1992

ANNUAL REPORT

The International Centre of
Insect Physiology and Ecology

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The International Centre of
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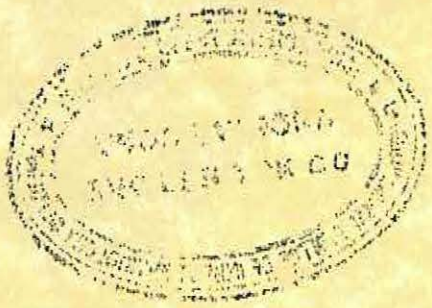

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The administrative centre at ICIPE International Headquarters at Duduville on the outskirts of Nairobi

About ICIPE

The International Centre of Insect Physiology and Ecology, better known by its acronym, ICIPE, is part of a global network of international research centres whose collective mandate is to improve the quality of life in developing countries through mission-oriented research. Founded in 1970 in Nairobi, Kenya, as a result of the initiative of Kenyan entomologist Professor Thomas R. Odhiambo and other concerned African scientists, and with the support of the international scientific and donor communities, ICIPE's research and development work over the past 24 years has focused on tropical insect pests, both as a constraint to food crop production and as vectors of human and animal disease. In addition to research, ICIPE's mandate includes human capacity building and utilisation in tropical insect science and its application, and the general strengthening of the scientific capacities of the developing countries, especially in Africa.

The Centre is governed by a Governing Council consisting of 16 members acting in their individual capacities. Of these, two members are drawn from the host country, while eight are elected from nominations put forward by the Sponsoring Group for the ICIPE (SGI), a consortium of funding agencies and governments subscribing to the ICIPE Charter. Five of the Council members are drawn from the international scientific community, eminent in the disciplines relevant to the Centre's areas of research.

The ICIPE is currently financed primarily through donations from international and government aid agencies, private foundations, and the United Nations agencies. The Government of Kenya is one of the major donors and consistently supports the Centre both financially and in kind.

ICIPE's research is organised around four principal Programmes: Crop Pests, Livestock Pests, Locust and Medical Vectors. Training, education, information and networking is consolidated together as the fifth Programme, known as Institutional Building, Interactive Research and Information (IBIRI). The Programmes are supported by five Research Units: Behavioural and Chemical Ecology Research Unit (BCERU), Molecular Biology Research Unit (MBRU), Biomathematics Research Unit (BRU), Insect and Animal Breeding Unit (IABU) and Social Science Interface Research Unit (SSIRU). The reports from these Programmes and Units constitute the bulk of this 20th Annual Report, which illustrates the multi-disciplinary nature of ICIPE's approach, and how ICIPE's research and development efforts have resulted in simple, low-cost, and sustainable pest control technologies and methods which can be applied by resource-poor rural farming communities.

1992 ICIPE Donors

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United Nations Environment Programme (UNEP)
United States Agency for International Development (USAID)

The next twenty-five years — a message from the Director

A month before the International Centre of Insect Physiology and Ecology (ICIPE) was legally and formally established in Nairobi under Kenya laws on 17th April 1970, a pre-establishment brochure stated the case for the founding of the ICIPE in a few words with pregnant prospects for the future of development-oriented science in Africa. It stated in the very first two pages:

Professor T.R. Odhiambo, Director of ICIPE

"The central aim of the ICIPE will be to carry out research of high quality in certain fields of insect physiology and ecology. The research contemplated will be of a fundamental nature, but the topics chosen are such as may well yield results which could transform current methods of insect control. Traditional techniques to control harmful insects with pesticides have met with a number of problems: most of the pesticides developed so far have been too broad in their action, proving toxic to other insects and other living things besides the target pest species; many of the pesticides...persist in the environment, thus progressively polluting it to a dangerous degree; and many insects have shown a remarkable ability to develop resistance to these pesticides. An aim of the Centre will be to find agents and methods which are highly selective in their effect, that do not lead to the pollution of the environment, and to which the pest species do not become resistant...

In addition to the advance of knowledge in these fields, a primary aim of the Centre will be educational: to strengthen the foundations of university institutions...by the training of research students at the post-graduate and post-doctoral levels... The single most severe constraint affecting technical advancement within the less developed countries is their shortage of highly trained manpower and institutions. A cadre of first-class scientists is needed, but their service in their own countries is hindered by at least two formidable obstacles: first, the difficulty of finding scientific frontier fields which relate at all closely to the problems facing developing countries; and second, the difficulty of attracting leading scientists from developed countries to work in a developing nation.

