best clones developed in Israel.

Work in progress

The activities of the project are as follows:

(i) To carry out biossays of *Bacillus thuringiensis israelensis, Bacillus sphaericus* and the clones from Israel on *Aedes aegypti, Anopheles* and *Culex* spp;
(ii) To carry out persistence tests of the cloned organisms and to compare and determine their LD_{50};
(iii) Testing of 11 newly received clones under field conditions; and
(iv) Training of ICIPE personnel in Israel on genetic engineering techniques.

The mosquito colonies have been strengthened to produce a large number of insects for bioassays. At present three species, i.e. *Aedes aegypti, Anopheles* spp. and *Culex* are being reared. The report on bioassays and persistence is being compiled and will soon be submitted to the Hebrew University of Israel.

Future activities

Eleven more *Bt* clones received from Israel will undergo bioassay, persistence, laboratory and field testings.

2. PRODUCTION OF *BACILLUS THURINGIENSIS* (*BT*)-BASED BIOPESTICIDES FOR STEMBORERS

Participating scientists: *M. Makayoto, M. Oketch, Z. Ngalo*

Donor partners: *ICIPE Core Fund, Rockefeller Foundation*

Collaborators: *ICIPE Crop Pests research staff*

The production of *Dudustop* in ICIPE for field application continues to be carried out in a laboratory fermentor of 15 litres. In a collaborative effort with the then Crop Pests Research Programme on the ISERIPM Project, 100 litres of *Bt kurstaki* (M44-2), a locally isolated *Bacillus thuringiensis* has been produced and distributed to farmers in the Coast Province for biological control of stemborers, especially *Chilo partellus*.

It is important to emphasise that the fermentation facility presently used is a big constraint to production. Many requests for supply of *Dudustop* are being received from international organisations such as OXFAM,

UNHCR, AMREF, etc. It is hoped that with the proposed establishment of the Science Park in future, a larger production facility will go a long way in making *Dudustop* available in large enough quantities for disease vector control on a large scale.

ICIPE and a private company Oy G.A.C. of Finland have signed a joint agreement for the production, handling and distribution of *Dudustop* in Africa.

3. BIOLOGICAL CONTROL OF FILTHFLIES IN BONGA SETTLEMENT, GAMBELA, SOUTHWEST ETHIOPIA

Participating scientists: *M. Makayoto, G. Tikubet, M. J. Mutinga*

Assissted by: *M. B. Muia*

Donor: *UNHCR*

Collaborators and partners: *Administration for Refugee and Returnee Affairs (ARRA), Addis Ababa; United Nations High Commissioner for Refugees (UNHCR), Addis Ababa, Ethiopia, Oy G.A.C., Finland*

Background

The *Bacillus thuringiensis* (*Bt*)-based biopesticides for control of fly larvae have been successfully applied in Finland, Tanzania and Kenya. These undertakings have shown clearly that *Bt* can effectively be used to control fly larvae in populated areas. Wider use of *Dudustop*, an ICIPE formulation of *Bt*, in other areas was hence recommended. Validation of this *Bt* technology in Ethiopia was especially important because the application was being extended to a different environment where temperatures rise to 40–48°C, and hence it was imperative that field testing be carried out. The Bonga Refugee Camp in Gambela, southwest Ethiopia was found to be a suitable site for the control of flies. This was part of a collaborative project, "The Pilot Project on the Control of Mosquitoes, Tsetse Flies and Filthflies in Bonga Refugee Camp" between ICIPE, ARRA and UNHCR.

Work in progress

Efficacy tests and application of Dudustop *in Bonga*

An experiment was set up where 20 toilets were chosen for treatment and 10 toilets for the control to monitor and evaluate the effect of *Bt*. The toilets were chosen on the basis of heavy infestation with larvae and adult flies. The ratio of active ingredient and water in the *Dudustop* preparation used was 1:30. Each of the 20 toilets was treated with 1 litre of preparation. While the experiment was going on, the 400 camp toilets in clinics, school, homes, etc., were treated with *Bt* at the same time to monitor the overall impact on the reduction in fly population and disease transmission. Monitoring and evaluation techniques previously carried out in Kenya were used (*1992 ICIPE Annual Report*).

Bacillus thuringiensis (*Bt*) was produced using soybean (3%), molasses (1%) and phosphate (0.5%) medium. The cell and spore counts averaged 10^9 ml^{-1}. The active ingredient consisted of spores and bacteria. The evaluation was done by visual observation for both larval and adult fly populations in and around the toilets twice a week. The results show that after 2–3 weeks *Dudustop* considerably reduced the number of the larvae in the treated toilets while there was no fly larvae reduction in the control (Table 1). The adult fly population also went down. The impact on reduction of fly population within the whole camp after the treatment of all 400 toilets continued for 3–4 months, confirming the long-lasting effect of *Dudustop*. It is important to mention that the overall cleanliness in the camp also contributed to the general lowering of fly density.

Table 1. Effect of *Dudustop* in killing filthfly larvae in Bonga Refugee Camp toilets

Toilet designation	December				January									February		March		Flies after 2 weeks			
	14	19	22	27	29	3	5	10	12	15	20	26	31	15	25	10	20				
T1	+++	+++	+++	+++	++		++	++	++	++	++	++	+	+		++	++	+	-	-	NO
T2	+++	+++	++	++	++		+	-	-	-	-	-	-	-		-	-	-	-	-	NO
T3	+++	+++	+++	++	++		+	+	+	+	+	+	-	-		-	-	-	-	-	NO
T4	+++	+++	++	+	+		-	-	-	-	-	-	-	+		++	+	-	-	-	NO
T5	+++	+++	+++	+	++		++	-	+	-	-	-	+	+		-	-	-	-	-	NO
T6	+++	+++	+++	++	+		+	-	-	+	-	-	-	+		++	-	-	-	-	NO
T7	+++	+++	++	+	+		-	-	-	-	-	-	-	-		-	-	-	-	-	NO
T8	+++	+++	++	+	+		-	-	-	-	-	-	-	-		-	-	-	-	-	NO
T9	+++	+++	++	+	+		+	+	+	-	-	-	-	-		-	-	-	-	-	NO
T10	+++	+++	+++	++	+		+	-	-	-	-	-	-	-		-	-	-	-	-	NO
T11	+++	+++	++	+	+		+	+	+	+	-	-	-	-		-	-	-	-	-	NO
T12	+++	+++	++	++	+		+	+	+	-	-	-	-	-		-	-	-	-	-	NO
T13	+++	+++	++	+	+		+	+	+	+	-	-	-	-		-	-	-	-	-	NO
T14	+++	+++	++	+	+		+	+	-(+)	-	-	-	-	-		-	-	-	-	-	NO
T15	+++	+++	+++	+++	++		++	++	++	++	++	++	+++	++		-	-	-	-	-	NO
T16	+++	+++	+++	+++	+		-	-	-	-	-	-	-	-		-	-	-	-	-	NO
T17	+++	+++	++	+	+		-	-	-	-	-	-	-	-		-	-	-	-	-	NO
T18	+++	+++	++	++	++		++	++	+	+	-	-	+	+		+	-	-	-	-	NO
T19	+++	+++	++	+++	+++		++	+	-	-	-	-	-	-		-	-	-	-	-	NO
T20	+++	+++	++	+++	+++		+++	+++	+++	+++	+++	+++	+++	+++		+++	+++	+++	+++	+++	MF
Controls C_1–C_{10}																					

Key:
+++, Heavily infested with larvae; ++, Reduced number of larvae; +, Very few larvae in the toilet; -(+), Almost no larvae; -, No larvae observed; MF, Many flies; NO, No flies.

Arthropod Biodiversity, Conservation and Utilisation Programme

Arthropod Biodiversity, Conservation and Utilisation Programme

PROGRAMME OVERVIEW

by H. R. Herren, Interim Programme Leader

Throughout Africa, the main vegetation types and associated habitats are changing, often drastically. These habitats support diverse species of plants and animals, including insects and other arthropods, which are now being threatened. In terms of biomass and diversity, insects and other arthropods represent a much larger group than the other more publicised species of wildlife. Arthropods play an important and often critical ecological role: as herbivore convertors, as links in the food webs of local ecosystems, as regulators of pest and potential pest populations, and as contributors to soil quality. Some (honeybees, silkmoths, lac insects, etc.) are important economically and others (termites, locusts, silkworms, etc.) are an important source of dietary protein for local communities.

ICIPE's research for the past 25 years has been based on developing methods for pest control that respect the integrity of the environment and of man's place in the natural world. IPM itself is a management system that is based on the principle of maintaining and exploiting biodiversity as a component of sustainable agriculture. IPM entails the preservation of natural enemies, and of employing other non-chemical pest control techniques that produce minimum disruption and pollution of the environment.

ICIPE's new Arthropod Biodiversity, Conservation and Utilisation Programme will serve to focus on arthropods and their diversity as a source of environmental services and as a resource for commercial development. The African continent has 23% of the world's land, and almost a third of the world's tropical forest cover. Yet, this enormous potential remains largely untapped. In agricultural-based economies, there is an especially close link between economic development and the conservation and sustainable exploitation of renewable resources. In this new Programme, arthropods are being viewed as a natural resource which can be managed and exploited for income generation to help alleviate rural poverty.

By virtue of its mandate and due to its strategic location in the tropics, ICIPE will seek to play a stewardship role by generating baseline information for better understanding of arthropod biodiversity and its influence on the agriculture, forestry and health sectors. This will be achieved through biological surveys and inventories that will later serve as indices of the patterns of species distribution and nature of communities. ICIPE will also study the systems dynamics, and how species diversity is influenced by agriculture, forestry and other human activities. This knowledge base will, in turn, help in developing management and conservation practices which will safeguard the system's integrity and which work in harmony with nature. The arthropods in four ecosystems will be examined: land-dwelling (terrestrial), tree-dwelling (arboreal); soil-dwelling, and water-dwelling (aquatic) arthropods. The data generated will provide tools for long-term monitoring of ecosystem sustainability, using arthropods as indicators. It will also lay the groundwork for developing improved conservation and utilisation practices, for developing overall strategies for sustainable rural development. The information garnered, of value to the world as a whole, will be distributed through networks linking scientists, NGOs, and universities of the South and North.

Commercial insects

In 1994 several pilot projects were initiated that are providing the support data for development into full project proposals in 1995. Foremost among these are preliminary studies on the African honeybee, *Apis mellifera* sspp. and the silkmoth, *Bombyx mori*. In this report, we provide an overview of the kind of research ICIPE will be conducting on these commercial insects.

Arthropod biodiversity and conservation

Biodiversity studies are not new at ICIPE. Many of the projects described elsewhere in this Report have a biodiversity component. For instance, in our plant pests research, surveys of stemborer species and comparison of their behavioural patterns to pheromones and traps, as well as the genetic diversity of their natural enemies, are essential components in developing a comprehensive management strategy for these pests. Likewise, surveying and assessing the attractiveness of diverse species of wild grasses to stemborers is an intrinsic component of habitat management. Our surveys of wild plant hosts for sandfly sugar meals and forage for the desert locust are included as essential pieces in the puzzle of understanding how these insects interact with biotic factors in their environment. Genetic and species surveys are also planned for some of our 'new' target insects, i.e., the Mediterranean fruitfly and other fruitflies, honeybees and the wild silkmoths.

ICIPE's new programme will serve to broaden our biodiversity research perspective, and this year, pilot biological surveys were initiated in two ecological zones in Kenya, one in indigenous forest and the other in the coastal agroecozone. The objectives are to estimate the abundance, community structure and patterns of distribution of arthropods in these two sites. This preliminary data will be included in an Africa-wide data base of species and their distribution and habitat range.

The practical application of biodiversity conservation and utilisation can be realised through future planned studies on the following:

- Inventory and monitoring of selected target arthropods. Through inventories and monitoring of target arthropods regionally, information on estimates of total species richness, their regional distribution and biology will be obtained. This baseline data will allow valid comparisons of spatial and temporal changes in the target arthropod fauna in the sub-Saharan region. It will help bolster efforts to estimate biodiversity worldwide and provide the key factors that may permit prediction of future trends in arthropod populations. Candidates for regional surveys include selected families in the orders Coleoptera, Diptera, Hymenoptera and Isoptera, among others.

- Arthropods as indicators of ecological and environmental change and condition. Monitoring of arthropod indicators will provide early warning systems that will enable timely interventions which could forestall the need for high cost recovery programmes that are needed when environmental and ecological problems are allowed to amplify to organisms of higher trophic levels. The response of indicators to known environmental pertubations, including management activities, can provide information that can help suggest better management practices. For example, early warnings on pesticide pollution could enable governments to make sound decisions on pesticide use and formulation of a sound framework for pesticide regulation and control. This can help countries to achieve sounder more sustainable agricultural programmes.

Because they play such a major role in agricultural production and health care, women will be targeted for training in biodiversity conservation and utilisation. Other groups which will play a major role in implementing this programme area are universities (both staff and students), research institutions and museums throughout Africa.

I. Honeybee (Apiculture) Research Pilot Project

Participating scientist: *S. Raina* (*Project Coordinator)*

Donor: *ICIPE Core Funds, voluntary contributions 'Harambee' from ICIPE scientists*

1. CUBITAL INDEX AS AN INDICATOR OF HONEYBEE BIODIVERSITY IN EAST AFRICA

Background

Traditional bee-keeping (apiculture) in Africa often results in substantial losses in biodiversity. Due to lack of technical knowledge, the colonies are often destroyed during honey harvesting, and diseases and pests such as the wax moth, introduced. ICIPE's apiculture project will seek to improve both the art and science of bee-keeping. Modern techniques of honey harvesting, queen rearing, colony hygiene and colony splitting need to be incorporated into African bee-keeping practices. The science of apiculture needs to be developed through research on the notorious stinging and absconding tendencies of the African bees, backed up by studies on their behavioural biology and chemical communication in the wild. ICIPE will provide the research and training backstopping to allow development of apiculture into an agro-based microenterprise for small-scale African farmers for production of honey, beeswax, royal jelly, propolis and other hive products.

Work in progress

As a first step in assessing honeybee diversity, preliminary studies in 1994 were undertaken to compare the cubital index of the proboscis length in two known *Apis mellifera* species in Kenya, *A. m. scutellata* and *A. m. monticola*. The double-peak distribution curves in both subspecies indicates that there is an intercrossing between the two strains in the stocks maintained at ICIPE. The higher second peak of *A. m. scutellata* and the lower of *A. m. monticola* is a strong indication of a higher degree of hybridisation in the former species (Figure 1). All individuals in both groups fall below class 18 of the cubital index. The extent of their hybridisation ranges between classes 14–18. The pure races and the hybrid

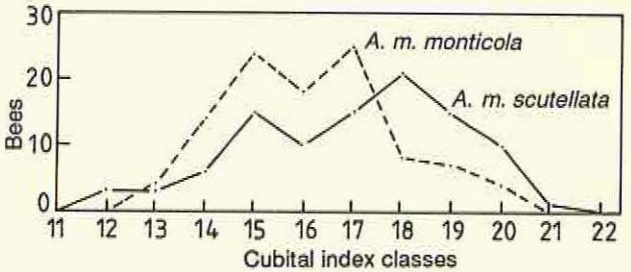


Figure 1. Distribution curves of the cubital index classes of *Apis mellifera* sspp. from ICIPE, Kasarani, Kenya.

ones are being compared for honey yield, pollination capability, royal jelly production and stinging tendency. The floral calendar of different locations in Kenya, particularly the honey-producing areas of Kitui, Mwingi, Machakos and Kikuyu, are being monitored to promote the use of Langstroth hives. Methods for improved queen rearing are being perfected for colony multiplication and for studying other behavioural traits.

Future activities

The output of ICIPE's proposed honeybee research project will be as follows:

(i) Queen rearing by artificial insemination and colony splitting methods will be developed using Langstroth hives. This will help in genetic selection of the desired trait in a colony.
(ii) A floral calendar will be developed for the African region so that the pollination requirements of local crops will be known.
(iii) The behavioural biology and migration pattern of different ecotypes of *A. mellifera* will be determined so as to establish an appropriate strain for productivity of honey and other bee-hive products.
(iv) Appropriate methodologies for management of bee pests and diseases will be devised.
(v) Pilot units for beekeeping will be established for training and demonstration purposes.
(vi) Audio-visual training and working modules will be developed for NARS and NGOs.

II. Silkmoth (Sericulture) Pilot Project

Participating scientist: S. Raina* (*Project Coordinator)

Donor: ICIPE Core Funds, 'Harambee' from ICIPE staff

Background

The raising of the domesticated silkmoth, *Bombyx mori* is a new agroforestry option for Africa. Sericulture can be practiced in even the most modest circumstances to provide a high-value silk fibre with a ready world market, as well as other useful by-products such as high-protein animal feed and industrial oils.

Wild silkmoths provide the special tussah silk that must be harvested from the forests. These wild species are under threat due to over-exploitation of the larvae as protein food (they contain up to 23% protein) and to loss of habitat.

ICIPE's proposed project on the sustainable conservation of saturniid silkmoths and commercial utilisation of selected bombyciid races will provide the scientific back-up for development of integrated land-use systems. Several previous efforts at sericulture in Africa have failed due to lack of research underpinning and understanding of the problems of disease, egg diapause, and of the grainage required for producing bivoltine hybrids.

Work in progress

1. SELECTION OF MOST PRODUCTIVE BIVOLTINE SILKWORM RACE AND MULBERRY CULTIVAR FOR COMMERCIAL SILK PRODUCTION

In pilot studies this year, seven cultivars of the mulberry, *Morus alba* (Kanva/2; S41; S36; S54; Thailand; Embu and Thika) were screened against three races of *B. mori* (NB_{18}; NB_4D_2 and Sanish) in order to select the most productive race of silkmoth for commercial exploitation. Kanva/2 ranked first among the seven mulberries, followed by Embu and S41. The parameters followed were development time of the silkworm larvae, moulting time, oviposition, occurrence of disease and the silk fibre length per cocoon. These preliminary experiments were performed at 20–26°C with a relative humidity of 75–85%. The silkmoth race which performed best is NB_{18} and its survival rate is 95% with no incidence of disease if proper management techniques are followed. The female lays an average of 450–570 eggs and the hatching of larvae is 90 ± 5%. The length of the yarn checked with a single cocoon reeling machine is 800–870 metres per cocoon (Figure 1). This race has been selected for commercial production and distribution to farmers.