The ICIPE holds a powerful attraction to some of the world's leading scientists in the fields related to biological pesticides, developmental biology, insect physiology, insect behaviour, ecology and the chemistry of natural products. The ingredients exist for creating Joint Projects involving scientists from both developed and developing countries on topics which are scientifically exciting and are, at the same time, urgently relevant to meeting insect control needs in Africa and the rest of the world."

This twin-track agenda was most challenging when promulgated more than two decades ago. The ICIPE has, in the meantime, sometimes under great difficulties of financial resources or perceived credibility gap, demonstrated clearly and substantively, that the agenda can indeed be accomplished within Africa *in situ*, and that the twin goals are definitely reachable — provided the genesis of impetus is African, and there is international partnership to see it through.

Three prospective strategies are available for assuring the accomplishment of these goals as they particularly impinge on the uplifting of the quality of life of the preponderant resource-poor rural communities of the tropical and subtropical areas of Africa and other developing regions. First and foremost, there is a need for Africa to make a *strategic food security decision to produce its own staple food crops* in sufficient amounts, variety, and quality to satisfy its population, without recourse to significant imports from outside Africa. Already, it is estimated that within the next seven years, Africa's food deficits in West Africa, Eastern and Southern Africa, and in Central Africa will have reached 34 million tonnes, 12 million tonnes, and 5 million tonnes, respectively. Africa's decision to produce its own total food needs will require that dumping of cheap food, even in the context of food aid for refugees, would be severely discouraged through tariffs and other economic means. Africa fed itself before 1960. There is no reason, agronomic or economic, why it should not be able to do so again — even in the face of the high rate of population increase — if adequate incentives are given to the farmers.

Second, *productivity per unit area must be enhanced* considerably. Labour productivity in Africa is one of the lowest in the world, for several reasons:

- the very high incidence of rural tropical diseases — malaria, leishmaniasis, diarrhoeal diseases, river blindness, bilharzia, etc. — which not only lead to high mortality, particularly among the young, but also lead to considerable loss of working time during the most vital periods of cropping seasons;

- lack of adequate marketing facilities within the rural areas and associated inadequate transportation facilities for agricultural commodities and agricultural inputs between these rural production zones and the industrial zones in distant urban centres;

- inadequate articulation of farmers' agricultural research needs, and untimely payments for the delivered commodities;

- a pricing structure and tax impositions that act as a disincentive in competition with imports and manufactured goods.

These roadblocks to higher productivity need to be removed in a planned, deliberate manner.

Third, the farming community must be empowered by grafting on to their traditional knowledge base a *systemic mechanism for improving technological know-how*, through the design, development, field testing, and validation of innovative technologies that respond directly to their specific problem-solving agenda, in terms of enhanced production and productivity of target crops, as well as creating a basic economic security.

It is in this particular field, of improving technological know-how of the farming community, and in this context of establishing an interactive system of value-added farmer education and training, that the international scientific research and technology development (R&D) institutions, such as the ICIPE, can be most vital. *Interactive partnership* is the key operational approach that must be adopted in the working relationship between the farmers, the R&D institutions, the extension services, the entrepreneurial communities, and the policy makers. Such an approach must start with what the farmer already knows and practices, as I had occasion to state four years ago:

"There is a widespread mistaken idea that print-based information is the only type of information that is important, and that anyone who is not conversant with the technology or its acquisition is illiterate and beyond rehabilitation. But Africans are highly literate in oral and traditional knowledge, in which most modern scientists are illiterate. Both sides need to develop accommodation so as to provide an environment for interactive communication and productive partnership."

Such an interactive partnership can be translated into a broad-based institutional working relationship between the R&D institution (such as the ICIPE) and the technology consumer community in terms of three principal activities:

- *first*, updating of the technology (for example, of durable pest management) and upgrading of the target consumers;
- *second*, undertaking problem-solving R&D to provide technically efficacious, environmentally sustainable, least-cost pest management;
- *third*, providing an opportunity to rural farming households to work and learn in partnership with R&D experts and extension and information specialists.

Major issues face the implementation of ICIPE's resolve to institute a systemic mechanism for setting a medium-term problem-solving R&D agenda, and thereby enhancing farmers' technological know-how.

First, there is a lack of fit between what the farmers need in order to upgrade their technologies and what the R&D community actually have on the shelf, or what the extension specialists can actually supply. This lack reveals an astonishing ignorance of the farmers' current problems that cry for solutions, or a disinterest in those problems because they happen to be outside the specialists' own universe of contemporary interest.

Second, know-how and technological needs of the farmers are not only for the purpose of increasing agricultural production, but also for linking the latter to basic economic issues in order for the farmers to pole-vault over the absolute poverty line, as well as for providing a basis for income generation from non-farm related activities.

Third, there is a need for development of an efficient farmer-centred mechanism for assessing the needs of the market for food agriculture — its size, seasonality, and the prices it can command.

These issues are serious, but there is an even more threatening and problematic issue in the financial resource area.

There is no doubt that during the 1990s, when the entire world geoeconomic system has been undergoing a profound transition — with most of the G-7 countries experiencing what threatens to become a permanent economic recession, while the Pacific Rim Asian states are undergoing an unprecedented economic growth — that the development aid half-century may well be coming to a sudden demise. The signs are already there for those who reflect on such matters.

A case in point are the meagre financial resources available to developing regions of the world for vitally needed R&D to solve tropical health problems on a sustainable basis. According to statistics provided by the Report published in 1990 by the Commission on Health Research for Development, entitled *Health Research: Essential Link to Equity in Development*, the world expends a total of US$ 30 billion a year on health research, from both public and private corporate sources. A mere US$ 1.6 billion (or 5.3% of the total) is spent on developing country-oriented health research, of which only US$ 685 million originates from within the developing countries themselves, while the remainder of US$ 950 million comes from the industrialised countries of the North. However, of this latter figure, only one-sixth actually reaches the developing regions. Thus, only

about US$ 835 million (or 2.7% of the world total) is spent a year on health research within the developing regions, spread over three continents. Africa spends only a small fraction of this health R&D money, since three-quarters of the $ 835 million is spent by eight countries in South America and Asia: Argentina, Brazil, Mexico, China, India, Saudi Arabia, South Korea, and Taiwan.

It is therefore essential for the ICIPE management and Governing Council, together with our worldwide network of friends and partners, to urgently explore new avenues of longer-term funding. It is a matter of priority that can no longer be pushed aside to the back-burner if the ICIPE is to aspire to its twin goal of developing highly efficacious, bio-intensive pest and vector management technologies and of building up the human capital for science-led development in Africa. This is the principal assignment for the next twenty-five years.

END-PIECE

The ICIPE is a pathfinder and pioneer in Africa's science-led future. It has refused to follow the trodden path of safety, which has led to scoring goals in other societies and at other times. The current geopolitical and geoeconomic environment in the developed industrialised world has shifted the goal posts for Africa, and Africa has, in consequence, become even more vulnerable than at any time since the beginning of the era of political independence in the early 1960s. In these circumstances, Africa and Africa-centred R&D institutions, need to keep sacred their resolve to build their own institutional R&D capacity and to maintain the creativity to solve their own unique science-oriented development problems. Genuine partners have a crucial role to play in this process.

THOMAS R. ODHIAMBO
Director, ICIPE

1992 Overview of Research on ICIPE's Target Pests

Crop Pests — food *vs* famine

Africa's food deficit is due in large part to pre- and post-harvest crop losses, particularly for graminaceous crops (e.g., sorghum, maize, rice, wheat) and for leguminous crops (cowpea, chickpea, etc.) and banana. Crop yields in Africa are substantially below world averages. Africa produces only about 39% of the world average of maize and 56% of sorghum per hectare. Paradoxically, introduction of high-yielding varieties and other improved agricultural practices in tropical countries has often been paralleled by an increase in crop pest levels and diseases.

ICIPE's Crop Pests Research Programme (CPRP) in 1992 concentrated on five of Africa's major food crops and their most important pests: sorghum, maize, cowpea, rice and banana. The main goal of the CPRP is to develop socio-economically acceptable, biologically intensive pest management (BIPM) strategies that reduce crop losses caused by insect pests, and thus contribute to an increase in food crop production by resource-limited, small scale farmers in the tropics. Pest management in maize and sorghum, the major staple cereal crops of Africa, is being studied in relation to the stemborers *Chilo partellus* and *Busseola fusca*. In cowpea, which is commonly used as an intercrop by many farmers, management of the pod borer, *Maruca testulalis*, the aphid, *Aphis craccivora* and thrips, *Megalurothrips sjostedti*, are priority areas of concern. Banana has been included among ICIPE's target crops due to its importance as food in many tropical countries, especially in Africa and in Central and South America. The key banana pests are the banana weevil, *Cosmopolites sordidus* and various nematodes, especially *Pratylenchus* spp. Research on rice pests and highland and lowland rice agronomy also continued in 1992.