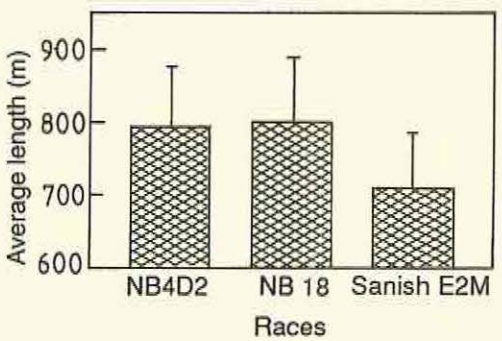


Figure 1. Average fibre length of cocoons from three races of the silkmoth, *Bombyx mori* evaluated at ICIPE.

Future activities

The outcome of the proposed project will be as follows:

(i) The best silk yielding varieties from the families Saturniidae and Bombycidae will be screened for favourable attributes, such as fibre quality and protein value.

(ii) A disease diagnostic kit for silkmoth and its life stages will be developed and made available for end-users and therapy for disease prevention and cure will be prescribed.

(iii) Pure line races and grainage for production of disease-free silkmoth eggs will be established.

(iv) The socioeconomic and market survey will be completed.

(v) A model for an integrated land use system for mulberry and other wild host plants will be developed.

Research Support Units*

*(*The research reports of the Behavioural and Chemical Ecology, Molecular Biology and Biotechnology Research Units have all been included under the funding and thematic project reports.)*

I. Animal Rearing and Quarantine Unit

Participating scientists: *J. P. R. Ochieng'-Odero*, G. W. Oloo**, F. O. Onyango (*Unit Head, ** Ag. Unit Head)*

Senior assistance by: *M. D. O. Bungu, J. U. Wanyonje, S. M. Ndugo, J. M. Okomo, H. K. Banda, J. M. Kagoiya, A. K. Ikhunyalo, P. E. W. Njoroge, J. M. Ongudha*

OVERVIEW

The Animal Rearing and Quarantine Unit is one of the oldest departments of the ICIPE, having been established at the inception of the centre in 1970. Even though its name has changed several times, the prime duties, responsibilities, and objectives of the Unit remain the same. These are to:

- Produce and supply quality target insects and other arthropods of the ICIPE, as well as small laboratory mammals.
- Carry out research and develop new and improved techniques of laboratory animal and arthropod production.
- Assess quality of insects and other arthropods produced in the Unit.
- Carry out training of scientists, technologists, and technical personnel from national programmes on techniques of insect/arthropod production.
- Act as a resource and advisory centre for other international and national institutions on insect/arthropod rearing technology.
- Carry out quarantine activities on importation of research insects and other arthropods.
- Control entry of arthropods and potential plant/animal pathogenic microorganisms;
- Maintain cultures of imported arthropods/microorganisms under controlled conditions so as to exclude possible escape of such obnoxious insects;
- Determine the health status of all arthropods imported through the ICIPE;
- Multiply arthropods under quarantine for supply to users.

The Animal Rearing and Quarantine Unit (ARQU) is organised into four sections, each of which has major activities concerned with a target pest or vector, or groups of animals:

- Haematophagous arthropods (tsetse, mosquitoes, and ticks)
- Phytophagous arthropods (stemborers and locusts)
- Small mammals (rabbits, rats, mice, and hamsters)
- Large mammals (cows and goats)

In its efforts to provide effective service in the production of quality insects and other arthropods as well as small mammals to various users, the ARQU has collaborated with various sections inside and outside the Centre. Although some of these collaborative projects were only at the level of the provision of quality insects for the utilisation by the project, in several there was a substantive research element which saw the generation of significantly important information mutually beneficial to both parties. In the 'Neem' project, for example, the Unit carried out investigations on the effect of various neem preparations on the various growth stages of *Chilo partellus*.

In this report, we cover the various activities that have been in progress during 1994. Raising of specific insect pests such as tsetse, locusts, mosquitoes is included in the respective projects under Plant Pests and Disease Vectors Management Programmes.

Work in progress

1. RESEARCH AND DEVELOPMENT (R&D) ON REARING TECHNIQUES

Animal Rearing and Quarantine Unit (ARQU) has undertaken various R&D projects aimed at improving techniques for a reliable and cost-efficient production of arthropods and laboratory animals. Some of the projects being carried out are:

- Evaluation of techniques for the rearing of cereal stemborers;
- Assessment of the ideal conditions for the maintenance of colonies of various tsetse species;
- Tests on the effect of local versus imported rabbit diets on the performance of tsetse colonies maintained on these rabbits;
- Survival of local versus exotic rabbits kept in a hot and arid environment for tsetse rearing;
- Development of techniques for quick assessment of the quality of small mammals in the maintenance of rabbits for tsetse production.

2. INFORMATION MANAGEMENT ON INSECT REARING THROUGH THE USE OF MICROCOMPUTERS

Participating staff: *J. M. Okomo, J. P. R. Ochieng'-Odero, G. W. Oloo*

In the last few years, the ARQU has built a comprehensive database on the rearing of insects and other arthropods. Currently, some 2500 papers have been built into this information area, covering all aspects of insect production. Stress has been put in the areas of insect rearing and management, methodology on arthropod breeding, breeding and maintenance of laboratory animals, disease control in laboratory cultures, and quality control in laboratory insects and animals. The database has had a positive influence on the research in progress in the Unit, by providing up-to-date information on technologies for arthropod and laboratory animal production.

3. BREEDING AND MAINTENANCE OF SMALL MAMMALS

Participating staff: *J. M. Kagoiya, J. P. R. Ochieng'-Odero, G. W. Oloo*

The breeding and supply of rodents and rabbits for the rearing of blood sucking arthropods within ARQU, as well as for various experimental activities, was carried out successfully. The section supplied 1734 rabbits, 2463 mice, 1613 rats and 14 hamsters during this period.

Quality standards included spot checks on the animals before and during usage. Some parameters recorded were rabbit weight (3–4 kg at 5–6 months, New Zealand White), packed cell volume (PCV) (40%), haemoglobin level (13 g/100 ml), and reticulocyte count (below 2%).

Rabbits for the rearing of tsetse flies were maintained on a special diet (SDS) imported from England. The level of cleanliness in the rabbit breeding area was high, as a more efficient and effective technique of collecting rabbit droppings for disposal was introduced.

Training activities

The Unit acts as a centre for the training of technical and scientific staff in the area of the production of insects and other arthropods. Personnel from several institutions, such as the Kenya Polytechnic, spent some time in the insectary to acquaint themselves with techniques of arthropod production.

Completed studies

Ochieng'-Odero J. P. R., Mzingirwa A. M., Njoroge P. E. W., Bungu M. D. O., Munyinyi D. M. and Onyango F. O. Larval critical weight, pupation and adult fecundity in the spotted stem borer *Chilo partellus* Swinhoe (Lepidoptera: Pyralidae): An index of quality. *Insect Science and its Application* 15(2) 123–127.

The larval critical weight (L_{cw}) in the spotted stem borer, *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) was 54.6 ± 1.0 mg for average sized male and female final instar larvae and was 63% and 39% of the larval maximum weight (L_{mw}) of males and females, respectively. There was a consistent decrease in weight from L_{mw} to pupal weight of 35% in both males and females over successive generations of rearing two laboratory populations. The adult weight was consistently about 37% and 22% lower than the pupal weight for males and females, respectively. During starvation, 25% of the final instar larvae produced a supernumerary moult. A positive correlation was derived between female pupal weight and fecundity. The results were similar to those derived from a study on the progeny of a wild population. A model representing the various fresh weight changes in relation to the L_{mw} has been suggested for this species. The model is similar to that proposed for other Lepidoptera. The results of this study are largely consistent with those carried out on other species of Lepidoptera and underline the value of using stable standards in assessing the quality of laboratoty reared insects.

Onyango F. O. and Bungu M. D. O. Standard rearing procedure for the sorghum stemborer *Chilo partellus*. In *Techniques of Insect Rearing for the Development of Integrated Pest and Vector Management Strategies* (Edited by J. P. R. Ochieng-Odero), pp. 367–376. ICIPE Science Press, Nairobi.

Onyango F. O. and Nyangwara A. G. Standard rearing procedures for the maize stem borer *Busseola fusca*. *Ibid.*, pp. 407–416. ICIPE Science Press, Nairobi.

Onyango F. O. and Ochieng'-Odero J. P. R. Continuous rearing of maize stem borer *Busseola fusca* on an artificial diet. *Entomologia Experimentalis et Applicata* 73, 139–144.

Busseola fusca (Fuller) (Lepidoptera: Noctuidae) is a major pest of maize and sorghum in many countries of tropical Africa. Hitherto, research on this important pest has been hampered by the occurrence of a six-month long diapause in the last larval stage and the lack of an artificial diet for rearing the insect in the laboratory. Incorporating 4 to 8-week-old sorghum powder in a nutritionally adequate diet and rearing larvae individually in vials at ambient laboratory conditions (25–30°C, 50–80% RH, and L12: D12) have made it possible to rear 15 successive non-diapausing generations of *B. fusca* capable of producing between 35 to 40 healthy pupae/litre of diet and upto 70% pupation without loss of vigour or reproductive capacity. Five to six genrations were completed per year and the overall mean developmental period (egg-egg) was 68 days (egg 6, larval 45, pre-pupal 1, pupal 14 and pre-oviposition 2 days). Larval period lasted 70 days in the first generation compared to 32.3 days in the fifteenth generation. Average fecundity increased from 158.0 to 394.6 eggs per female with a concomitant increase of egg hatch from 44.8 to 79.6% in the first and fifteenth generation, respectively.

Onyango F. O. and Wagara P. O. Standard rearing procedures for the legume pod borer *Maruca testulalis* on artifical diet. *Ibid.*, pp. 393–400. ICIPE Science Press, Nairobi.

Onyango F. O. and Ochieng'-Odero J. P. R. Laboratory rearing of the legume pod borer *Maruca testulalis* Geyer (Lepidoptera: Pyralidae) on a semi-synthetic diet. *Insect Science and its Application* 14, 719–722.

The legume pod-borer, *Maruca testulalis* was reared in the laboratory for 10 successive generations using a semi-synthetic diet. The diet was composed of locally available soybean flour and cowpea flower powder as basal ingredients. The artifical medium was as suitable as the cowpea host plant for *M. testulalis* in supporting larval growth and development. Fecundity increased with advancing generations on the artificial medium. Field collected pupae were heavier than diet-reared pupae. However, the fecundity, fertility, adult life span, and sex ratio did not differ between the two rearing regimes. The laboratory-reared insects were of acceptable uniform quality and predictable performance even after 10 successive generations of laboratory rearing. Adult emergence ranged between 70–90%. One litre of diet produced on average 400 pupae or adults with a mean fecundity of 200 eggs per female. One person working 8 h/day can produce a minimum of 1000 healthy pupae or adults daily. The laboratory rearing management protocol is described.

II. Biomathematics Unit

OVERVIEW

Participating staff: *A. Odulaja*, D. M. Munyinyi, H. H. Meena, M. D. M. Gathoga (*Unit Head)*

Assisted by: *O. O. Okello, M. N. Akello*

The Unit continued its contributions towards improving the quality of research results at the Centre through various services in the area of biomathematics and geographic information systems (GIS). Collaborations with scientists in different projects increased and biostatistical research and modelling activities in the Unit were continued.

Teaching of biostatistics in ARPPIS was undertaken by the Unit and industrial attachment training was provided for students of Polytechnic and Universities in Kenya. Limited modelling activities, mainly on tsetse, and some biostatistical research aimed at improving data analysis methods in insect science were undertaken. Biostatistical services were offered in the areas of design of experiments, analysis of data and interpretation of results.

GIS services were in higher demand during the year with increasing awareness of the usefulness of GIS models. Most new projects now include some measure of GIS activities.

A member of staff of the Unit, Mr Onyango Okello resumed work in December, 1994, after a successful one-year course at ITC, Netherlands, on cartography. This will further strengthen the GIS work in the Centre. Some of the research achievements are described below, while others are reported under the Plant Pests Management and Disease Vectors Management Programme reports.

Work in progress

1. TSETSE POPULATION MODELLING

Tsetse longevity versus bloodmeal source/size

The need to establish tsetse laboratory colonies for research purposes makes it imperative to understand different factors which influence the longevity of the fly. Premature death (drop-out) of female tsetse (*Glossina morsitans centralis*) in relation to the source and size of bloodmeal was studied. Five bloodmeal sources (buffalo, eland, goat, rabbit and waterbuck) were used.

The probability of drop-out was found to depend more on previous rather than on current bloodmeal size before drop-out. This probability decreased, however, with increase in both previous and current bloodmeal size. The risk of drop-out increases when the current bloodmeal size is higher than the previous one while the risk decreases with increase in the mean of the two bloodmeals. Details are given under Tsetse Research in the Disease Vectors Management Programme.

Tsetse interlarval period

Growth rate is central to the modelling of any population. One of the important components of growth rate in tsetse population is the natality rate, which in turn is a function of the interlarval period. Hence, an understanding of the distribution of female tsetse interlarval period is crucial to modelling the population. We adopted a stochastic approach for modelling the distribution of tsetse interlarval period. The Weibull function was employed for this purpose using the Marquardt technique to obtain the least-square estimates of the parameters. This probability function, normalised, was tested with data obtained from a laboratory experiment on tsetse interlarval period and gave good results. Details are given under the Tsetse Research reports.

2. MODELS FOR AGRICULTURAL PRODUCTION BY SMALL-SCALE FARMERS IN SUB-SAHARAN AFRICA

Small-scale farmers, who provide the greater proportion of food consumed in Africa, produce at levels far below the capacities of various packages developed by scientists. Consequently, these farmers remain in abject poverty and, despite their relatively large number, cannot produce enough to feed the population.

To improve the quality of life of these farmers in particular, and the population of Africa in general, there is need to study the various factors responsible for low levels of agricultural production. Formulation of models

relating production to the various factors is necessary for a better understanding of the functional relationships which could lead to relevant national and international policies with respect to small-scale farmers in Africa.

The Biomathematics Unit has developed models to predict production given these factors. For simplicity, the parameters of the models were limited to land size (or herd size), environmental effect and management effect.

A statistical examination of our model fitted to a set of survey data on this subject revealed that improving the farmers' management level could greatly enhance their production. Further statistical analysis of the data set showed that the various factors constituting the farmers management level could broadly be classified into three groups: resources (labour and farm implements), personal characteristics (educational level and age) and external assistance (contact with extension agents/assistance) in that order of importance. Details are given under the Plant Pests Management Programme.

3. BIOSTATISTICAL ACTIVITIES

Participating scientists: D. Munyinyi, C. Olando

During the year under review, the greater part of our biostatistical work was spent on experimental designs, actual analysis of data and discussions of results with the involved staff. The majority of ICIPE personnel are now able to input data using Lotus 1-2-3, full screen editors and other data management software. Despite the limited number of biostatistical staff providing this vital service, the quality of work output is of very high standard and demand for biostatistical services continues to grow. Due to the changing trends in computer technology, we hope to move to window-based versions of the packages we use because of their versatility and ease of use.

4. GEOGRAPHIC INFORMATION SYSTEMS (GIS) ACTIVITIES

Participating scientist: H. H. Meena

Work continued on the compilation of the Kenya Coast database for the ISERIPM project. Collection and generation of socioeconomic data took precedence. Geo-location of trial sites was accomplished during the year. For the EU tsetse project based in Nguruman, data collected from tsetse monitoring traps over the period May 1993– December 1994 was used to generate spatio-temporal maps. These maps show tsetse population density dynamics by species and sex per trap per season.

Completed studies (*Biomathematics staff are starred*)

Kitron U., Otieno L. H., Hungerford L. L., Odulaja A.*, Brigham W. U., Okello O. O.*, Joselyn M., Mohamed-Ahmed M. M. and Cook E. Spatial analysis of the distribution of tsetse flies in the Lambwe Valley, Kenya, using TM satellite imagery and GIS. ***Journal of Animal Ecology*** **(submitted).**

Ochieng'-Odero J. P. R., Mzingirwa A. M., Njoroge P. E. W., Bungu, M. D. O. Munyinyi D.* and Onyango F. O. Larval critical weight, pupation and adult fecundity in the spotted stemborer, ***Chilo partellus*** **Swinhoe (Lepidoptera: Pyralidae): An index of quality.** ***Insect Science and its Application*** **15, 123–127.** *(See abstract under Project I of this section)*

Odulaja A.* Description of non-precision in experimental field scores. ***Discovery and Innovation*** **(submitted).**

Odulaja A.* Statistical analysis and design of crop evaluation trials for pest resistance: Some concerns. ***African Crop Science Journal*** **(submitted).**

Odulaja A.* and Kiros F. G. Modelling agricultural production of small-scale farmers in sub-Saharan Africa: A case study in western Kenya. ***Agricultural Economics*** **(submitted).**

Odulaja A.*, Afonja B. and Bamiduro T. A. Analysis of variety trials in the presence of non-random time effect. ***Biometrical Journal*** **36, 70–85.**

The assumption of random year effect in the analysis of variety trials data over locations and years clearly contradicts the practice of conducting the trials over only a few consecutive years. A method of analysis of such trials which assumes that the year-dependent effects are serially correlated is proposed in this paper to cater for the non-randomness in the selection of years of the experiments. A simple autoregressive model was assumed for the serial relationship. A reduction in the variance estimate of the difference between two variety means was obtained using this method.

Oghiakhe S. and Odulaja A.* Classification of cowpea cultivars for field resistance to the legume pod borer, ***Maruca testulalis,*** **in Nigeria using cluster analysis.** ***Annals of Applied Biology*** **122, 66–77.**

Cluster analysis was used to classify cowpea cultivars developed for resistance to *M. testulalis* in Nigeria based on data collected on four damage parameters. The cultivars are grouped into classes for each of two locations under two protection regimes. Differences were observed in the groupings for the two locations while one cultivar, MRx6-84F was found to have wide adaptability in the presence or absence of *M. testulalis* infestation. This is particularly useful for the selection of breeding materials in cultivar improvement for specific or general ecological zones.

Collaboration

Staff of the Unit collaborated with many scientists from the different ICIPE departments on various research projects. These have resulted in a number of joint publications, some of which are now undergoing review. Collaboration and linkages with external institutions during the year included the following:

1. The Global Initiative Research Project proposal on the development of a GIS model for the eradication of pseudorabies virus was initiated between ICIPE and Purdue University in the USA. A visit to Purdue was undertaken in January by a staff of the Unit to promote linkages, identify technical and administrative requirements for the project and for ICIPE to acquire GRASS GIS software.
2. A joint project between ICIPE and the University of

Illinois at Urbana-Champaign in connection with the use of ARC/INFO GIS, spatial analysis and expert systems for tsetse management. Plans for future joint projects are also being set up.