Crop pests facts

- Stemborers which attack maize and sorghum cause yield losses ranging from 30–80% around the African continent.
- Yields of sorghum in India and Sudan have been reduced by as much as 90% due to shootfly attack.
- Cowpea losses in tropical regions range from 20–100% due to attack by its three major pests: a pod borer, an aphid and thrips.

IPM strategies for crop pests

The integrated pest management (IPM) components under research and development at ICIPE combine both direct tactics and supportive tactics. The former include (i) developing plant resistance to insect pests, (ii) cultural control, (iii) biological control and for the first time, (iv) botanical control, utilising low-cost, natural and non-polluting botanicals as pest control agents. Supportive tactics include (i) the application of pheromonal biology and (ii) crop loss assessment.

Assessing crop losses

MAIZE AND SORGHUM

The assessment of crop losses and the determination of the minimum damage that a crop can endure before it shows economic damage due to infestation by insect pests are vital factors in the management of such pests. It is on the basis of information on crop loss assessment (CLA) as well as economic injury levels (EIL) that proper application of pest control strategies can be planned. When the phenological (growth) stages of the crop are synchronised with levels of the insect populations that inflict economic damage, then pest control measures need be applied only where necessary, hence making it possible to minimise unnecessary applications.

An experiment conducted at ICIPE's Mbita Point Field Station (MPFS) with the objectives of quantifying the yield losses in three sorghum cultivars and of ascertaining the relationship between insect pest infestation and actual grain yields, showed that grain yield losses, stem tunnelling and leaf injury due to *C. partellus* were highest when

RESEARCH HIGHLIGHTS

1. Factors affecting crop losses in sorghum by the stemborer *Chilo partellus* have been identified in relation to the phenological stage of the plant at the time of infestation.

2. Sorghum and maize lines and hybrids with high levels of resistance to stemborer attack and with improved grain yields have been identified and incorporated into national agricultural programmes (NARES).

3. The tiny wasp, *Cotesia flavipes* was shown to be an effective parasitoid for the destructive stemborer *C. partellus* at the Kenya Coast. Chemical cues from the borer and its host plant attract the wasp to its prey.

4. Thrips infestation in cowpea can be successfully controlled by application of neem seed extract. Grain yields rival those from plots treated with an expensive insecticide.

5. Optimal patterns of strip cropping sorghum with cowpea have been identified for reducing stemborer incidence.

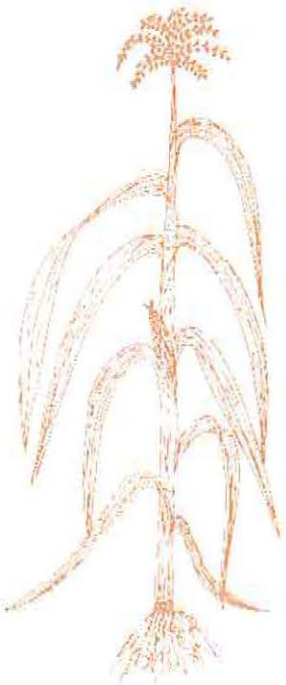
6. Field trials with several insect pathogens showed that the stemborer *C. partellus* can be effectively controlled in maize and sorghum by these bioinsecticides.

7. Forty rice varieties and breeding lines resistant to attack by the parasitic weed *Striga hermonthica* have been identified. Other rices tolerant to nutrient deficiencies and low rainfall have been developed. Twenty lines of early-maturing (75–85 DAE) rice have been identified.

8. 140 banana cultivars have been assembled and are being evaluated for their resistance/susceptibility levels to the banana weevil, *Cosmopolites sordidus* and the root lesion nematode *Pratylenchus goodeyii*. Some cultivars resistant to both pests have been identified.

plants were infested at 21 days after emergence and declined with advancing plant age at the time of infestation. The magnitude of these damages was directly proportional to larval densities, irrespective of the cultivar and crop growth stages.

Population monitoring with pheromonal traps



The surveillance of pest populations is a major component of IPM, for it is through such monitoring that possible pest outbreaks can be forecast. The efficient application of certain key agents for pest control, such as the timely release of predators and parasitoids or spraying of insect pathogens, directly depends on frequent surveillance of pest populations.

The effectiveness of traps for *Chilo partellus* baited with a synthetic blend of the female sex hormone components was improved considerably from 40% to 85% compared to virgin females. Field monitoring of the stemborer with traps baited with the blend proved to be a feasible technique.

Selecting plants that defend themselves

ICIPE research in this area is aimed at the development of strategies for efficient utilisation of plant resistance in maize, sorghum and cowpea against their major insect pests. The activities undertaken include elucidation of components; mechanisms and genetics of resistance in the target crops against the target pests; improvement of crop cultivars so as to combine pest-resistance/tolerance with other desirable agronomic characters, including yield.

Work on aspects of host plant resistance to the stemborer continued in 1992. In sorghum, pedigree selection for incorporation of resistance into a good agronomic background continued. Several derivatives having various combinations of resistance to stemborer or shootfly are now at an advanced (F_5 and F_6) generation. In addition,

several sorghum hybrids incorporating high levels of stemborer resistance and good agronomic traits were identified.

A complex interaction of several resistance factors affects the resistance/susceptibility of maize to *C. partellus*. Recurrent selection to improve on levels of resistance and extract lines from five maize populations continued, while selection procedures were initiated in ICZ 3 to improve on both the level of resistance and agronomic traits. Resistant lines having good general combining ability are now at advanced (S_5–S_6) generations of inbreeding.

Cultural practices for IPM

Research in this area aims at identifying and utilising the cultural practices that lead to a reduction of insect numbers, and which, therefore, can be incorporated into an IPM strategy. Over the last seven to eight years, the major CPRP activity on cultural practices has centered on intercropping, which has led to the identification of cereal/legume intercrop combinations that reduce pest populations on both crops.

Strip-cropping of 2, 3 or 4 rows of sorghum alternating with equal numbers of cowpea rows were found to be as effective as the traditional single row intercropping in reducing stemborer incidence. The strip-cropping had the added advantage of improved yields and increased efficiency and ease of field operations.

The beneficial-detrimental effects of other cultural practices on stemborers were established. For example, fewer cereal stemborers were recorded in ploughed plots with stubbles removed in contrast to plots with no-tillage or ploughing stubbles under. In the absence of phosphorous, stemborer incidence increased with additional nitrogen levels but this was nullified when phosphorous was applied.

Biological control of cereal stemborers

Insect pathogens were field-tested for the control of cereal stemborers. *Bacillus thuringiensis (Bt)*, *Nosema marucae* and *Beauveria bassiana* effectively reduced *C. partellus* infestation on sorghum and maize in the field, while *Metarhizium anisopliae* proved effective in laboratory studies.

Interaction of *Bt* and *Nosema* with other IPM components, especially host plant resistance, was studied. No incompatibility of the IPM components was observed in five sorghum lines or six maize hybrids.

Classical biological control of *Chilo partellus*

The ICIPE and the Department of Entomology, Wageningen Agricultural University are implementing a collaborative project on classical biological control of the introduced cereal stemborer, *Chilo partellus* which has been shown to be the most abundant stemborer species by far in maize and sorghum at the Kenya Coast. Moreover, natural enemies do not appear to be very effective in regulating densities of *C. partellus*.

The exotic larval endoparasitoid, *Cotesia flavipes*, has been introduced into Kenya for laboratory studies. Investigations indicate that *C. partellus* is a more acceptable and suitable host for *C. flavipes*, than for indigenous *Cotesia*. Studies on the foraging behaviour of *C. flavipes* suggest that volatile compounds emanating from the host plant complex provide important cues for host- and habitat-finding.

Botanical control for cowpea pests

In field trials conducted in western Kenya, high volume spray application of 3% aqueous

Cowpea grain yield compares favourably in plots treated with neem seed extracts (NSE) to those treated with an expensive insecticide in three field trials in western Kenya

	Yield (kg/ha)		
Treatment	Mbita	Ungoye	Mbita (off-season)
NSE 1%	1783	466	869
NSE 2%	2089	717	798
NSE 3%	2289	1150	941
Cypermethrin	2400	1683	988
Control (water spray)	1950	433	693

Three of the 140 banana cultivars assembled by ICIPE at the Mbita Point Field Station. Each cultivar is being assessed for its resistance to common banana pests. Selected varieties will be propagated for distribution to banana-growing farmers

neem seed (*Azadiracta indica*) extract on cowpea (*Vigna unguiculata*) at about 5, 6, and 7 weeks after emergence effectively controlled the cowpea thrips infestation and reduced larval populations. Grain yield in neem-treated plots was high and statistically equal to that in plots sprayed with a synthetic pyrethroid, Cypermethrin (0.04 kg a.i./ha).