3. Local linkages with international and national centres were maintained. Data on animal counts, domestic and wild, for the UNDP-funded Kwale/Kilifi project were obtained from the Department of Resource Survey and Remote Sensing (DRSRS) of Kenya. The data were for the period April 1989 and February 1993.
4. The Regional Centre for Services in Surveying Mapping and Remote Sensing (RCSSMRS) continued as a vital source of Normalised Difference Vegetation Index (NDVI) data. The data covers ICIPE's research sites in Kenya. Africa-wide data on tsetse species and distribution, ticks species and distribution and human population densities and administrative boundaries were obtained from UNEP/GRID, Nairobi.

Training activities/capacity building/outreach

The Unit continued to contribute towards capacity building of local expertise by hosting statistics and computing industrial attachment students from the polytechnic and several universities in Kenya.

The Unit participated in the 'International Group Training Course on Integrated Tsetse Management for Tropical Developing World', ICIPE, Nairobi, Kenya, 14 February–12 March, 1994, and presented lectures/practicals on modelling of tsetse populations.

The Unit also actively participated in the 'International Group Training Course on Components Essential for Ecologically Sound Pest and Vector Management Systems', ICIPE, Nairobi, Kenya, 14 August–10 September, 1994 and presented lectures and practicals on the following topics: (i) overview of mathematical applications in pest and vector management, (ii) experimental design, (iii) multivariate procedures, (iv) regression methodology, (v) determining insect population size, (vi) modelling the dynamics of insect population, (vii) sample survey methods and sample size determination, (viii) practical data computation using computers. The teaching of the ARPPIS 1994 class in Biostatistics and Experimental Design was also undertaken by the Unit.

III. Social Science Interface Research Unit

Participating staff: *F. G. Kiros*, G. T. lako, J. W. Ssennyonga, P. A. Chitere (*Unit Head)*

Senior assistance by: *A. N. Ngugi, J. N. Ombaso, G. G. O. Nyambane, P. E. Ragama, T. A. Ogono, B. A. Omollo, O. J. Nyapela*

OVERVIEW

The development of Social Science research in ICIPE is a direct response to the basic goal of the Centre to develop pest and vector management technologies appropriate for the production systems and economic and social circumstances of the potential users of such technologies, who largely consist of small-scale agricultural producers and pastoralists. Today, it is firmly established that the efficacy and sustainability of new pest and vector management technologies can be assured and its adoption and impact enhanced when socioeconomic analysis is effectively integrated in the R&D process.

Socioeconomic research can have a role to play, from the very inception of a research project to the final evaluation of the impact of the technologies emerging from such research. The research activities could encompass analysis aimed at clarifying and articulating objectives and methods, generating socioeconomic data which would be required in the technology design process, evaluating the economic viability and social compatibility of the resulting technologies, as well as their potential adoptability and impact.

Remarkable advances have been made within ICIPE toward the realisation of such a research approach. Whereas in the early stages, the scope of social science research was limited and its role subsidiary, it has now come to occupy a central place in the R&D system of the Centre. Indeed, two of the most important research projects of the Centre currently under implementation in the Coast and Western Provinces of Kenya are coordinated by the Social Sciences Department (SSD) with the social scientists working hand-in-hand with biological scientists in such areas as crop pests and vectors of livestock diseases. Highlights of the research accomplishments pertaining to these and other projects in which the SSD has participated in 1994 are provided below.

A. THE INTERACTIVE SOCIOECONOMIC RESEARCH FOR BIOINTENSIVE PEST MANAGEMENT PROJECT (ISERIPM)

This project has two components, each to be implemented in three phases covering the period 1993–1995: a crop pests component and a livestock ticks component. In 1994, Phase II of the main crop pests component of the project involved on-farm researcher-managed technology trials and a number of socio-economic research activities; these are being implemented in Kwale and Kilifi Districts of Coast Province of Kenya. Phase II of the livestock ticks component of the project being implemented on Rusinga Island in western Kenya also involved a number of biological and socioeconomic studies.

Crop pests component

With regard to the crop-pest component of the project, the first quarter of 1994 was a period of extreme pressure of work particularly for the Social Science staff. This was especially the case because they, with the collaboration of the biological scientists, had to complete both the village-level and household-level surveys which would form the basis for the selection of research sites and participating farmers, respectively.

Once the selection of research sites and participating farmers was accomplished, a number of field research activities had to be scheduled and executed, again within the constraints imposed by the agricultural season. Among the most important of these activities were the following:

- expediting the execution of farm trial activities including land preparation, planting, weeding, providing for the security of the trial fields harvesting and many other activities;
- ensuring the recording of essential socioeconomic data pertaining to the scientist-managed trials as well as the plots of the participating farmers;
- preparation for and conducting workshops for the benefit of the participating farmers and extension personnel of the Kenya Ministry of Agriculture, Livestock Development and Marketing (MOALDM), designed to familiarise them with the technology trials under implementation; and

- planning and coordination of the evaluation of the technology trials by the participating farmers.

In spite of the constraints imposed by the seasonality of the field operations, the basic research objectives of Phase II of the Project have been substantially accomplished. In summary, from the Social Sciences point of view, the accomplishments include the following:

1. the completion of the on-farm trials in all planned research sites during the long rains, the launching of the short rains trials which, contrary to 1993, were expected to benefit from abundant rainfall in 1994;
2. the maintenance of sustained interactive research processes involving the social and biological scientists at various levels, including the design of research instruments, the conduct of workshops for farmers and extension personnel, evaluation of technology trials, etc.;
3. enhanced collaboration with front-line extension agents and district and provincial MOALDM officials which has greatly facilitated farmer participation;
4. a high level of community participation in vital stages of the research process, including the selection of research sites and participating farmers, generation of socioeconomic information especially in relation with the village and household-level surveys, participation in training workshops and in the evaluation of the technology trials; and
5. active and sustained processes of documentation of experimental activities and field data generation and analysis which constitute the basis for the preparation of a number of research methodology papers currently in progress.

Livestock ticks component

The research activities undertaken in 1994 in the livestock ticks component of the ISERIPM project pertained to studies in management for reduction of tick-infestation levels and feasibility of using chicken as predators of livestock ticks. Both the studies have produced substantial biological and socioeconomic data and brought to light a number of issues bearing on the feasibility of the control of modified strategies of livestock management and the application of biological control.

In the case of the first study, an initial survey undertaken sought to determine the time allocated by the rural community to livestock production relative to other activities. Among a number of findings is that there appears to be room for introducing technologies which may require additional time allocation by households. Data collected to determine the seasonal and diurnal variation in the time cattle are grazed and patterns of grazing are currently being analysed.

In relation to the study on biological control of ticks, it was found that the mean ratio of cattle to adult birds at the time of the survey was adequate for predation. However, the chicken population, which is both unstable and declining, calls for intervention to enhance effective and sustainable predation of ticks.

The implementation of the ISERIPM Project will continue in 1995 more or less as planned. During this phase of the project increasing emphasis will be made on community participation in technology testing and evaluation.

(More information about the ISERIPM Project activities can be found under Project IX of the Plant Pests Management Programme and under Project V of Ticks Research of the Disease Vectors Management Programme.)

B. ADAPTIVE RESEARCH ON COMMUNITY-BASED MANAGEMENT OF TSETSE AND TRYPANOSOMIASIS (ARCMTT)

This project involves a number of interlinked research activities. In 1994 the main activities included:

- Promotion of the adoption of tsetse-control technology by means of community mobilisation, formation of community organisation and management for tsetse control, mobilisation of resources, trap making, placement and servicing; and
- Monitoring and assessment of the impact of community tsetse trapping on tsetse population and incidence of trypanosomiasis, livestock productivity, land use and related aspects.

The achievements in all aspects of the research project have been impressive. Among the main accomplishments are:

1. the creation of an effective community organisation for tsetse control;
2. the wide participation of the population of the research area in tsetse control activities including trap construction and servicing, financial contributions, monitoring impact of tsetse control in collaboration with the researchers;
3. the realisation of a successful approach of interactive research involving the social and biological scientists working on the project, and collaborative activities involving personnel of the MOALDM;
4. systematic documentation and reporting of research results covering all aspects of the project; and
5. last, but most important, the marked reductions of *Glossina pallidipes* and of the prevalence of trypanosomiasis in cattle in those settlements close to the control area attributable to community-managed tsetse control.

The monitoring activities and impact assessment covering biological and socioeconomic aspects will continue in 1995. The key test of the success of the community-based approach will be the sustainment of trapping even after very low levels of tsetse population and trypanosomiasis incidence have been attained.

(More information about this project can be found under Tsetse Research under the Disease Vectors Management Programme.)

C. OTHER RESEARCH ACTIVITIES

1. STUDY OF ADOPTION OF HOUSEHOLDS' CAPACITY TO MANAGE AND SUSTAIN PERMETHRIN-IMPREGNATED MBU CLOTH TECHNOLOGY IN MARIGAT AREA, KENYA

This study examined the potential for adoption, sustainability and community participation in the

evaluation of the Mbu Cloth technology for the control of malaria in Marigat, Baringo District of Kenya. In spite of the fact that systematic socioeconomic studies were initiated late, the research findings highlight a number of substantive and methodological issues which pertain not only to the Marigat project but also to future research relating to testing, adoption and assessment of the impact of the malaria-control technology.

The methodological issues concern the need for conducting adequate baseline surveys prior to the introduction of the technology and the adoption of a systematic process of testing, evaluation and promotion of adoption.

The substantive issues relate to the promotion of the community-based approach of technology management and the need to look into the adaptation of the technology to the patterns of population settlement and types of house structures and sanitary conditions which prevail in the research areas.

(See also Medical Vectors Research under the Disease Vectors Management Programme.)

2. INTERACTIVE DEVELOPMENT AND APPLICATION OF SUSTAINABLE TSETSE MANAGEMENT TECHNOLOGIES FOR AGROPASTORAL COMMUNITIES IN AFRICA

A number of research activities were undertaken in fulfillment of the socioeconomic objectives of this project. These included the assessment of the impact of testse trapping in Nguruman, investigation into problems hampering a community-based approach of tsetse control in this region, and a study on the capacity of the agropastoral community to adopt and manage the tsetse trapping technology.

The research results indicate that tsetse trapping in Nguruman has reduced the tsetse menace in the area, and has permitted the use of larger land areas both for livestock grazing and cultivation.

The importance of promoting a community-based and self-reliant approach is clearly demonstrated by one of the study results. In particular, it has been shown that heavy external dependence for the financing and management of tsetse trapping can hardly be expected to ensure the sustainability of the technology.

Traditional social structures are dominant in the pastoral areas. The potential of these social structures as well as of the governmental and nongovernmental institutions to promote the adoption and management of the tsetse trapping technology remains to be evaluated.

3. DEVELOPMENT OF EFFICIENT AND ENVIRONMENTALLY ACCEPTABLE TSETSE AND TICK CONTROL STRATEGIES FOR THE TROPICAL DEVELOPING WORLD

The socioeconomic aspect relating to this project concerned the study of community social organisation and capacity, and social division of labour and its implications for tsetse trapping in Kwale District, Kenya.

A number of local organisations were identified which have the potential for participating in tsetse control, notably women's groups and village committees.

Labour appears to be generally in short supply due to seasonal agricultural activities. However, the study suggests that each household might be able to contribute a proportion of its labour time, however small, to community tsetse control activities.

(See also Tsetse Research for more information about activities 2 and 3 above.)

Completed studies

Chitere P. O. and Kiros F. G. Study of adoption of and households' capacity to manage and sustain permethrin impregnated Mbu Cloth technology in Marigat area, Kenya.

The objectives of the study were: (1) to examine the potential for widespread adoption and sustainability of the technology in the stuy area, and (2) to look into the problems and potential for involvement of the community in the testing and validation of the technology.

Kiros F. G. Spearheading social science interface research at ICIPE. *Dudu* No. 48/49 June 1994.

Kiros F. G., et al. Farmers' participation in the adaptation of IPM technology in the Coast Province, Kenya. *African Crop Science Journal* (in press).

Participation of resource-limited farmers in agricultural research projects in ways that can help ensure their adoption and sustenance of farm technologies is a challenge for most agricultural research agencies. The Interactive Socioeconomic Research for Biointensive Pest Management (ISERIPM) project is an adaptive research project which, among other things, explores methods of involving farmers in various phases of its implementation. The involvement is based on ICIPE's approach of IPM technology development which provides for minimal involvement at on-station trials, somewhat increased involvement at on-farm researcher-managed trials. At on-station trials which were carried out in 1993, farmers' participation was restricted to evaluation of some of the IPM components which included maize and sorghum cultivars and various forms of intercropping.

The sites for the on-farm trials (4 sub-locations and 8 villages), and 89 farmers as potential participants were selected following GIS characterisation of the research districts of Kwale and Kilifi on the basis of agroecological and socioeconomic conditions, and macro-village- and household-level surveys. In subsequent meetings, members of the chosen villages selected 8 trial farmers (TFs) one per village from among those chosen as project farmers. The rest of the farmers who met the selection criteria are termed non-trial participating farmers (NTPFs) and participated in the various educational activities of the researcher managed trials in 1994. In 1995, all of the farmers became participants in the farmer-managed on-farm trials.

Lako G. T. Cost of tsetse trapping using the NG2G tsetse trap: A case study in Kenya. *Insect Science and its Application* (in press).

The study aimed at assessing the costs of the trap not only in terms of materials needed but also labour used based on ICIPE's experience at its Nguruman field station.

More specifically, the study aimed at:

(a) determining the cost of making a single trap as well as

maintaining it for a period of one year;

(b) establishing the labour requirements/costs of making a trap;

(c) establishing the labour requirements of servicing one trap in a year; and

(d) assessing the serving activities of the traps.

The study was started in November, 1990 and lasted 20 months through July, 1992. A total of 246 traps were observed from their making, installation, operation and servicing/replacement stages. Technical staff from the Tsetse Research Programme visited each trap once a month on average for purposes of carrying out repairs or maintenance work needed and to replenish odour baits. In all, 4164 visits were made to the traps, i.e., an average of 17 visits to each trap over the study period.

The analysis of the data gathered has depended largely on descriptive statistical tools (e.g. frequencies, cumulative frequencies and percentages) as well as simple accounting procedures and probability theory concepts.

Ssennyonga J. W. Resource allocation in polygamous families in the Lake Victoria Basin in Kenya: Its implications for development. In *African Family: Its Responses to Changes* (Edited by Wesner S. and Bradley C.). Greenwood Press, USA.

Ssennyonga J. W., Implementing community-based IPM projects: Case study of community managed tsetse trapping technology in Lambwe Valley, W. Kenya. In *Sustainable Community-Based Pest Management for Rural Development* (Edited by OtienoL. H. and Bugembe M. H.). ICIPE Science Press, Nairobi.

Implementation of community-based IPM projects is severely constrained by two closely related problems. First, implementors generally do not have a clear understanding of what a community-based project (CBP) is all about. The paper addresses this problem by providing indicators of a CBP. Second, there is lack of conceptual framework for guiding implementation of a CBP. The paper presents an eight-phase implementation plan with a built-in logical sequence of activities. These two theoretical issues are illustrated with case study material from an on-going community-managed tsetse trapping technology in Lambwe Valley, W. Kenya.

Institution Building, Interactive Research and Information Programme

Institution Building, Interactive Research and Information Programme

PROGRAMME OVERVIEW

by V. O. Musewe, Programme Leader 1994, and ARPPIS Coordinator

A crucial component of ICIPE's mandate is to help national research and extension systems (NARES) in Africa build up their capacities for research and training in arthropod science and its application for development. This mandate is achieved through harnessing human and material resources of national and international agencies, and translating them into action-oriented capacity building programmes for the benefit of user countries in the region.

The specific objectives of ICIPE's training, information and outreach activities are to:

- develop and implement educational programmes for training scientific and technical manpower as well as user communities;
- facilitate interactive technology development, validation, packaging and demonstration;
- establish and coordinate capacity building networks among African countries and institutions;
- provide an effective information and documentation back-up, specialised in the biology and management of insect pests and vectors;
- maintain a dynamic communication and information system for exchange of information on insect science and other related sciences.

Education and training activities

For sustained technological development, the ICIPE believes that there is need for training and education at every stage of the technology transfer process. Therefore, training for technology generation must go side-by-side with training of extension specialists and education of consumers and policy makers. To this end, the ICIPE has attempted to cater for the whole array of parties whose inputs are essential to technological development by establishing: (a) science leadership training and professional development programmes; (b) programmes for the training of practitioners of insect management technologies; and (c) consumer-based training and educational programmes (presented below under PESTNET).

The ARPPIS PhD and MSc Programmes

The cornerstone of degree-oriented training at the ICIPE has been the African Regional Postgraduate Programme in Insect Science (ARPPIS) since 1983 when the programme was inaugurated. This is a programme in which the ICIPE collaborates with African universities in research training leading to the award of the MSc and PhD degrees from the participating universities.

Through this cooperation, the universities benefit from ICIPE's excellent research and training facilities, the availability of highly specialised research staff, and an international research environment that promotes multidisciplinary collaborative research and educational projects. The Centre benefits from the rich and heterogeneous composition of academic professionals, and the diverse ecosystems that the universities make available. To date, 29 universities are participating in the ARPPIS programme.

The **ARPPIS PhD programme** has been based fully at the ICIPE, where all course work and thesis research are undertaken under the supervision of scientists from both the ICIPE and the participating universities. The ICIPE provides training scholarships and research support, while the universities examine the students and award degrees.

In 1994, a total of 41 students were enrolled in the PhD programme; of these, seven students (1994 class) joined early in the year, while 11 students (1991 class) completed their programmes later that year. By the end of 1994, ARPPIS had, since its inception, produced 47 PhD graduates, with three of them graduating in 1994. Most of the graduates are now university lecturers or scientists in national universities and research institutions.

The **ARPPIS Sub-Regional MSc Programme** aims to train masters level scientists within their own geographical regions, and on research problems that are unique to those regions. The programme is also aimed at academically preparing the graduates for admission to PhD programmes, particularly ARPPIS, by introducing compulsory taught courses at this level to enable the students concentrate only on research in the PhD programme.