Plant resistance

Studies on cowpea resistance to insect pests showed that nonpreference conferred resistance to aphids. Antibiosis does not play any role in cowpea resistance to the pod borer, *Maruca testulalis*.

Upland, lowland rainfed rice improvement project

Nine rices yielding 7–9 t/ha under favourable conditions were identified; under erratic rainfall (420 mm) they produced 0.5–1.3 t/ha. Ten upland varieties and 30 breeding lines (ICOX1 progenies and outcrossed varieties) were identified as resistant to *Striga hermonthica*. Also, 20 lines maturing in only 75–85 days after emergence were identified from outcrosses. Two were tolerant both to iron and zinc deficiencies. Thirty-five lines, six of which yielded 4–5 t/ha, were identified in an agro-ecology with frequent submergence (5–20 cm) for two weeks.

ICIPE-PhilRice Project

RICE

A survey conducted in the environs of Munoz, Philippines, revealed a strong need for the development of various IPM components for the management of the yellow stemborer in the irrigated rice ecosystem. Studies on the population dynamics of this insect showed that rice crops planted either in the last week of June or the first week of July will escape borer attack. Also, rice varieties evaluated for stemborer resistance differed with respect to oviposition, larval-pupal recovery, percent white heads and percent deadheart.

Banana-based IPM for the Lake Victoria Basin

BANANA

One may not think of bananas as being a food staple, but the annual world production of bananas and plantains (*Musa* spp) is about 69 million tonnes, of which 35% originates in Africa. Banana yields are declining in some countries due to a variety of pests, among the most important of which are the banana nematode and the banana weevil, *Cosmopolites sordidus* which burrows into the rhizome and pseudostem and causes it to fall over with its unripe bunch.

Eight of the 140 banana cultivars assembled by ICIPE which have proven resistant to weevil and nematode damage

Local cultivar name (genotype)		Use	Cultivar group
Giant Bogoya	(AAA)	dessert	Gross Michel
Gonja	(AAB)	roasting	French plantain
Kainja	(ABB)	multi-purp*	Pisang awak
Kivivuu	(ABB)	multi-purp*	Silver Bluggoe
Lusumba	(AAA)	cooking	East African Highland
Mbidde	(AAA)	beer	East African Highland
Nakyetengu	(AAA)	cooking	East African Highland
Sukali Ndizi (AAB)	(AB)	dessert	Ney poovan (AB), Silk

*Multi-purpose cultivars can be used for brewing, cooking or eaten ripe. Beer and dessert cultivars can be cooked in case of famine.

ICIPE's agronomic approaches to improvement of banana yield have included intercropping with local food crops, application of mulches, identification of high-yielding cultivars and cultivars resistant to root nematodes (*Pratylenchus* spp) and root rot (necrosis). Banana culture is particularly inhibited by lack of knowledge about this crop among extension workers, lack of inputs and a poor marketing structure, as well as pest infestation. ICIPE researchers are addressing these economic issues for increased production through effective pest management strategies.

Locusts — an ancient pest from pre-Biblical times

The desert locust, *Schistocerca gregaria* (Forsk) is one of the most devastating pests known to man since prehistoric times. In recent years, a 1986–89 desert locust plague occurred which required mobilisation of resources costing some $300 million and an application of 15 million litres of pesticides over more than 17 million hectares.

The migratory swarms of this highly mobile insect originate from low density (solitarious) populations which occupy a wide belt of semi-arid environment extending from the Indian sub-continent in the East, to the Atlantic coast of Northwest Africa. The desert locust is a pest of regional and international status: during plague periods, swarms are known to cross the borders of 60 countries in Africa and Asia.

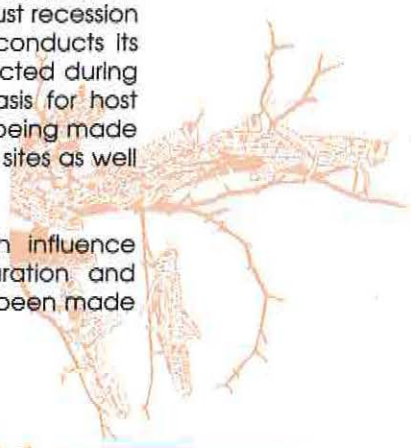
Solitarious desert locust individuals are usually inconspicuous and cause no economic loss. However, under certain favourable ecological conditions, plagues develop from these widely scattered low density populations, causing serious damage to crops and natural flora. Insecticides have been extensively used since the 1940s to alleviate the menace of desert locust swarms, but these chemicals are ecologically incompatible with the fragile semi-desert environment, and are beyond the financial means of most of the desert locust-affected countries. In addition, there is no evidence to suggest that these environmentally hostile chemicals have ever succeeded in ending a locust plague.

ICIPE's Locust Research Programme

The main objective of the ICIPE Locust Research Programme (LRP) is to develop a non-insecticidal, sustainable and environmentally-friendly desert locust management and control strategy. Our target is to keep the desert locust permanently solitarious by disrupting the gregarisation process and/or preventing solitary populations from gregarising. Our two-pronged approach to this goal is through (i) research on semiochemicals leading to the development of technologies for the disruption of the vital processes involved in swarm formation, and (ii) on the development of viable biological control agents. An understanding of locust behaviour and ecology is also a necessary component of control strategies.

Unlike the other major African locusts (*Nomadacris septemfaciata, Locusta migratoria migratoriodes* and *Locustana pardalina*), which have relatively well-defined outbreak centres, the desert locust can gregarise in any suitable habitat within its vast recession zone of approximately 17 million square kilometres. However, there are areas of relatively high locust activity within this zone, which, if properly studied, can provide significant clues to gregarisation behaviour. One such area is the desert locust recession and breeding habitat along the Red Sea Coast of Sudan where ICIPE conducts its ecological studies. Data on locust/host plant interactions have been collected during recession and at times of active gregarisation. Some aspects of the basis for host plant preference by the locust have been investigated. Attempts are also being made to investigate the population dynamics between complementary seasonal sites as well as within those sites.

A number of semiochemicals appear to mediate processes which influence gregarisation/solitarisation dynamics, sex attraction, synchronised maturation and oviposition (egg-laying), as well as host plant selection. Good progress has been made on the different aspects of semiochemicals research during 1992.



RESEARCH

1. Two pheromone systems regulating the cohesive behaviour of the desert locust have been identified by LRP scientists, one produced exclusively by the juveniles and the other by the adult insects. The chemical components considered responsible for the aggregation behaviour are being investigated.

2. Group egg-laying behaviour in the desert locust was shown to be regulated by volatile signals associated with the egg foam. Identification of the component compounds has been initiated.

3. The maturation process in the locust was shown to be regulated by a volatile signal emitted by mature males. A series of compounds present in this signal has been identified.

4. The airstream from solitarious mature live female locusts was shown to attract solitarious males, thereby demonstrating a long-range chemical communication between the sexes.

5. The stage or phase that an individual locust is in may be identifiable by certain chemical 'markers' present in its haemolymph and in the volatiles it

Chemical messages control locust behaviour

Behavioural bioassay techniques, together with electrophysiological and chemical analytical methods, have helped to demonstrate the mediation of four semiochemical systems in the desert locust and to define the chemical nature of some of the putative pheromones. Behavioural bioassay tests indicate the mediation of two releaser pheromonal systems in the cohesive behaviour of *S. gregaria*: a juvenile cohesion pheromone produced by nymphae (immature stages) and an adult cohesion pheromone specific to adults. The compounds considered to be responsible have been identified and their role in the aggregation behaviour is currently being investigated. Similarly, investigations into the possible role of oviposition aggregation pheromones (the chemicals that bring males and females together for a mass egg-laying activity), have indicated the presence of two or three GC-EAD active peaks which are currently being analysed to determine their chemical identity.

As regards studies on maturation, four volatile male-produced components, which have been detected by gas chromatography and chemically identified by GC-MS, are considered as candidates for regulating the maturation process. Bioassays to determine the way in which these compounds regulate synchronous maturation in the desert locust are in progress. Chemical 'markers' are compounds in the locust body which give some clue as to the stage an individual insect is in. This year, good progress was made in defining specific maturation and gregarisation markers. Certain volatiles produced by locusts and also some specific haemolymph proteins show good potential as gregarisation/maturation markers.

Volatiles produced by sexually mature females are postulated to be the primary source of a sex pheromone; male locusts were found to positively respond to volatiles in air streams blown over concealed mature females.

Locust facts

- One million locusts can eat in one day the food of 5000 people.
- A locust swarm in Mali in 1988 consisted of 120 million locusts.
- This plague caused losses to crops and livestock estimated at US$ 1 billion.