In 1994, the MSc programme made tremendous progress at three universities hosting the Sub-Regional Centres. The Centre for Southern Africa Sub-Region at the University of Zimbabwe, Harare, admitted its second stream of five students for the 1994–96 Master of Tropical Entomology (MTE) course. At the University of Ghana, Legon, the Centre for the West Africa Sub-Region started its first MPhil course on 30 September 1994, with an intake of 15 candidates from the sub-region. For the Eastern and North-Eastern Africa Sub-Region, the Centre hosted by Addis Ababa University successfully carried out consultations with universities in the sub-region over the MSc course curriculum, and the programme is due to take off in 1996. A fourth Centre is yet to be established, to cater for French-speaking African countries.

Dissertation Research Internship Scheme

This training attachment scheme enables ICIPE to collaborate with universities and sponsoring agencies outside of the ARPPIS programme. Students registered at universities anywhere in the world are admitted for research training leading to the doctoral or masters degrees of those universities, under joint ICIPE-university supervision. The scheme allows ICIPE to attract scholars of diverse interests, not necessarily within ICIPE's targets, in order to help broaden and enrich ICIPE's academic environment. In 1994, two doctoral scholars from Sri Lanka and the USA were admitted to the scheme for part of their thesis research.

Professional career development programmes

The ICIPE implements five programmes that enable individuals to advance their careers through training. These include:

- the postdoctoral fellowship programme which admits young scientists from Africa and abroad on a competitive basis, for advanced research internship;
- the research associateship scheme, through which scientists from national research and training institutions in Africa, and young graduates from developed countries, gain research attachment for short periods;
- the visiting scientist scheme through which accomplished scientists from any part of the world come to ICIPE for short or long-term collaborative work;
- the field attachment scheme for trainee technologists and undergraduate students; and
- the staff development programme for career development of ICIPE's own staff.

The year 1994 saw marked activity in career development training at ICIPE. Fifteen postdoctoral fellows, 14 from Africa and one from China, were assigned to various research projects, while two research associates from Tanzania and the Netherlands, and two visiting scientists from Kenya and the USA served at ICIPE. A reduction in field attachment was recorded as opposed to previous years, as only 15 trainees were admitted to the scheme; however, staff development training was active with 12 members enrolling in various types of courses held locally and abroad, while some were approved at the staff member's own cost.

Specialised training for IPVM practitioners

Technology is only useful if it reaches and is internalised by the end-users. As ICIPE's mandate excludes the actual transfer of technology to individual consumers within countries under her constituency, it was found appropriate to train mid-level insect pest and vector management specialists, as well as extension personnel, who would eventually train field workers and the final consumers of technology.

Towards this goal, the ICIPE mounted four international group training courses in 1994, covering the biology and management of vectors of livestock diseases (tsetse and ticks) and cereal stemborers, in which a total of 56 participants from 18 African countries were trained. In addition to these practitioner courses, an international training workshop for scientists specialising on tsetse behaviour and ecology was held at the Kenya coast, in which 80 specialists from Africa and abroad participated. Training for consumers which was conducted under the auspices of the PESTNET programme is described below under PESTNET.

Capacity building through interactive research and training: The role of PESTNET

The **African Regional Pest Management Research and Development Network (PESTNET)** has been implemented over the past eight years in ten countries, although with variable success. The aim of the programme has been to enhance the technological capacities of African countries through on-site activities which include the following:

- interactive technology development and adaptation;
- training needs assessment and implementation, and information exchange, with the ICIPE providing a coordination secretariat and scientific back-stopping, and
- an information exchange service through the ICIPE's Pest Management Documentation and Information System and Service (PMDISS). As the activities of PESTNET are undertaken with the participation of national programme staff, the programme was designed to provide the ICIPE with an avenue for more direct contact with consumer communities in each participating country.

In 1994, PESTNET activities were in progress in only five out of ten member countries; these are Kenya, Tanzania, Zambia, Ethiopia and the Sudan. Previously, the programme had pulled out resident scientific teams from Somalia and Rwanda due to prevailing civil unrest, while funds and activities were yet to be identified for collaboration with the other three member countries: Uganda, Zimbabwe and Malawi.

PESTNET made significant achievements in three countries where there were resident scientific teams. In Kenya, useful collaboration was made with KARI on two joint projects at the Kenya coast, leading to achievements in the testing and demonstration of tsetse and stemborer management technologies, with the involvement of farming communities, and in training at both scientist and consumer levels. PESTNET is working with national scientists in Ethiopia to adapt ICIPE-developed tsetse trapping technologies to the local tsetse species; in addition, successful demonstrations of bio-control of filthflies with strains of *Bacillus thuringiensis* (*Bt*) developed at the ICIPE have been staged in refugee camps. Cooperative work in Bukoba, Tanzania, provided training opportunity for national scientists on the control of banana pests, and also supported thesis research for one doctoral student from Uganda in preparation for future collaboration with that country on problems of banana, which is a major staple food crop.

Training activities continued in collaboration with KARI for extending the adoption of environment-friendly technologies by the beneficiary farmers in coastal Kenya. Field days were held at the three on-farm locations in which 20–30 farmers each were trained in the adoption of pest-resistant cultivars of maize and sorghum as well as early intercropping of cowpeas in maize as a means of sustainable reduction in yield losses.

In addition, a three-stage training programme was implemented for mass deployment of tsetse traps in Shimba Hills (adjoining the Game Reserve) in Kwale district, with the following target groups participating: district/divisional extension subject matter specialists (12); frontline extension officers in different locations (16); coastal farmers (60).

Information and publishing activities

The Information Resource Centre (IRC) continued to grow in terms of bookstock and services in 1994. Since its commissioning four years ago, the Centre has provided the necessary back-up and support to research activities at ICIPE.

ICIPE is the focal point of the **Pest Management Documentation and Information System (PMDISS).** ICIPE/PMDISS are linked by CGNET to all CGIAR centres through an improved electronic mail facility. Collaboration with AGRIS (Agricultural Information System) of FAO was maintained and an exchange of data on CD-ROM from the FAO was the backbone of the literature searches carried out during the year. The IRC contributed to current awareness by in-house generation of indexes and abstracts by systematic scanning of all in-coming journals for relevant articles and searching the available CD-ROM packages. This information is available to all PMDISS subscribers.

The **ICIPE Science Press** focuses on dissemination of information on integrated management of tropical insect pests and disease vectors by publishing and document processing for the Centre. This year the Press introduced two new projects: The Environmental Publishing Network (ENVIRONET Links) and the University Students Attachment Programme (USAP). The Press continues with complete in-house production and distribution of the international journal, *Insect Science and its Application*, now in its 15th volume. In addition to this journal, the Press has completed several important publications in 1994, which are listed in the publications list (see page 177).

The office of the **Science Editor** is responsible for editing of manuscripts generated by ICIPE scientists destined for international journals, and for preparing the *Annual Reports*. This office has also recently assumed interim coordination for the editing of *Insect Science and its Application* until a new scientific editor can be appointed to replace the out-going editor. In 1994, preparations for the publication of two books reviewing the current status of IPM were finalised in collaboration with UNEP.

The **Public Relations** office is responsible for organising the programme for all visitors to ICIPE, and organising workshops and conferences, which this year included the 24th Annual Research Conference. In addition, the PR office organises induction of new staff and seminars. Some of the major activities this year included organisation of the very successful Third International Conference on Tropical Entomology from 30 October to 9 November. The event was attended by over 200 scientists from 35 different countries around the world.

Among the many visitors to the Centre were the women members of a credit scheme for productive activities of women in Tanzania, a UNIFEM-funded project that deals with mobilisation, training and credit delivery for women in the rural areas. The week's study tour focused on control of mosquitoes and malaria. Among the many important visitors to the Centre were Dr Fawzi H. Al-Sultan, President of IFAD; Prof. Frederico Mayor, Director General, UNESCO; Dr H. Hayakawa, Director, JIRCAS; Prof. C. M. Karssen, Vice-Chancellor, WAU and Mr Richard Jacobs, Director, DAAD Regional Office for Africa, Nairobi.

I. Capacity Development and Institution Building

Participating staff: *V. O. Musewe* (*Head of Training)*

Assisted by: *R. Runo, V. Manene, J. Monyancha, F. Owoko*

Donors: *DAAD; UNDP; British Council; Government of Canada; Winrock International; International Science Programme of Uppsala University, Sweden; Social Science Research Council (SSRC), New York; Japanese Society for the Promotion of Science (JSPS); Netherlands Government (DSO); EEC; NORAD; IFAD; BMZ*

Collaborators: *Participating African Universities (29), University of Peradeniya, Sri Lanka; Michigan State University; Wageningen University, Netherlands; National Museums of Kenya*

Capacity development and institution-building activities of IBIRI were undertaken under the following programmes:

1. POSTGRADUATE TRAINING PROGRAMMES

The ARPPIS PhD Programme

The African Regional Postgraduate Programme in Insect Science (ARPPIS) was established in 1983 as a collaborative training programme between the ICIPE and African Universities, and with the prime objective of helping to meet the need for insect scientists and pest management specialists in Africa. To date, 29 universities from 15 African countries are collaborating with the ICIPE in ARPPIS; while ARPPIS graduates constitute an elaborate network of insect scientists that continues to expand annually, thereby providing cooperative links between research organisations throughout the continent.

The ARPPIS PhD programme is based at ICIPE, where students undergo 3 years of training through coursework and dissertation research. Students are registered at Participating Universities which examine and award them with degrees. The ICIPE provides a thesis project and research facilities and secures a fellowship to support student's maintenance, university fees and research costs, totalling US$ 20,000 per student per year. Each class is composed of an average of 10 students. Currently, 40 students at various stages of research work, data analysis and thesis writing are at the ICIPE.

The graduating PhD Class of 1991

Scholars of the 1991 class (Table 1) formally completed their 3-year programmes on 28 February 1994 under sponsorship by various donors. However, most of the students required extension of their training fellowships for 2 to 6 months. Most of the students remained at the ICIPE beyond the extended fellowship periods in order to finalise and submit their dissertations to registering universities.

The 1994 ARPPIS PhD Class

Seven students from 6 different African countries joined ARPPIS on 1 March 1994. From March to September, they were enrolled in six compulsory taught courses and three non-examined courses. Examinations in the six mandatory courses were administered between October to November. There were no supplementary examinations as all students qualified to proceed to the research stage of their training. The students developed their PhD research projects with the assistance of ICIPE scientists, and in consultation with their prospective registering universities. The list of scholars, their research topics and registering universities are shown in Table 2, while the programme for the 1994 teaching semester is given in Table 3.

Continuing PhD Students

Twenty-three students progressed into 1994 and continued their theses research with support from supervisors both at the ICIPE and from the universities. Out of these, the fellowships of three students were terminated; two on disciplinary grounds, and one for unsatisfactory performance in the coursework. Consultation visits made by students to registering universities and by their university supervisors to the ICIPE are shown in Table 4.

Award of PhD Degrees

Three scholars of the ARPPIS programme were awarded PhD degrees in 1994. Table 5 shows the names, dissertation titles, awarding universities and dates of their convocation.

Table 1. The 1991 ARPPIS graduating class — students, supervisors, research projects and sponsors

NAME & COUNTRY	RESEARCH PROJECT TITLE	ICIPE SUPERVISORS	UNIVERSITY SUPERVISORS	REGISTERING UNIVERSITY	SPONSOR
Bekele Jembere Adgeh (Ethiopia)	Effects and use of some *Ocimum* plant species and their essential oils on some storage insect pests	Prof. A. Hassanali Dr D. Obeng-Ofori	Dr G. H. N. Nyamasyo	University of Nairobi	DAAD
Adil Omar Ahmed (Sudan)	Comparative visual ecology of desert locust	Dr C. Inayatullah Prof. A. Hassanali Dr R. C. Saxena	Dr Magzoub O. Bashir	University of Khartoum	IFAD/ DAAD
Samuel Idrissa Kamara (Sierra Leone)	Effect of host semiochemicals on the behaviour of *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae)	Dr S. M. Waladde Dr W. Lwande Dr R. C. Saxena	Prof. Hector G. Morgan	University of Sierra Leone	DAAD
Susan W. Kimani (Kenya)	Morphological and biochemical systematics of the *Cotesia* parasitoid complex (Hym. Braconidae)	Dr W. A. Overholt Prof. A. Hassanali	Dr Lucy Rogo Prof. T. K. Mukiama	University of Nairobi	DSO
Jedidah A. Kongoro (Kenya)	Susceptibility of tsetse (*Glossina* spp.) to trypanosome infection in relation to midgut trypsin-like enzymes and other molecules	Dr E. Osir Dr M. Imbuga	Dr N. Oguge Dr P. Majiwa (ILRAD)	Kenyatta University	UNDP
Sika Fra Kutua (Zaire)	Behavioural responses of *Rhipicephalus appendiculatus* Neuman 1901 to host and non-host semiochemicals	Dr S. M. Waladde Prof. A. Hassanali	Dr D. S. Jitla Dr A. S. S. Orago	Kenyatta University	UNDP
Jacob C. Mbapila (Tanzania)	Comparative seasonal adaptation of *Cotesia flavipes* (Hymenoptera: Braconidae) to *Chilo partellus* (Lepidoptera: Pyralidae) on the Kenyan Coast	Dr W. A. Overholt	Dr H. Y. Kayumbo	University of Dar-es-Salaam	DSO
Githiri S. Mwangi (Kenya	Inheritance and linkage studies with isoenzymes and morphological characters in aphid resistant/susceptible cowpea cultivars	Dr E. Osir Dr K. Ampong-Nyarko	Dr P.M. Kimani	University of Nairobi	DAAD
Adele Ngi-Song (Cameroon)	Chemical ecology of host finding behaviour in *Cotesia flavipes* (Cameron) and *Cotesia sesamiae* (Cameron)	Dr W. A. Overholt Dr W. Lwande Dr P. Njagi	Prof. J. N. Ayertey	University of Ghana	DAAD
Edward O. Omollo (Kenya)	Cloning and sequence analysis of the genes that enclose the delta endotoxin of novel *Bacillus thuringiensis* strains, effective against tsetse flies *(Glossina morsitans morsitans)* and armyworms *(Spodoptera exempta)*	Dr E. Osir Dr M. Limo	Prof D. Makawitti Dr P. Majiwa (ILRAD)	University of Nairobi	DSO
Emil F. Rwekika (Tanzania)	Feeding allelochemicals for the banana weevil, *Cosmopolites sordidus* Germar	Prof. A. Hassanali Dr W. Lwande Dr I. Ndiege	Dr G. Mhehe	University of Dar-es-Salaam	NORAD-Banana

Table 2. List of scholars, research projects, registering universities and sponsors for the ARPPIS 1994 PhD class

NAME & COUNTRY	RESEARCH PROJECT TITLE	REGISTERING UNIVERSITY	SPONSOR
Godwin M. Zimba (Malawi)	Synthesis of a lectin-trypsin complex and its role in *Trypanosoma brucei* differentiation in the tsetse fly, *Glossina* sp.	University of Malawi	DAAD
Zipporah Njagu (Kenya)	Role of the monitor lizard *(Varamis niloticus)* in trypanosome epidemiology	Kenyatta University	DAAD
Fanuel A. Demas (Namibia)	Mechanisms of location of *Amblyomma variegatum* and other ticks by the parasitoid, *Ixodiphagus hookeri*	University of Zimbabwe	DAAD
Vivian C. Ofomata (Nigeria)	Investigations into the mechanisms of displacement of *Chilo orichalcociliellus* Strand by *Chilo partellus* (Swinhoe) (Lepidoptera-Pyralidae) on the Kenya coast	Nnamdi Azikiwe University, Awka	DAAD
Mohamed N. S. Sallam (Egypt)	Comparative evaluation of *Cotesia flavipes* & *Cotesia sesamia* (Hymenoptera: Braconidae) for the management of *Chilo partellus* (Lepidoptera: Pyralidae) in Kenya	Kenyatta University	DAAD
Jean-Berkmans B. Muhigwa (Zaire)	Behavioural responsiveness of *Glossina fuscipes* Newstead (1910) to visual cues and host odours, with particular reference to lizard	Moi University	DAAD
Syprine Akinyi (Kenya)	Reproductive behaviour of *Glossina fuscipes fuscipes* (Diptera: Glossinidae)	Kenyatta University	EEC

Todate, ARPPIS has produced 47 PhD graduates who are serving in various capacities in Africa and abroad, and constituting the ARPPIS network of scientists.

University participation in ARPPIS

The ARPPIS programme started off with only seven universities willing to participate in the programme. Due to the success of the programme in efficiently producing scientists of international quality, there has been a high demand for university participation in ARPPIS. Many universities have used ARPPIS for their own staff development and have greatly benefitted from ICIPE's abilities in securing training fellowships and in providing excellent facilities and supervision for research training. To date, 29 universities are collaborating with the ICIPE on ARPPIS and several others have applied for admission. Table 6 shows the list of institutions participating in the programme and the names of their representatives in the ARPPIS Academic Board, with ICIPE providing the ARPPIS Secretariat.

The ARPPIS Sub-Regional MSc Programme

The ARPPIS Sub-Regional MSc Programme, which was established following its endorsement at a meeting of university vice-chancellors in 1991, is now operational at three Sub-Regional Centres. Implementation of the programme is at various stages at each of the Centres.

The ARPPIS MSc Sub-Regional Centre for Southern Africa (University of Zimbabwe, Harare)

Five students (all Zimbabweans) were enrolled in the ARPPIS MSc in Tropical Entomology (MTE) for the 1994–96 programme, with scholarships from the British Council (1), Canada (1), DAAD (2) and University of Zimbabwe (1). The course commenced on 28 March 1994 in the Department of Biological Sciences. The programme is being coordinated by Mrs Audrey Mutambara-Mabveni of the University of Zimbabwe, while lecturers were from various institutions within Zimbabwe. Professor J. N. Ayertey from the University of Ghana at Legon was the External Examiner at the MTE examinations for the taught courses held from 17 October to 10 December 1994.

On completion of the taught coursework, the students embarked on thesis research for the second phase of their training programmes. The programme for the taught semester is shown in Table 7, while Table 8 shows the students' theses titles and their supervisors.

The ARPPIS MSc Sub-Regional Centre for Western Africa (University of Ghana, Legon)

The ARPPIS MPhil programme at the University of Ghana was officially inaugurated by the Vice-Chancellor at the 1994 Graduation Ceremony. Selection for the first intake was completed on 15 March 1994 and admission of 15 qualifying candidates (9 Ghanaians and 6 other nationals from the region) was approved by the university.

Table 3. Programme of the 1994 teaching semester

DATE	COURSE AND LECTURERS
11–12 April	Documentation and Information Retrieval Mr N. Nsubuga and Ms D. Barasa, ICIPE
6–8 April	Project Management Course Dr V. O. Musewe, Mrs R. Odingo and Dr A. Mengech, ICIPE
6–8 April	Project Identification, Formulation, Evaluation and Budgeting Mrs R. A. Odingo, Drs V. O. Musewe and A. Mengech, ICIPE
18 April–7 May	Insect Functional Morphology Dr K. J. Mbata, University of Zambia, Lusaka and Dr W. G. Z. O. Jura, ICIPE
9–31 May	Insect Taxonomy Prof. A. E. Akingbohungbe, Obafemi Awolowo University, Ile-Ife, Nigeria and Dr R. K. Bagine, National Museums of Kenya
2 June–8 July	Insect Physiology and Biochemistry Drs R. K. Saini and E. O. Osir, ICIPE
11–15 July	Introduction to Microcomputers and Wordprocessing Mr H. Meena, ICIPE
18 July–12 August	Biostatistics and Experimental Design Dr Odulaja, Prof. W. Ogana and Mr D. Munyinyi, ICIPE
15 August–9 September	Insect Ecology Prof. H. Morgan, University of Sierra Leone and Dr C. M. Mutero, ICIPE
12–30 September	Biological Control Drs W. A. Overholt, G. P. Kaaya, S. K. Raina and M. O. Odindo, ICIPE and Dr Gary Hill, CAB International Institute of Biological Control, Kenya Station
3–4 October	The Role of Social Sciences in Insect Pest Management Prof. F. Kiros, Drs J. Ssennyonga, G. T. Lako, K. Chitere and O. Oendo, ICIPE
5–12 October	Insect Taxonomy (Seminars and Practicals on Insect Identification) Dr R. K. Bagine, National Museums of Kenya
13–27 October	Examinations

Table 4. Consultation visits by students and university supervisors

a. Visits by students to registering universities

NAME OF STUDENT	DATE OF VISIT	UNIVERSITY VISITED
1. Assad Yousif	27–30 September	University of Gezira
2. M. Nabasirye	17–14 October	Makerere University
3. Fred Masaninga	20 & 27 October	University of Zambia
4. M. A. Mohamed	20–23 November	University of Gezira
5. T. Epidi	20–23 November	Rivers State Univ. of Science & Technology
6. I. S. T. Jalloh	20–23 November	Rivers State Univ. of Science & Technology
7. Joseph Sumani	6 & 14 December	University of Zambia

b. Visits by university supervisors to ICIPE

NAME OF SUPERVISOR	DATE OF VISIT	STUDENT VISITED	UNIVERSITY VISITED
1. Prof. N. H . H . Bashir	8–13 May	Yousif Assad	University of Gezira
2. Prof. R. I. S. Agbede	26 –31 July	S. Bengaly	Ahmadu Bello University
3. Dr P. O. Ayiecho	10 –12 August and 22 –23 September	C. M. Mutinda	Nairobi University
4. Dr L. S . Luboobi	9– 12 September	M. Nabasirye	Makerere University
5. Dr K. J. Mbata	11 –20 November	J. A. Sumani	University of Zambia

Table 5. List of three ARPPIS scholars awarded with PhD in 1994, their thesis title, awarding university and date of the award

NAME & COUNTRY	THESIS TITLE	AWARDING UNIVERSITY	DATE OF AWARD
Henry Kiara (1989 Class) KENYA	Immune protection potential of membrane bound proteins from midgut of *Amblyomma variegatum*, Fabr. (Acarina:Ixodidae)	Rivers State University of Science & Technology	19 August 1994
Muhinda Mugunga (1990 Class) ZAIRE	Effects of plant diets on selected aspects of biology of some species of Phlebotomine sandflies (Diptera: Psychodidae) and the infectivity of *Leishmania major* Yakimoff and Schokhor 1914 (Kinetoploastidae: Trypanosomatidae)	Rivers State University of Science & Technology	21 September 1994
Ahmed Salim Mohamed (1990 Class) SUDAN	Transovarial transmission and reproductive parameters in the desert locust, *Schistocerca gregaria* (Orthoptera: Acrididae) infected with a protozoan, *Malamoeba locustae*	University of Khartoum	October 1994

Table 6. Members of the Academic Board and ARPPIS Participating Universities in 1994

REPRESENTATIVE		UNIVERSITY
1.	Prof. H. G. Morgan	University of Sierra Leone, Freetown
2.	Prof. J. N. Ayertey	University of Ghana, Legon
3.	Dr J. A. Odebiyi	University of Ibadan, Nigeria
4.	Prof. R. I. Egwuatu	Nnamdi Azikiwe University, Enugu, Nigeria
5.	Dr B. A. Okwakpam	Rivers State University of Science & Technology, Nigeria
6.	Dr I. Parh	D'Schang University Centre, Cameroon
7.	Prof. I. El Khidir	University of Khartoum, Sudan
8.	Dr M. H. Zeinelabdin	University of Gezira
9.	Dr T. Gemetchu	Addis Ababa University, Ethiopia
10.	Prof. J. N. Situma	Makerere University, Uganda
11.	Prof. J. Mueke	Kenyatta University, Kenya
12.	Prof. K. Ole Karei	Moi University, Kenya
13.	Prof. R. W. Mwangi	University of Nairobi, Kenya
14.	Dr J. G. Yarro	University of Dar es Salaam, Tanzania
15.	Dr D. C. Munthali	University of Malawi
16.	Prof. A. Siwela	University of Zambia
17.	Dr S. B. Feresu	University of Zimbabwe
18.	Dr E. E. Etienne	Universite de Côte d'Ivoire
19.	Prof. M. C. Eluwa	University of Nigeria, Nsukka
20.	Dr V. A. Awoderu	Ogun State University, Nigeria
21.	Prof. T. Mubamba	Universite du Burundi
22.	Dr R. I. S. Agbede	Ahmadu Bello University, Nigeria
23.	Dr B. A. Kalu	University of Agriculture, Makurdi, Nigeria
24.	Prof. P. O. Ugherughe	University of Maiduguri, Nigeria
25.	Dr E. D. N. Umeh	Enugu State University of Science & Technology, Nigeria
26.	Prof. Dr Adelfattah Khalifa	Ain Shams University, Egypt
27.	Dr M. Botchey	University of Cape Coast, Ghana
28.	Dr E. Mamo	Alemaya University of Agriculture, Ethiopia
29.	Prof. Dr. S. H. A. Ismail	Assiut University, Egypt
ARPPIS SECRETARIAT		
30.	Dr H. R. Herren	Director General, ICIPE — Chairman
31.	Dr V. O. Musewe	ARPPIS Coordinator and Secretary, Board of Studies
32.	Mrs R. A. Odingo	Chief Planning Officer, ICIPE
33.	Prof. S. El Bashir	Representative of the Board of Studies

Table 7. The Programme of the ARPPIS Masters in Tropical Entomology (MTE) Course at the University of Zimbabwe (UZ)

COURSE	DURATION	LECTURE
MTE 503 Insect Physiology & Biochemistry	28/3–29/4	A. R. Mutambara-Mabveni (UZ) A. Gardiner (WWF)
MTE 503 Insect Functional Morphology & Systematics	30/5–24/6	A. R. Mutambara-Mabveni (UZ) S. Z. Sithole (DR & SS - PPRI)
MTE 501 Biostatistics, Experimental Design & Modelling	30/5–24/6	R. Crust (UZ) P. Frost (UZ) J. Jackson (CASS-UZ)
PROJECT	27/6–22/7	Seminar 21/7/94
MTE 504 Insect Ecology and Behaviour	25/7–19/8	A. R. Mutambara-Mabveni (UZ) E. Kunjeku (UZ)
MTE 505 Pest Management	22/3–16/9	E. Kunjeku (UZ) P. Jowah (RFP)
MTE 506 Economic Entomology	19/9–10/12	E. Kunjeku (UZ) R. Tanyongana (GMB) W. Shereni (TTCB)
EXAMINATIONS	17/10–10/12	Prof. J. N. Ayertey (UG) (External Examiner)

UZ – University of Zimbabwe
WWF – World Wide Fund for Nature Multispecies Animal Production System
DR & SS – Department of Research and Specialist Services, Zimbabwe
PPRI – Plant Protection Research Institute, Zimbabwe
CASS – Centre for Applied Social Studies
RFP – Risk Fund Project: Ciba-Geigy, Zimbabwe
GMB – Grain Marketing Board, Zimbabwe
TTCB – Tsetse and Trypanosomiasis Control Branch
UG – University of Ghana

The ARPPIS MPhil programme for the 1994–96 class started as scheduled, on 30 September 1994. So far, 6 students had received scholarships: 4 scholarships from DAAD under ARPPIS programme, 1 scholarship under In-Country Programme and one scholarship from Winrock International. Other donors were still being sought to support the rest of the students. The MPhil programme is coordinated by Professor J. N. Ayertey, who is also the Vice-Chancellor's nominee as ARPPIS Representative at the University of Ghana, Legon.

ARPPIS MSc Sub-Regional Centre for Eastern and North-Eastern Africa (Addis Ababa University, Ethiopia)

The Coordinator of the ARPPIS MSc programme at Addis Ababa University, Dr Yalemtsehay Mekonnen, gave a detailed report on the programme during the 25th ARPPIS Academic Board held at ICIPE on 26 July 1994. The Board noted the coordinator's progress on the development of the course curriculum. Her sensitisation mission which covered universities in Ethiopia, Kenya, Tanzania and Uganda was supported with a grant awarded to the ICIPE by the Rockefeller Foundation.

The ARPPIS Academic Board recommended that the programme be scheduled to start in the 1996/97 academic year in order to allow adequate time for planning. It was further recommended that a grant proposal for programme support be developed by the Sub-Regional Centre and that Addis Ababa University takes initiative in circulating the proposal, curricula and other related documents to the universities in the region.

ARPPIS MSc Sub-Regional Centre for French-Speaking Africa

During the year, little progress was made towards establishing the ARPPIS MSc Sub-Regional Centre for French-speaking Africa. At the 25th ARPPIS Academic Board meeting held at ICIPE on 26 July 1994, it was argued that there could be further criteria other than language for identifying location for the fourth MSc sub-regional centre. This issue will be conclusively dealt with in subsequent ARPPIS Academic Board Meetings to be held in 1995 and 1996.

Dissertation Research Internship Scheme

The ICIPE cooperates with universities both in Africa and abroad, and with donor agencies, on research training outside of (and parallel to) the ARPPIS programmes. Through this dissertation research internship scheme, postgraduate students at PhD or MSc levels who are registered at any university in the world, and who have completed the coursework requirements of the registering universities are enrolled for thesis research at the ICIPE. The students continue to receive scholarship support (personal expenses and university fees) from their sponsors, while the ICIPE provides them with a research project, research facilities and supplies, as well as research supervision upto thesis preparation. Depending on sponsor and nature of project the ICIPE may not charge

Table 8. List of students, thesis title and supervisors of the 1994–96 class of the MTE Programme at University of Zimbabwe

NAME	THESIS TITLE	SUPERVISORS
Walter Dirorimwe	The impact of coccinellids on aphid populations in cotton and the effect of commonly used aphiades on these predators	Dr J. H. Brettel Dr E. R. Kunjeku
Samukelo Moyo	An investigation of the biology of fruit eating beetles (Coleoptera: Scarabaeidae)	Dr E. R. Kunjeku
Joseph Bare	Life cycle and host plant specificity of the scale insect (*Aspidoprotus* sp.) in Hurungwe area of Zimbabwe	Mrs A. M. Mabveni Dr A. J. Masuka Mr R. Mazodze
Mr Mawanza	Investigation of factors which affect the success of *Crytobagous salviniae* (Coleoptera: Curculionidae) in controlling *Salvinia molesta* in Zimbabwe	Dr G. Chikevenhere Dr E. Kunjeku
Fortune C. Murahwa	Susceptibility of *Anopheles gambiae* s.l. to the insecticides used by the national malaria control programme	S. M. Mpofu A. Mutambara-Mabveni

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.

In 1994 two trainees were enrolled in this programme under sponsorship by scientific agencies as follows:

1. Mr Premaratne K. A. N. Bandara

   Purpose: Training in research skills in the following areas: (i) insect mass rearing; (ii) bioassay techniques and development; (iii) processing and interpretation of bioassay results, and (iv) current research on *Chilo partellus*.

   Supervisor/Department: Professor Ahmed Hassanali, Behavioural and Chemical Ecology Research Unit and Crop Pests Research Programme, ICIPE.

   Degree/Registering university: PhD student, University of Peradeniya, Peradeniya, Sri Lanka.

   Sponsor: International Science Programmes Uppsala University, Sweden.

2. Ms Hanna-Andrea Rother

   Purpose: Socioeconomic studies of ICIPE's approaches to insect pest management including studies on (i) major pest management issues; (ii) pest management strategies relevant to Africa; (iii) biocontrol and alternative pest control methods; (iv) collection and use of socioeconomic information; and (v) cost-benefit analyses of pest management strategies.

   Supervisor/Department: Prof. Fassil Kiros, Social Science Interface Research Unit, ICIPE.

   Degree/Registering university: PhD student, Michigan State University.

   Sponsor: Social Science Research Council (SSRC) New York, USA.

2. PROFESSIONAL CAREER DEVELOPMENT PROGRAMMES

The general objective of professional development programmes at the ICIPE is to help scientists and technologists from developing and developed countries acquire specialised research techniques and practices, while the trainees themselves provide a service or make an intellectual contribution to the Centre. A wide range of schemes under this programme permits attachment of senior research and academic professionals, fresh doctoral graduates, experienced field staff of NARES as well as science students and technical support trainees from universities, polytechnics and colleges.

Postdoctoral Fellowship (PDF) Programme

Fifteen (15) young PhDs worked at ICIPE under the PDF training programme in 1994. Their countries of origin were as follows: Kenya (9), Sudan (2), Ghana (1), Sierra Leone (1), Chad (1), and China (1). The trainees added vigour to ICIPE's research in the fields of tsetse ecology (3), locust semiochemicals (3), tick ecology and biocontrol (4), biochemistry and molecular biology (3), biological control of stemborers (1) and biomathematics and population modelling (2).

Research Associateship Scheme

Two scientists were attached to ICIPE under the research associateship scheme. Mr Ali Said Singano Mbwana from Tanzania worked on the control of banana pests based at Bukoba in Tanzania. A graduate of ICIPE's ARPPIS programme, Mr Mbwana has since been awarded with the PhD degree of the Kenyatta University. Mr Paulus Maria Lammers, a national of the Netherlands, was attached to the ICIPE/Wageningen Agricultural University Project on the Control of Stemborers. He was based at ICIPE's Muhaka Field Station at the Kenya coast.

Visiting Scientist Scheme

Under this scheme, the ICIPE receives experienced research scientists and university professors for specific short-term assignments on collaborative research and training projects. The scheme is supported either from ICIPE's own grants, or from multilateral scientist exchange schemes in which ICIPE is a participant.

In 1994, Professor Wandera Ogana of the department of Mathematics, University of Nairobi, worked as a population modeller for the UNDP-funded project on

tsetse and ticks. Dr William Overholt continued to serve as the coordinator of the ICIPE/WAU project on biological control of stemborers. Also, two scientists, Drs Keiji Takasu and Takahiko Hariyama worked at ICIPE under sponsorship by the Japanese Society for the Promotion of Science (JSPS).

Field attachment for technologists and science undergraduates

Working in collaboration with national universities, colleges and polytechnics, the ICIPE offered short-term field training attachment to a total of 15 trainees (Table 9). Most of the trainees were diploma students of science laboratory technology wishing to gain field experience in laboratory techniques and analytical procedures; however, university undergraduates were also offered opportunities for field experience in research methods. In addition, pest and vector management technologists were offered individually tailored courses in field application of pest and vector monitoring and control methods.

Staff Development Programme

A total of 12 staff members were involved in officially-approved staff development training, as shown in Table 10. The training programmes ranged from time-release for business courses in Nairobi City, to full-time degree training programmes undertaken abroad. Most of the trainees were offered staff development training fellowships, with funds from ICIPE's project grants or from collaborating institutions. However, a number of staff members took initiative to self-sponsor themselves for technical courses at polytechnics or for registration for higher degrees at Kenyan universities. In the latter case the ICIPE, through the staff development scheme, contributed staff time and/or research facilities and resources.

Table 9. The 1994 beneficiaries in ICIPE's field attachment programme

NAME & COUNTRY	COLLEGE	DEPARTMENT ATTACHED	DURATION	SUPERVISOR	SPONSOR
David Kimbu (Kenya)	Moi University	BMRU	3 January–2 May	Unit Head	Self
Virginia W. Gitari (Kenya)	Kenya Polytechnic	Library	28 April–15 July	Senior Librarian	Self
Robert M. Mokaa (Kenya)	Mombasa Polytechnic	BMRU	11 July–11 October	Unit Head	Self
B. W. Musuya (Kenya)	University of Nairobi	ARQU	11 July–11 October	Unit Head	Self
Hanna-Andrea Rother (USA)	Michigan State University	Social Science Unit	1 September–30 November	Unit Head	Michigan State University
K. M. Saleh (Zanzibar)	FAO Fellow	LPRP	18 January – December	Dr Steve Mihok	FAO
Basilio N. Njiru (Kenya)	Muranga College of Technology	BCERU	1 August–31 December	Unit Head	Self
Lilian Kimotho (Kenya)	Kenya Polytechnic	BMRU	15 August–14 November	Unit Head	Self
Susan Kabui (Kenya)	Professional Centre	Library	5 September – 4 December	Senior Librarian	Self
Rose Anyika (Kenya)	Kenya Polytechnic	Library	5 September – 11 December	Senior Librarian	Self
Shelmith Kimondo (Kenya)	School of Professional Studies	Library	5 September – 4 December	Senior Librarian	Self
J. Nganga (Kenya)	Sigalagala Tech. Training Institute	Library	14 November – 10 January 1995	Senior Librarian	Self
Humphrey M. C. Lwamba	JKUCAT	MBRU	17 January – 15 March	Unit Head	Self
Joseph O. Adero	Kenya Polytechnic	BMRU	1 August – 20 December	Unit Head	Self

Table 10. ICIPE's staff development training 1994: List of beneficiaries

NAME	PROGRAMME	TYPE OF COURSE	INSTITUTION	COURSE DURATION	SPONSOR
Mrs Keli C. Yaa	LRP	French Language	Private	January–December 1994	Self
Mr Jason Kapkirwok	Director's Office	MBA Course	Eastern College, PA, USA	September 1993— 2 yrs	ICIPE
Mr Samuel Adhola Ochieng	BCERU	MSc— Chemical Ecology	University of Sweden	1 Sept. 1993 – 31 March 1995	University of Sweden/ WHO
Mr Joseph Owaga Okello	ICIPE/WAU	Diploma in Data Processing	School of Professional Studies, Nairobi	March 1994 – February 1995	ICIPE/WAU
Mr Jeremiah A. Ojude	ARQU	Technical Training in *G. pallidipes* rearing	ILRAD	4 July –3 October 1994	ICIPE/EU Project
Dr Samson O. Ajala	CPRP	Research techniques in plant biotechnology (somaclonal variation, quantitative trait loci (QTL), marker assisted section and amplified DNA)		28 October 1994 – 28 January 1995	Royal Society & UNESCO-ROSTA
Mrs Lilly Aduke	Library	Short course on Publishing	ICIPE Science Press - Chiromo	7 November 1994 –31 March 1995	IDRC through ENVIRONENT Project, ICIPE
Mr Richard K. Rotich	MBRU	Diploma in MLT	Kenya Polytechnic, Nairobi	12 January 1993 –11 January 1997 (2 days per week)	Self
Mr Meshak Khadiakala	LPRP	Junior Laboratory Technician	Kenya Polytechnic, Nairobi	25 July –19 August 1994 & 21 Nov – 31 Dec 1994 (5 days per week for 10 weeks)	Self
Mr Hassan El-Tigani Abdel Rahmani	Locust Research Programme - Sudan	PhD	Khartoum University		Self
Mr Onyango O. Okello	BMRU	Diploma in Cartography	The International Institute for Aerospace Survey and Earth Sciences ITC, the Netherlands	January – December 1994	Netherlands Ministry of Foreign Affairs

3. CONSUMER-BASED TRAINING PROGRAMMES

International group training for IPVM specialists

Four International Group Training Courses were offered to insect pest and vector management (IPVM) practitioners from the national research and extension services (NARES) and universities. A total of 56 scientists and technologists from 18 developing countries attended courses on the management of ticks, tsetse and borers of food crops. All courses were planned by committees chaired by Dr Vitalis O. Musewe, Head of Training at ICIPE, while each course was implemented by a scientific coordinator.

International Group Training Course on the Management of Livestock Pests in the Developing Tropical World—Ticks and Tsetse: 17 January–18 February 1994

This course was designed for mid-level professionals involved in tick and tsetse research and control from African countries. The course was offered in the English

language, and provided an overview on tick identification, biology and ecology, tsetse and trypanosome biology and ecology, focusing on aspects that relate to the technologies available for managing these vectors and some aspects for control based on ICIPE's current research achievements. The objective of the course was to provide a sound understanding of the biological, ecological and epidemiological constraints on the methods used in tick and tsetse control, and for participants to be able to assess and implement technologies appropriate to their own specific situations in their countries. The scientific coordinator for this course was Dr Suliman Essuman of ICIPE.

International Group Training Course on Integrated Tsetse Management for Tropical Developing World: 14 February–12 March 1994

This course was restricted to participants from six African countries in the tsetse belt: Ethiopia, Kenya, Rwanda, Senegal, Sudan and Zambia. The course was almost exclusively applications-oriented, with two weeks of laboratory practicals and two weeks of field application. The first component of the course consisted of laboratory practicals, demonstrations and workshops on basic fly taxonomy; methods for isolating and characterising trypanosomes; use of ELISA for bloodmeal identification; and use of wind tunnels and EAGs for odour bait assessment. A three-day afternoon workshop was held on trap design, where participants made their own traps for field-testing. The last part of the course consisted of field work at ICIPE's field site at Mbita Point near Lake Victoria, with *Glossina pallidipes* and *G. fuscipes*. In the field, students tested conventional tsetse traps as well as their own designs developed in the workshop. Features of tsetse behaviour and ecology were illustrated through trapping experiments and demonstration of electric screens, and techniques of tsetse dissection and trypanosome isolation were taught in the field. The scientific course coordinator was Dr Steve Mihok of ICIPE.

Training Course on Cereal Stemborers in Africa: Taxonomy, Natural Enemies and Control: 8–19 August 1994

This was a collaborative training course sponsored jointly by the Netherlands Ministry of Foreign Affairs, the National Museums of Kenya (NMK) and the ICIPE. The course was designed for entomologists from national research and extension systems, (NARES), particularly those serving in IPM research networks. The course placed great emphasis on the taxonomy of stemborers and their parasitoids in Africa. Attention was also paid to pathogens with potential for biological control of stemborers; plant hosts of stemborers and the importance of wild hosts for control; and identification of stemborer damage and assessment of losses caused by the pests. The scientific coordinator of this course was Dr Andrew Polaszek of the Wageningen Agricultural University, the Netherlands.

Group Training Course on Components Essential for Ecologically Sound Pest and Vector Management Systems: 14 August–10 September 1994

This was the first of two courses planned under this title; the second course will be held in 1996 in Niger, for West African countries. The present course was mounted for participants from eastern and southern Africa.

The course programme included (i) lectures on the philosophy, development and utilisation of pest management techniques; (ii) consideration of the impact of managements of pests and vectors using chemical pesticides; (iii) practical and field observations in the use of IPVM; and (iv) case studies. The programme was designed around thematic groups of subject coverage, including those on (i) concept of pest management, (ii) pest management as a form of applied ecology, (iii) applied insect systematics; (iv) current insect management practices; (v) controlled uses of pesticides in insect pest/vector management; (vi) case studies on quantitative bases of pest/vector management; (vii) socioeconomic considerations in IPVM; and (viii) special lectures on subjects relevant to pest management. The course was coordinated by Dr Morris Oduor Odindo of ICIPE.

Training at consumer level

Technology demonstration and training of farmers were undertaken within countries collaborating with ICIPE in the Regional Pest Management Research and Development Network (PESTNET), and are reported under PESTNET activities in the various countries (see Project II in this section).

Training workshops

With a grant support from the UNDP, an International Workshop on Tsetse Behaviour and Ecology was held at Diani Reef Grand Hotel in Mombasa, Kenya, from 6–9 November 1994. The workshop enabled ICIPE scientists to review their own performance in tsetse biology and to take stock of achievements made so far and to outline strategies for future research. The workshop, which was a satellite meeting immediately after the 3rd International Conference in Tropical Entomology, was attended by over 80 participants from Africa and abroad, and representing national, regional and international research organisations. Participants deliberated on four selected themes covering tsetse population dynamics, disease transmission by tsetse, tsetse behaviour, and tsetse control and socioeconomic impact.

II. Outreach through the Pest Management Research and Development Network (PESTNET)

Participating staff: *J. J. Ondieki*, J. A. Lago, V. K. Manene*
*(*PESTNET Coordinator)*

Donors: *UNDP*

PESTNET coordination activities

PESTNET was established in 1986 as a collaborative programme between the ICIPE and national agricultural research institutions, and with the objective of developing national scientific capabilities and skills in insect science. The major activities of PESTNET are

- interactive technology development,
- training, and
- information exchange.

Ten African countries (Rwanda, Kenya, Somalia, Sudan, Tanzania, Uganda, Zambia, Zimbabwe, Malawi and Ethiopia) have signed an agreement to cooperate with the ICIPE through PESTNET. In 1994, however, activities progressed only in Kenya (crop and livestock pests), Tanzania (banana pests), Zambia (crop pests), Ethiopia (livestock pests) and the Sudan (locust), where PESTNET resident scientific teams have been located. Research and development activities of PESTNET within the collaborating countries are reported under the respective research programmes which provide the scientific backstopping to the resident teams, while training and information exchange activities are reported here.

PESTNET activities in Kenya

The research and development activities under PESTNET-Kenya were mainly based at the Kenya coast, under the ICIPE/KARI Kwale/Kilifi Adaptive Research Project supported by the UNDP. The research and development activities are described under the Plant Pests and Disease Vectors Management Programmes as well as under Social Science Interface Research at ICIPE. The capacity building activities are described hereunder.

Training activities continued in collaboration with KARI for extending the adoption of environment-friendly technologies by the beneficiary farmers in coastal Kenya. Field days were held at the three on-farm locations in which 20–30 farmers each were trained in the adoption of pest-resistant cultivars of maize and sorghum as well as early intercropping of cowpeas in maize as a means of sustainable reduction in yield losses.

In addition, a three-stage training programme was implemented for mass deployment of tsetse traps in Shimba Hills (adjoining the Game Reserve) in Kwale District, with the following target groups participating: district/divisional extension subject matter specialists (12); frontline extension officers in different locations (16); coastal farmers (60).

In addition to training activities reported under the Kwale/Kilifi project mentioned above, the ICIPE continued to support human resources development in Kenya at three levels. Eight Kenyans (4 women and 4 men) were receiving postgraduate training through the ARPPIS programme, while two graduated early in the year. Seven scientists were on training at postdoctoral level, while 13 Kenyans received training through the technical attachment scheme. At consumer level, 12 Kenyans were trained in four international group training courses held that year.

PESTNET activities in Ethiopia

The 4th ICIPE International Mobile Seminar was held in Africa Hall at the UNECA, Addis Ababa on 28–29 September 1993. The seminar was opened by the Honorable Minister for Agriculture, with a keynote address by Dr Layashi Yaker of the UNECA. The closing ceremony was addressed by the OAU Acting Secretary General, Dr M. T. Muparanga.

As a result of this seminar, collaboration between the ICIPE and Ethiopia picked up pace. This was facilitated by a post-seminar consultation meeting between the ICIPE team and the Science and Technology Commission of Ethiopia, where areas of collaboration were identified. Since that time, the ICIPE's PESTNET Resident Scientist in Ethiopia, Dr Getachew Tikubet spearheaded the laying down of formal arrangements for collaborative activities.

The research and development activities in Ethiopia have concentrated on research towards the management of tsetse under the EU-funded tsetse

project; a detailed report on these activities can be found in the report under Disease Vectors Research. Also, with support from the UNHCR, the ICIPE undertook field trials and demonstration on the control of filthflies in refugee camps, using an ICIPE-developed biocontrol system based on *Bacillus thuringiensis* (*Bt*). Details of this work are found under the Medical Vectors Research project reports.

On human resources development, three Ethiopian students, Mr Solomon Gebre, Mr Samuel Kabede Merassa, and Mr Bekele Adge completed their PhD training in ARPPIS and are due to present their theses to Addis Ababa University. Another PhD student, Mr Habte Tekie is due to complete the ARPPIS course in February 1995. At IPM practitioner level, the ICIPE trained a total of six Ethiopians, who attended international group training courses at ICIPE in 1994, while one scientist, Mr Getachew Tikubet was retained as a trainee-scientist.

PESTNET activities in Zambia

The PESTNET Resident Team, led by Dr Charles Mugoya was based within the Plant Protection Unit at Mt Makulu Central Research Station. The team continued with adaptive research and locale-specific trials on the management of stemborers using various technologies developed at ICIPE, including biological control with parasitoids, resistant crop varieties, natural products, behavioural manipulation and intercropping. The details of these studies are contained in this report under Plant Pests Research, project II.

A national symposium on the use of natural plant products as pesticides was held in Zambia from 2–5 August 1994. The symposium aimed to (i) identify and bring together resource persons involved in natural plant pesticides research, into a forum for exchange of ideas; (ii) establish the state of R&D on natural pesticides and how the products were used by small-scale farmers in Zambia; and (iii) identify priority products for plant crops and livestock, and set goals for the future. There was no regional training activity in 1994.

Training of Zambians under other training programmes of ICIPE in 1994 were as follows: two PhD students continued their thesis projects at ICIPE, while five students were trained through short courses held at the Centre.

PESTNET activities in the Sudan

Research and development in the Sudan is based at ICIPE's field station in the Red Sea area, and were focused on developing strategies for the management of desert locust (see the Locust Research project XI under Plant Pests Research for a detailed report). The activities are part of the IFAD-supported locust semiochemicals project at ICIPE. There was no training activity in the Sudan under PESTNET, but 11 Sudanese were being trained in the ARPPIS programme while a total of 23 nationals participated in specialised short courses held at ICIPE headquarters, and two nationals were at the ICIPE as visiting scientists. Also, approval was given to the Resident Scientist, Mr H. E. Abdelrahman to register as a private candidate for the PhD degree at the University of Khartoum.

PESTNET activities in Tanzania

Research and development activities in Tanzania were based at Bukoba, and were focused on banana pests, under a BMZ-supported project of ICIPE (see Plant Pests Research for a detailed report). The team was headed by a former ARPPIS student Mr A. A. S. Mbwana, who received his PhD from Kenyatta University, Kenya during the year. The Bukoba base provided research facilities for a Ugandan ARPPIS student, Mr Magyembe Mwesigwa, who researched on the banana weevil for his PhD at Makerere University. Two other Tanzanians were trained in ARPPIS during the year, while four participated in short courses and one was a postdoctoral trainee at the ICIPE.

PESTNET information and exchange

The Pest Management Documentation and Information System and Service (PMDISS) is the mechanism by which IPM activities and research results can be shared among PESTNET member countries. PMDISS progress is reported under project III of this section of the report.

III. Information and Communications

Participating staff: *N. S. M. Nsubuga, L. Aduke, K. M. Mwangi, E. Ndegwa*

1. INFORMATION RESOURCES

Information Resource Centre

The Information Resource Centre (IRC) continued to grow in terms of bookstock and services in 1994. Since its commissioning four years ago, the Centre has provided the necessary back-up and support to research activities at ICIPE. The staff have endeavoured to make available all relevant materials in the most appropriate format, place and time. They have also continued to strive for efficiency in the delivery of documents from publishers to the users and or from the existing stock which includes a number of carefully selected books and periodicals, reprints and a computer database.

The following reading materials were acquired this year:

- Books received: 1546
- Reprints processed: 238
- Reprints received but not processed: 57
- Subscriptions received: 222
- Gifts, donations and exchange: 854

Some of the services rendered on behalf of ICIPE include:

- Current awareness;
- Indexing and abstracting of journals subscribed to by the Centre;
- Production of the quarterly *Library and Documentation Bulletin;*
- Compilation of personnel data of ICIPE scientists
- Computerisation; and
- Searches done on the 'grey' literature.

Training activities

The Information Resource Centre accepted 6 students on industrial attachment from various institutions, namely, Moi University, Kenya Polytechnic, School of Professional Studies, Sigalagala Technical Institute and Kenyatta University.

Donations

The IRC was fortunate to receive a substantial number of books and periodicals through gifts and donations to the Centre. Among the donors were: IDRC, IRRI, ICLARM, and Library of Congress. The Swiss Academy of Sciences has continued to pay for up to 23 scholarly journals annually since the completion and inauguration of the IRC.

Computerisation

The computer database continues to serve the ICIPE users and beyond. We received about 2000 requests which we were able to fulfil from our existing resources at the IRC. Other queries were handled through the CGNET network and other available Internet facilities. We were also able to complete 135 searches on our CD-ROM for ICIPE staff. Our database has grown bigger as a result of the addition of 1784 records during the year.

2. PEST MANAGEMENT DOCUMENTATION AND INFORMATION SYSTEM AND SERVICE (PMDISS)

Member countries of PESTNET continued to draw from our resources here either through mail correspondence or through personal visits. We were able to receive from other institutions useful additions particularly in the area of integrated pest management. We feel, however, there is need for our PESTNET collaborating countries to send more data for our database. We are still linked by CGNET to all CGIAR centres through our improved electronic mail facility. Our collaboration with AGRIS (Agricultural Information System) of Food and Agriculture Organisation of the United Nations (FAO) has been maintained and an exchange of data and CD-ROM from the organisation was the backbone of our literature searches during the year. In addition, PMDISS activities included production of the quarterly PMDISS Bibliography.

3. COMMUNICATIONS

Participating staff: *R. A. Washika, R. P. O. Ortega*

The Public Relations office is responsible for organising the programme for all visitors to ICIPE, and organising workshops and conferences, which this year included the 24th Annual Research Conference. In addition, the PR office organises induction of new staff and seminars. Some of the major activities this year included organisation of the very successful Third International Conference on Tropical Entomology from 30 October to 9 November. The event was attended by over 200 scientists from 35 different countries around the world.

Among the many visitors to the Centre were the women members of a credit scheme for productive activities of women in Tanzania, a UNIFEM-funded project that deals with mobilisation, training and credit delivery for women in the rural areas. The week's study tour focused on control of mosquitoes and malaria. Among the many important visitors to the centre were Dr Fawzi H. Al-Sultan, President of IFAD; Prof. Frederico Mayor, Director General, UNESCO; Dr H. Hayakawa, Director, JIRCAS; Prof. C. M. Karssen, Vice-Chancellor, WAU; and Mr Richard Jacobs, Director, DAAD Regional Office for Africa, Nairobi.

IV. Editing and Publishing Activities

1. SCIENCE EDITING

Participating staff: *A. Ng'eny-Mengech, S. Mwanycky*

Science editing at ICIPE has recently been consolidated into the office of the Science Editor, who is responsible for editing of manuscripts generated from ICIPE scientists destined for international journals, and for preparing the *Annual Reports*. This office has also recently assumed interim coordination for the editing of *Insect Science and its Application* until a new scientific editor can be appointed to replace the out-going editor. In 1994, preparations for the publication of two books reviewing the current status of IPM were finalised in collaboration with UNEP.

In addition to the above, the editorial office seeks to improve the presentation, organisation and style of ICIPE documents, reports and publicity material, as well as advising the staff on publication procedures and priorities.

2. ICIPE SCIENCE PRESS (ISP)

Participating staff: *A. Katama*, W. Oyuko, N. M. Komeri, D. Odhiambo, D. Munene, I. Ogendo, G. Suka (*Manager, ISP)*

The Press, being a special project of the ICIPE, focuses on dissemination of information on integrated management of tropical insect pests and disease vectors by publishing and document processing for the Centre. It seeks to foster scientific communication within Africa and the rest of the international scientific community through the publication and marketing of books and journals.

While striving to achieve its goals, the Press introduced two projects: 'The Environmental Publishing Network' (ENVIRONET Links) and the 'University Students Attachment Programme' (USAP). ENVIRONET is an initiative that can give a boost to environmental publishing, especially in Eastern Africa. The project is described in a separate section below.

USAP, the second project of the Press, was formed earlier but came into the limelight in 1994. This is a 'Women Empowerment' project that has enhanced the day to day smooth running of the Press. This programme takes on attachment university students who are on vacation for a duration rarely exceeding 6 months. The project aims at empowering women with on-the-job practical experience with all aspects of work at ISP and subsequently acquiring various managerial skills. USAP greatly assists the Press in that production and labour costs are kept to a minimum, while providing students with transport and basic upkeep.

The Press continued to have a complete in-house production of the international journal, *Insect Science and its Application*, now in its 15th volume. This involves typesetting, layout, design, illustrating, proofreading and liaising with printers, marketing and distribution. Besides this journal, the Press has completed the following publications in 1994:

- *Insect Physiology and Biochemistry* by M. F. B. Chaudhury (PEW Africa Ecology Series). A manual expressly prepared for the Insect Physiology Course given by the African Regional Postgraduate Programme in Insect Science (ARPPIS) at ICIPE, Nairobi, Kenya. ISBN 92 9064 064 2, 202 pp. March 1994.
- *Insect Population Ecology: An African Perspective* by J. S. Elkinton (PEW African Ecology Series). ISBN 92 9064 063 4, 99 pp.
- ICIPE. *Proceedings of the Workshop on Effective Networking of Research and Development on Environmentally Sustainable Locust Control Methods Among Locust Affected Countries*. ICIPE, Duduville, Nairobi, Kenya, 16–18 September 1991. Edited by P. G. N. Njagi and M. F. B. Chaudhury. ISBN 92 9064 066 9. 147 pp. April 1994.
- ICIPE. *Techniques of Insect Rearing for the Development of Integrated Pest and Vector Management Strategies* (Vol. 1). Proceedings of the International Group Training Course on Techniques of Insect Rearing for the Development of Integrated Pest and Vector Management Strategies. 16 March–3 April 1992, ICIPE, Nairobi, Kenya. Edited by J. P. R. Ochieng'-Odero. ISBN 92 9064 065 X. 284 pp.
- ICIPE. *Annual Report Highlights 1993*. ISBN 92 9064 070 7. 63 pp.
- Kenya Marine and Fisheries Research Institute and the European Economic Community. *Recent Trends of Research on Lake Victoria Fisheries*. Proceedings of the Second EEC Regional Seminar on Recent Trends of Research on Lake Victoria Fisheries. 25–27 September 1991, Kisumu, Kenya. Edited by E. Okemwa, E. Wakwabi and A. Getabu. ISBN 92 9064 078 9. 198 pp.

- *Development's Last Frontier: What Prospects?* Four Essays on African Development. Edited by Sadig Rasheed. ISBN 92 9064 071 5. 144 pp. June 1994.
- Food and Agriculture Organisation of the United Nations: *Integrated Vegetable Crop Management in the Sudan*. Edited by Z. T. Dabrowski. ISBN 92 9064 087 1. 71 pp. November 1994.
- AAPAM. Monograph series on Administrative Responses to the African Economic Crisis:
  - *The Case of Tanzania*. Edited by R. Baguma, M. Halfani and A. Sendaro. ISBN 92 9064 080 4, 102 pp.
  - *The Case of Nigeria*. Edited by Dele Olowu, Mufu Laleye and Victor Ayeni. ISBN 92 9064 082 X, 103 pp.

Outside work, in addition to ICIPE assignments, has enabled the Press to generate revenue. The Printing Press and Graphics Studio have been working at full capacity.

Apart from the publications, the Press was involved in publicity and networking activities including the CTA-Conference on Tropical Entomology, the Nairobi Bookfair, and the launching of *Ethics and Accountability* book, amongst others.

3. ENVIRONET: ENVIRONMENTAL PUBLISHING NETWORK

Participating staff: *A. Katama*, V. O. Musewe (*Project Leader)*

Donor: *IDRC*

Collaborators: *The International Centre for Research in Agroforestry (ICRAF); Environmental Liaison Centre International (ELCI); African Crop Science Society (ACSS), Kampala, Uganda; Organisation for Social Science Research in Eastern Africa (OSSREA), Addis Ababa, Ethiopia*

Background

The project ENVIRONET (Environmental Publishing Network) is an undertaking of the ICIPE Science Press (ISP), the Publishing Unit of the International Centre of Insect Physiology and Ecology (ICIPE) in collaboration with other institutions in the Eastern African Region. Collaborating institutions are listed above.

ENVIRONET has a Board of Advisors comprised mostly of members of the participating institutions. They are:

- Dr V. O. Musewe, Head of Training, ICIPE
- Ms Helen van Houten, Senior Science Editor, ICRAF
- Dr Rannil Senanayake, Co-Executive Director, ELCI
- Prof. Abdel Ghaffer, Executive Secretary, OSSREA
- Dr Jonathan Baranga, Director, Institute of Tropical Forest Conservation (ITFC).

In addition to the members of the Board there is a Team Director, Michael Hailu who is a Programme Coordinator in ICRAF. Agnes Katama, the Manager of ICIPE Science Press, is the Project Leader.

The basic aim of this network is "to facilitate the production in a coordinated fashion of a sizeable part of print-worthy environmental studies generated by both participating and other institutions throughout the Eastern African region". The publications will target desertification, food security, crop sciences, soil management and management of natural resources.

ICIPE Science Press undertook this venture following the need for the creation of sub-regional, self-sustaining specialised publishing outlets which meet the local needs in a coherent fashion.

Progress and future of ENVIRONET

The implementation of the project is to be covered in two phases. The main concerns of Phase I which is in its completion stages were to establish self-sustaining methods of managing the funds available for this activity, and create a basic minimum skilled workmanship for the distribution and marketing of the publications created within the participating institutions. The workmanship comprised selected personnel from the participating institutions who underwent an intensive 4-month course in Desktop Publishing at the ICIPE Science Press premises.

With the now coming ENVIRONET Phase II, attention will be focused on the creation of a well managed Information Centre to facilitate the sharing of information and other resources. It is hoped that through the Information Centre, the transfer of scientific manuscripts by email for their effective editing and re-transmission to a collection node will become a reality. This could be the answer for those ailing journals, bulletins whose editorial costs shoot through the ceiling of any funds they have set aside. It will also be able to supplement information on current literature on environmental matters. There is a possibility of increasing the capacity of ISP to carry out Electronic Publishing through (a) electronic mail, (b) on-line access to the central database, (c) interactive exchange of information, and (d) storage of important archival information on CD-ROM and the development of this capability, particularly as a way to take stock of all existing grey literature in science, agriculture and environment.

4. UNIVERSITY STUDENTS ATTACHMENT PROGRAMME (USAP)

The University Students Attachment Programme (USAP), is now an integral component of ENVIRONET. It is a women-empowerment project which started in 1993. It has the following aims:

- To expose students to the production of various documents and books that they shall later use in their areas of study;
- To train the university students on attachment who can contribute to the general working of the Press;
- To enable the students to gain working experience and subsequently acquire various managerial skills.

This project takes on female students on vacation for three months. At any one time there are at most ten (10) students on attachment. They are selected on the basis of qualifications by an interview panel in conjunction with former USAP students. The interviewing panel is composed of the permanent staff of ISP. The successful students receive intensive on-the-job training before being assigned various administrative tasks which include project management, general administration, public relations and book publishing, particularly in graphic design and layout as well as basic editing.

Also incorporated into the USAP programme is a series of management and personality development courses which span the duration of the attachment. At the end of the course, the students receive certificates signed by both the Manager of the ICIPE Science Press and the Director General of the ICIPE. The course programme has a positive effect on the students as it equips them with practical experience enabling the students to start their own projects, Women in Management, Women in Science and Women in Law.

The greatest advantage of running this attachment to ISP and ENVIRONET is that the Press has been able to cut down administrative costs by almost 40%. The project also helps to harmonise the work flow at the operations of the Press.

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C. Publications of ICIPE Science Press

AAPAM. Monograph series on Administrative Responses to the African Economic Crisis:
– *The Case of Tanzania.* Edited by R. Baguma, M. Halfani and A. Sendaro. ISBN 92 9064 080 4, 102 pp.
– *The Case of Nigeria.* Edited by Dele Olowu, Mufu Laleye and Victor Ayeni. ISBN 92 9064 082 X, 103 pp.

Chaudhury M. F. B. (ed.) *Insect Physiology and Biochemistry.* (Pew Africa Ecology Series). ISBN 92 9064 064 2, 202 pp.

Development's Last Frontier: What Prospects? Four essays on African Development. Edited by Sadig Rasheed. ISBN 92 9064 071 5. 144 pp.

Elkinton J. S. *Insect Population Ecology: An African Perspective.* (Pew Africa Ecology Series). ISBN 92 9064 063 4, 99 pp.

Food and Agriculture Organization of the United Nations (FAO). *Integrated Vegetable Crop Management in the Sudan.* Edited by Z. T. Dabrowski. ISBN 92 9064 087 1. 71 pp.

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ICIPE. *Techniques of Insect Rearing for the Development of Integrated Pest and Vector Management Strategies* (Vol. 1). Edited by J. P. R. Ochieng'-Odero. Proceedings of the International Group Training Course on Techniques of Insect Rearing for the Development of Integrated Pest and Vector Management Strategies. 16 March–3 April 1992. ISBN 92 9064 065 X. 284 pp.

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Mr F. O. Ujiji, *Driver*
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Ms R. A. Okoth, *Data Input Clerk*
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Mr E. E. O. Obuya, *Clerical Assistant*

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Mr V. M. Kamanyi, *Accountant*
Mr P. O. Ngugi, *Accountant*
Mr P. O. Okune, *Assistant Accountant*
Mr G. J. Rugendo, *Assistant Accountant*
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Mr N. K. Mulwa, *Accounts Assistant*
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Mr D. K. Mungai, *Junior Technician/Driver*
Mr A. Bubusi, *Senior Cleaner/Messenger*

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Mr P. N. K. Kathenya, *Supplies Assistant*
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Mr E. M. Aosa, *Assistant Storekeeper*
Mr J. B. Oyondi, *Senior Driver/Messenger*

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Mr P. O. Akello, *Laboratory/Field Assistant*

Kwale-based
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Dr P. G. N. Njagi, *Postdoctoral Research Fellow*
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Mr H. H. Korina, *Technician/Driver*

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Mr S. M. Singi, *Laboratory/Field Assistant*
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Mr N. O. Otieno, *Driver/Technical Assistant*

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Mr S. Kelwon, *Technical Assistant/Enumerator*

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Mr O. K. Wambua, *Technical Assistant/Enumerator*
Mr M. R. Mungai, *Technical Assistant/Driver*

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Mr N. O. Dibogo, *Technical Assistant/Enumerator*
Mr J. S. Oluoch, *Technical Assistant/Enumerator*

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Mr M. O. Chacha, *Technical Assistant*
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Mr P. O. Wagara, *Technical Assistant*
Mr A. G. Nyagwara, *Technical Assistant*
Mr B. O. Owiyo, *Technical Assistant*

ICIPE SCIENCE PRESS

Ms A. Katama, *Manager (on secondment from Kianda Foundation)*
Mrs W. A. Oyuko, *Production Officer*
Mr N. M. Komeri, *Senior Scientific Illustrator*
Miss D. M. Munene, *Senior Phototypesetter*
Mrs D. O. Odhiambo, *Proof-reader*
Miss I. A. Ogendo, *Graphic Artist*
Mr J. M. Kariuki, *Accounts Assistant*
Mr G. K. N. Suka, *Printing and Offset Machine Operator*
Mr J. M. Kisini, *Cleaner/Messenger*

DUDU ENGINEERING WORKS

Duduville-based

Mr J. A. Mando, *Principal Controller for Technical Services*
Mr D. Murali, *Electronics and Instrumentation Engineer*
Mr M. S. Nakitare, *Electronics and Instrument Technologist*
Mr A. R. S. Abdalla, *Refrigeration Technologist*
Mr P. O. Nyachieo, *Chief Technician*
Mr J. M. Maina, *Chief Technician*
Mr. J. O. Ogalo, *Principal Technician*
Mr J. B. Omullo, *Senior Technician*
Mr P. A. Oluya, *Senior Technician*
Mr K. Kibe, *Technician*
Mr A. M. Wanyama, *Technician*
Mr J. O. Omondi, *Technician*
Mr M. O. Odada, *Junior Technician*
Mr T. O. Ochieng', *Junior Technician*
Mr M. M. O. Orwe, *Workshops Assistant*

MPFS-based

Mr K. G. Ogweno, *Principal Technician (Power Supply)*
Mr P. M. Alianda, *Principal Technician (Water Works)*
Mr T. L. Ngutu, *Senior Technician (Metal Works and Machines)*
Mr E. E. Okello, *Senior Technician (Electronics)*
Mr J. O. A. Wasinda, *Technician (Electrical)*
Mr R. M. Nzioka, *Technician (Plumbing)*
Mr S. M. Karanja, *Technician (General Maintenance)*
Mr J. H. Ohato, *Senior Mechanic/Driver*
Mr E. O. Ndiao, *Assistant Mechanic*
Mr S. O. Haira, *Assistant Mechanic*
Mr D. O. Wanjara, *Junior Technician (Carpentry)*
Mr W. O. Omonge, *Junior Technician (Welding)*
Mr C. A. Otuta, *Workshops Assistant*
Mr N. O. Otengo, *Workshops Assistant*
Mr W. A. Atieno, *Painter/Sign-writer*
Mr T. W. Manga, *Cushion Maker*
Mr P. Otieno, *Panel Beater*

CENTRAL ADMINISTRATIVE SERVICES AND UTILITIES

Mr L. Okola *(In charge)*

Utilities Section

Mrs M. B. Mohochi, *Ag Telephonist/Receptionist Supervisor*
Mrs S. O. Oyugi, *Senior Telephonist/Receptionist*
Mrs M. Assetto, *Telephonist/Receptionist*
Mr E. Asami, *Mail Clerk*

Janitorial Section

Mr C. F. O. Onoka, *Janitorial Supervisor*
Mr W. O. Adhiambo, *Cleaner/Messenger*
Miss P. Siva, *Cleaner/Messenger*
Mr R. M. Masaka, *Cleaner/Messenger*
Mr D. M. Muthama, *Cleaner/Messenger*
Mr E. Ondeyo, *Cleaner/Messenger*
Miss E. J. Tirop, *Cleaner/Messenger*
Mr T. O. Adongo, *Cleaner/Messenger*
Miss L. W. Mwaura, *Cleaner/Messenger*
Mr B. M. Oketch, *Cleaner/Messenger*
Mr W. Ambaka, *Cleaner/Messenger*
Mr G. S. K. Kariuki, *Cleaner/Messenger*
Mrs M. A. Ochanda, *Cleaner/Messenger*
Mrs S. Onyango, *Cleaner/Messenger*
Mrs L. W. Mburu, *Cleaner/Messenger*
Mr F. O. Athula, *Cleaner/Messenger*
Mr S. M. Mkamba, *Janitorial/Gardening Assistant*

Security Section

Mr A. M. Bwana, *Ag Security Officer*
Mr A. M. Ouma, *Security Supervisor*
Mr D. R. M. Njeru, *Security Supervisor*
Mr M. M. Kinguu, *Senior Security Guard*
Mr J. D. Nyawalo, *Senior Security Guard*
Mr E. H. Otieno, *Senior Security Guard*
Mr D. M. Mwilu, *Senior Security Guard*
Mr J. A. Vudavira, *Security Guard*
Mr P. O. Apodo, *Security Guard*
Mrs M. N. Muiruri, *Security Guard*
Mr J. N. Aburi, *Security Guard*
Mr G. O. Omondi, *Security Guard*
Mr G. M. Kinyuah, *Security Guard*
Mr G. M. Ongoncho, *Security Guard*

Transport Section

Mr V. O. Odhiambo, *Transport Assistant*

Mr J. O. Madero, *Data-Input Clerk*
Mr P. N. Mahogo, *Senior Driver*
Mr U. Ibrahim, *Driver/Mechanic*
Mr R. M. Mugi, *Driver/Assistant Mechanic*
Mr A. O. Kirimba, *Driver*
Mr J. K. Nzioki, *Driver*

MBITA POINT FIELD STATION AND SATELLITE FIELD RESEARCH SITES

Administrative and Janitorial Services

Mr E. O. Anyango, *Senior Administrative Officer/ Officer-in-Charge*
Mrs R. A. Okoth, *Senior Secretary*
Mr C. A. Amolo, *Supervisor, Gardening and Janitorial Services*
Mr P. O. Gati, *Technical Assistant (Oxidation Ponds)*
Mr Z. O. Nyandere, *Cleaner/Messenger*
Mrs S. A. Otila, *Cleaner/Messenger*
Mrs M. O. Walter, *Janitorial/Gardening Assistant*
Mr G. O. Ogero, *Janitorial/Gardening Assistant*
Mr T. A. Owiti, *Janitorial/Gardening Assistant*
Mr V. O. Nyangute, *Janitorial/Gardening Assistant*
Mr T. K. Adwar, *Janitorial/Gardening Assistant*
Mr M. O. Omollo, *Janitorial/Gardening Assistant*
Mr J. D. Orimbo, *Janitorial/Gardening Assistant*
Mrs Z. P. Mmbone, *Janitorial/Gardening Assistant*
Mr B. O. Yana, *Janitorial/Gardening Assistant*
Mr A. A. Awich, *Janitorial/Gardening Assistant*
Miss D. A. Achieng', *Secretary*
Mr G. R. Khisa, *Telephonist/Receptionist*
Miss M. A. Okoth, *Telephonist/Receptionist/Typist*
Mr R. R. Nyaridi, *Clerical Assistant*

Accounts and Supplies Section

Mr M. Kawaka, *Accountant*
Mr E. O. D. Odhiambo, *Accounts Assistant*
Mr P. O. Otieno, *Accounts Assistant*
Mr J. O. Gombe, *Senior Assistant Supplies Officer*
Mr E. O. Jasor, *Stores Clerk*

Security Section

Mrs P. A. Oriwa, *Principal Security Officer*
Mr J. K. N. Birir, *Security Supervisor*
Mr J. Omogi, *Security Supervisor*
Mr A. O. Omondi, *Senior Security Guard*
Mr J. O. Musingo, *Security Guard*
Mr M. O. Omom, *Security Guard*
Mr N. N. Omurumba, *Security Guard*
Mr E. O. Raringo, *Security Guard*
Mr J. T. Rege, *Security Guard*
Mr G. O. Aunga, *Security Guard*
Mr S. O. Mboga, *Security Guard*
Mr N. O. Mbija, *Security Guard*
Mr J. M. Chacha, *Security Guard*
Mr D. K. Bett, *Security Guard*
Mr P. R. Manga, *Security Guard*

Farm Services

Mr P. Nyongesa, *Senior Farm Supervisor*
Mr P. L. Rakwach, *Tractor Driver/Mechanic*
Mr E. O. Ogutu, *Tractor Driver/Mechanic*
Mr Z. B. Ooko, *Farm Assistant*
Mr J. W. Achola, *Farm Assistant*
Mrs P. Ogito, *Farm Assistant*
Mr J. Sagini, *Farm Assistant*
Mr S. O. Odero, *Farm Assistant*
Mr W. J. O. Odhiambo, *Farm Assistant*
Mr J. O. Obilo, *Farm Assistant*

Library Section

Miss D. Achieng, *Librarian*
Mr E. A. Sonye, *Clerical Assistant*

Transport

Mr W. N. Omino, *Boatmaster*
Mr P. O. Mbuya, *Senior Driver*
Mr L. O. Otieno, *Driver*
Mr J. O. Otunge, *Driver*

UNGOYE FIELD SITE

Farm Services

Mr E. G. Kabiru, *Farm Foreman*
Mr P. O. Ouma, *Senior Farm Assistant*
Mr D. O. Oyoo, *Senior Farm Assistant*
Mr F. O. Bwire, *Farm Assistant*

Security

Mr S. M. Abaya, *Security Supervisor*
Mr W. K. Makori, *Security Guard*
Mr P. O. Okech, *Security Guard*
Mr J. M. Motari, *Security Guard*
Mr P. O. Kisaria, *Security Guard*

MUHAKA FIELD STATION

Mr S. Abdalla, *Senior Security Guard*
Mr M. O. Otiende, *Senior Security Guard*

SELF-FINANCING UNITS

INTERNATIONAL GUEST CENTRE SYSTEM

Duduville-based

Mr J. A. Achilla, *Principal Business and Catering Controller*
Mr S. M. Aritho, *Accountant*
Mr P. A. M. Kasina, *Chef*
Mr C. B. Oyieyo, *Food and Beverages Supervisor*
Mr A. Lweya, *Assistant Head Cook*
Mr G. Gichuru, *Cook*
Mr P. A. Omollo, *Senior Barman/Waiter*
Mrs P. A. Ochola, *Assistant Housekeeper*
Mrs R. M. Wekesa, *Senior Telephonist/Receptionist/Cashier*
Mr L. M. Mulae, *Room Steward*
Mrs T. A. Ogongo, *Room Steward*
Mr J. O. Mukhobi, *Janitorial Assistant*
Mr K. K. Omari, *Janitorial Assistant*
Miss N. Ifire, *Guest-house Attendant*
Mr S. O. Ojwang', *Guest-house Attendant*
Mr J. N. Kipserem, *Laundry Assistant*
Mrs J. A. Awich, *Laundry Assistant*
Mr P. Mungithya, *Waiter*
Mr D. O. Resa, *Front Office Assistant*

MPFS-Based

Mr J. A. Kooro, *Business and Catering Controller*
Mr S. Nyangi, *General Assistant*
Mr S. A. Alos, *Assistant Barman*
Mr P. O. Odote, *Chef*
Mr J. O. Koyaa, *Stores Clerk*
Mr A. O. Were, *Messenger/Waiter/Cleaner*
Mr F. O. Orwa, *Kitchen Assistant*
Mr C. O. Nyagaya, *Housekeeping Assistant*
Miss M. A. Nalo, *Housekeeping Assistant*
Mr W. M. Esirenyi, *Guest-house Attendant*
Mr S. O. Odhako, *Guest-house Attendant*
Mr F. N. Omutsembi, *Laundry Assistant*
Mrs H. A. Ouma, *Laundry Assistant*

MEDICAL AND CLINICAL SERVICES UNIT

St Luke's Clinic-Duduville

Dr R. W. Kimokoti, *Medical Officer*
Mrs F. P. Mbogo, *Senior Clinical Officer*
Mrs I. A. Wadundwe, *Nurse*
Mrs C. E. Okoth, *Nurse*
Mr J. K. Awino, *Pharmaceutical Technologist*
Mr S. K. Kirera, *Laboratory Technologist*
Mr J. M. Silingi, *Accounts Clerk*
Miss J. W. Mwaniki, *Medical Secretary*
Mr J. M. Asitiba, *Janitorial Assistant*

** Left before 31 December*

St Jude's Clinic-MPFS

Dr E. C. Achieng', *Medical Officer*
Mr J. H. Odoyo, *Senior Clinical Officer*
Mrs A. A. Miruka, *Enrolled Community Nurse*
Mrs F. K. W. Mukoko, *Clerical Assistant*
Mr A. O. Olwoko, *Senior Driver*
Mrs L. A. Abuya, *Clinical Attendant*
Mrs C. A. Abonyo, *Janitorial Assistant*

MBITA POINT INTERNATIONAL SCHOOL

Mr F. O. Omolo, *Deputy Principal*
Mr Y. M. Koko, *Teacher*
Mrs C. O. M. Ndiege, *Teacher*
Mr P. W. Mburu, *Teacher*
Mr P. W. Mitugo, *Teacher*
Mrs L. G. Chacha, *Teacher*
Mr J. B. A. Sune, *Teacher*
Miss V. Olwali, *Teacher (French)*
Mrs M. N. Okach, *Secretary*
Miss S. A. Omune, *School Attendant*
Mrs O. A. Ojwang', *School Attendant/Cleaner*

DUDU TRAVEL SERVICES

Mr F. J. Utanje, *Travel Officer*
Miss P. W. Njenga, *Travel Assistant*

DUDU COOPERATIVE SAVINGS AND CREDIT SOCIETY LTD (DUSCO)

Elected officials

Mr P. A. Oluya, *Chairman*
Mr P. O. Okune, *Vice-Chairman*
Mr V. Kamanyi, *Treasurer*
Mr L. V. Moreka, *Secretary*
Mr W. O. Bundi, *Credit Committee*
Mr P. Ngugi, *Credit Committee*
Mr P. Ollimo, *Credit Committee*
Mrs P. Owitti, *Education Committee*
Mr J. Kilori, *Education Committee*
Mr D. O. Olalo, *Supervisory Committee*
Mr E. Nyandat, *Supervisory Committee*
Mr P. Owuor, *Supervisory Committee*
Mr E. Odhiambo, *Mbita Representative Committee*
Mr R. Yogoh, *Mbita Representative Committee*
Mr E. Sonye, *Mbita Representative Committee*

Staff

Mr R. O. Olunga, *Senior Accountant*
Mr J. L. Kasiera, *Accounts Assistant*
Mr L. O. Kwelu, *Bookkeeper*

Staff distribution by Programme and category as at 24 November 1994

Programme	IPS	VS	PDF	OPS		TAS		Total	%	GS
				SCI	ADMIN	DSR	ISR			
Plant Pests Research										
1. Crop Pests Research (+ off campus)	5	5	1	2	–	54	–	67	11.7	–
2. Locusts Research	5	–	3	3	–	10	–	21	3.7	–
Disease Vectors Research										
3. Livestock Pests Research	12	1	5	–	–	56	–	74	12.9	–
4. Medical Vectors Research (+ off campus)	2	–	–	–	–	22	–	24	4.2	–
Institutional Building, Interactive Research and Information										
5. IBIRI (includes PESTNET and ARPPIS Secretariats and ARPPIS PhD Students)	4	–	–	2	3	8	9	26	4.5	31
Research Support Units										
6. Behavioural and Chemical Ecology	5	–	1	2	–	11	–	19	3.3	–
7. Molecular Biology	4	–	2	–	–	9	–	15	2.6	–
8. Biomathematics (+ off-campus)	1	–	–	1	–	6	–	8	1.4	–
9. Social Sciences (+ off-campus)	3	1	–	1	–	19	–	24	4.2	–
10. Biotechnology	2	–	1	–	–	2	–	5	0.9	–
Research Support Services										
11. Animal Rearing and Quarantine Unit (+ off-campus)	1	–	–	1	–	29	–	31	5.4	–
12. Mbita Point Field Station (including Field Research Sites)	–	–	–	–	–	18	47	65	11.3	–
13. Muhaka Field Station	–	–	–	–	–	–	2	2	0.3	–
14. ICIPE Science Press	–	–	–	2	–	7	–	9	1.6	–
15. Dudu Engineering Works	–	–	–	2	–	30	–	32	5.6	–
Self-Financing Units										
16. International Guest Centres	–	–	–	–	1	–	31	32	5.6	–
17. Medical Clinics	–	–	–	–	2	–	14	16	2.8	–
18. Mbita Point International School	–	–	–	–	–	–	11	11	1.9	–
19. Dudu Travel Services	–	–	–	–	–	–	2	2	0.3	–
Administration and Finance										
20. Office of the Director	3	–	–	–	1	–	10	14	2.4	–
21. Administration Division	1	–	–	–	2	–	50	53	9.2	–
22. Finance Division	1	–	–	–	4	–	19	24	4.2	–
Total	49	7	13	16	13	281	195	574	100%	31
%	8.5	1.2	2.3	2.8	2.3	48.9	34.0		100%	

Notes:
- IPS = International professional staff (senior scientists and managers)
- VS = Visiting Scientist
- PDF = Postdoctoral Research Fellow
- OPS = Other professional staff
  - SCI – Scientific Officers and Senior Technical Staff
  - ADM – Senior Administrative Staff
- TAS = Technical and administrative support staff
  - DSR – Direct Support for Research
  - ISR – Indirect Support for Research
- GS = Graduate Scholar
- PESTNET = Pest Management R&D Network
- ARPPIS = African Regional Postgraduate Programme in Insect Science

ICIPE Governing Council 1994

Dr W. T. Mashler, ***Chairman***	Formerly Senior Director, UNDP	USA
Professor M. Ashburner	University of Cambridge	UK
Professor P. Esbjerg	Royal Veterinary University, Copenhagen	Denmark
Dr D. P. Gapasin	World Bank	Philippines
Professor S. O. Keya	University of Nairobi	Kenya
Dr B. E. Kipkorir	Kenyan Ambassador to the United States of America	Kenya
Dr J. W. Meagher	Formerly Chairman, Centro International de la Papa (CIP)	Australia
Dr M. Mensah	Formerly of IFAD, Economic Planning	Benin
Professor J. L. Ngu	Immuno-Biology Laboratory (WHO/IBL)	Cameroon
Professor H. Rembold	Max Planck Institute	Germany
Professor C. Safilios-Rothschild	Professor of Sociology	Greece
Dr R. W. Sutherst	Commonwealth Scientific and Industrial Research Organisation (CSIRO)	Australia
Professor S. Takahashi	Kyoto University	Japan
Dr M. Toure	World Bank	Senegal
Dr H. R. Herren	Director General, ICIPE	Switzerland

1994 ICIPE Donors

- African Development Bank (ADB)
- African Fund for Economic and Social Development (AFESD)
- Danish International Development Agency (DANIDA)
- Directorate for NGO, International Education and Research Programme (DPO), Netherlands Government (Biocontrol Project and Human Resource Development)
- European Union—European Development Fund (EDF)
- Finnish Government
- The Gatsby Charitable Foundation
- German Academic Exchange Service (DAAD)
- International Bank for Reconstruction and Development (World Bank)
- International Development Research Centre (IDRC)
- International Fund for Agricultural Development (IFAD)
- Japan Society for the Promotion of Science (JSPS)
- Kenya Government
- Natural Resources Institute (NRI), UK
- Norwegian Government
- Overseas Development Administration (ODA), UK
- The Rockefeller Foundation
- Swedish Agency for Research Cooperation with Developing Countries (SAREC)
- Swiss Development Cooperation (SDC)
- United Nations Development Programme (UNDP)
- United Nations High Commissioner for Refugees (UNHCR)
- United Nations Environment Programme (UNEP)
- United States Agency for International Development (USAID), through the Hebrew University of Jerusalem

Financial Report

Income and Expenditure Account for the year ended 31 December 1994	US$ 000 1994	*1993*
INCOME		
Grants	9,081.6	*6,206.4*
Premium on foreign exchange certificates	—	*81.6*
Miscellaneous	115.5	*558.6*
	9,197.1	*6,846.6*
EXPENDITURE		
Core Research	5,779.0	*4,401.2*
Research Support Services	446.1	*290.4*
Training and International Cooperation	1,098.7	*615.4*
Information	125.7	*121.3*
Management and General Operations	1,093.7	*794.7*
Currency Translation Loss	299.7	—
	8,842.9	*6,223.0*
Land and Buildings	159.2	*6.6*
Scientific Equipment	70.7	*165.4*
Office Equipment and Furniture	70.2	*38.2*
Vehicles	54.9	*168.8*
Generators	—	*20.5*
	9,197.9	*6,622.5*
(LOSS) SURPLUS for the year	(0.8)	*224.1*
Cost of Restructuring	219.5	—
TOTAL (LOSS) SURPLUS FOR THE YEAR	(220.3)	*224.1*

Balance Sheet as at 31 December 1994	US$ 000 **1994**	***1993***
FIXED ASSETS		
Nominal value	*	*
ICIPE Riverside House	276.9	*284.6*
CURRENT ASSETS :		
Consumable Stores	13.4	*6.1*
Grants Receivable	1,712.0	*506.5*
Debtors and Prepayments	1,554.2	*478.2*
Deposits — Building Maintenance Fund	215.2	*184.3*
— Others	—	*1,416.8*
Bank Balances and Cash	1,686.2	*840.5*
	5,181.0	*3,432.4*
CURRENT LIABILITIES		
Bank Overdraft (Secured)	2,037.2	*398.2*
Loan Repayable Within One Year	32.8	*14.6*
Creditors and Accruals	1,912.1	*1,448.9*
Unexpended Operating Grants	1,016.6	*1,261.5*
	4,998.7	*3,123.2*
NET CURRENT ASSETS	182.3	*309.2*
TOTAL NET ASSETS	459.2	*593.8*
FINANCED BY:		
Reserve Funds	(59.9)	*160.3*
Buildings Maintenance Fund	215.2	*184.3*
	155.3	*344.6*
Deferred Financing	80.4	*90.5*
Long Term Loan (Secured)	223.5	*158.7*
	459.2	*593.8*

** In accordance with the ICIPE Accounting Policy, all assets are written off to the Income & Expenditure account in the year of purchase. However, the Fixed Assets held by ICIPE as at 31 December, 1994, at cost, amount to US$ 6,750,680. (1993—US$ 6,435,187)*

Donors for 1994

	(US$ 000)	
GRANTS RECEIVED AND RECEIVABLE	***1994***	***1993***
African Development Bank (ADB)	—	*326.6*
African Fund for Economic and Social Development (AFESD)	241.9	*122.9*
Danish International Development Agency (DANIDA) — Danish Government	746.8	*452.5*
European Economic Union (EEU)	1,463.4	*838.3*
Finnish Government	120.0	*19.6*
Gatsby Charitable Foundation	166.6	*4.5*
German Academic Exchange Service (DAAD)	230.0	*215.3*
German Federal Ministry of Economic Cooperation	374.5	*218.0*
Hebrew University of Jerusalem	30.7	—
Institute of Molecular Biology and Biotechnology—Greece	—	*34.6*
International Bank for Reconstruction and Development (World Bank)	480.0	*664.8*
International Development Research Centre (IDRC)	39.9	*14.4*
International Fund for Agricultural Development (IFAD)	349.2	*386.2*
Japan Society for the Promotion of Science (JSPS)	5.7	*5.4*
Kenya Government	29.3	*61.5*
Natural Resources Institute (NRI) —UK	246.8	*112.6*
Netherlands Government	752.0	*394.7*
Norwegian Government	549.6	*445.5*
Overseas Development Administration (ODA)—UK	—	*7.4*
PEW Trust (through World Wildlife Fund)	—	*3.2*
Rockefeller Foundation	328.5	*337.0*
Swedish Agency for Research Cooperation with Developing Countries (SAREC)	697.8	*712.8*
Swiss Government	6.0	—
United Nations Children's Fund (UNICEF)	—	*9.9*
United Nations Development Programme (UNDP)	1,891.3	*1,729.5*
United Nations Environment Programme (UNEP)	18.1	*83.7*
United Nations High Commissioner for Refugees (UNHCR)	54.8	—
United States Agency for International Development (USAID)	13.8	*5.7*
Wellcome Trust	—	*7.4*
TOTAL GRANTS RECEIVED AND RECEIVABLE	8,836.7	*7,214.0*
Add : Unexpended Grants — brought forward	1,261.5	*253.9*
	10,098.2	*7,467.9*
Less : Unexpended Grants — carried forward	(1,016.6)	*(1,261.5)*
GRANTS TAKEN INTO INCOME	9,081.6	*6,206.4*

Abbreviations and Acronyms

AGRIS	Agricultural Information System
ARCMTT	Adaptive Research Project on Community-based Management of Tsetse and Trypanosomiasis (ICIPE project)
ARPPIS	African Regional Postgraduate Programme in Insect Science
AVRDC	Asian Vegetable Research and Development Centre
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo
DAAD	German Academic Exchange Programme
ENVIRONET	Environmental Publishing Network
FAO	Food and Agriculture Organisation of the United Nations
GIS	Geographic information systems
IARC	International agricultural research centre
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICWG-IPM	Inter-Centre Working Group on IPM
IFAD	International Fund for Agricultural Development
IITA	International Institute of Tropical Agriculture
IPM	Integrated pest management
IPVM	Integrated pest and vector management
IRRI	International Rice Research Institute
ISERIPM	Interactive Socioeconomic Research for Biointensive Pest Management (ICIPE project)
JIRCAS	Japan International Research Centre for Agricultural Sciences
KARI	Kenya Agricultural Research Institute
MOALDM	Ministry of Agriculture, Livestock Development and Marketing
MPFS	Mbita Point Field Station
NARES	National agricultural research and extension systems
NGO	Non-governmental organisation
NRC	National research centre
PESTNET	Pest Management Research and Development Network
PMDISS	Pest Management Documentation and Information System
PPP	Purchasing Power Parity
R&D	Research and development
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNHCR	United Nations High Commissioner for Refugees
UNIFEM	United Nations Development Fund for Women
WAU	Wageningen Agricultural University

25th Anniversary

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