The environmental telegraph

A variety of physical and chemical signals arising from the environment influence the desert locust. Host plant kairomones have a role to play in the insects' orientation and behavioural responses. GC-EAD tests were carried out on volatiles from different host plants, including some desert plants, and 10–16 electrophysiologically active GC-peaks have been recorded. Some of the compounds eliciting these responses have already been identified.

Studies on the biophysical behaviour of the locust indicate a constant and higher response to certain colours in the blue and the red region of the light spectrum. Special

HIGHLIGHTS

emits. Some specific compounds have been proposed as potential markers.

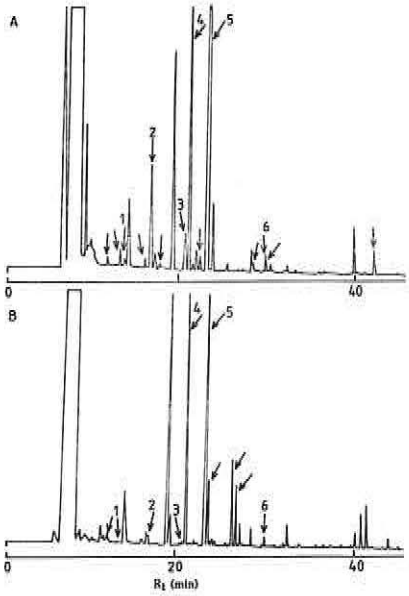
6 Desert locusts have been shown to respond most favourably to wavelengths of light in the blue and red regions of the electromagnetic spectrum.

7 The potential of a protozoal pathogen, *Malamoeba locustae*, as a control device is being explored through studies on its transovarial transmission within the locust population and on the insect's immune system.

8 Locust-active chemicals emitted by host plants in the desert environment have been identified and the insects' behavioural response to 10–16 of these compounds is being assessed for their role in helping to regulate orientation.

9 Locusts have been shown to prefer plants with the broadest canopy and degree of protection in the Red Sea Coast of Sudan, one of their major recession zones.

Gas chromatograms of volatile collections from two host plants of the desert locust. A, sorghum (Serena) seedlings and B, *Schouvia thebaica*. The arrows indicate the electrophysiologically active components, of which 1–6 are common to both plants

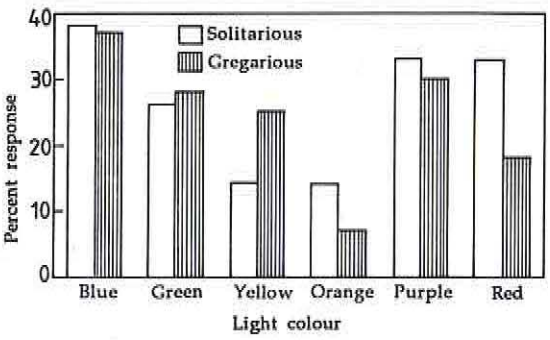


filters with specific wavelength bands have been used to define more precisely the effective wavelength bands to which locusts are attracted.

Biocontrol with locust pathogens

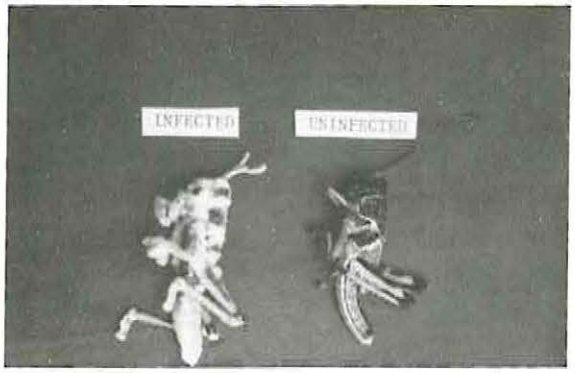
The primary objective of the biological control research project of LRP is to develop virulent pathogenic organisms which regulate field populations of the desert locust during times of recession in order to prevent development of swarms. These pathogens should be adaptable to the locust habitat and should perpetuate in the population transovarially, from one generation to another via the eggs of an infected female. The transovarial transmission of the selected organism for these studies (*Malamoeba locustae*), and its infection routes have been confirmed. Studies on the locust defence system against infection by this pathogen, a microscopic protozoa, have succeeded in identifying the nature of the defence mechanism. Another pathogen under investigation in the programme is *Beauveria bassiana*, a fungus which attacks all stages of *S. gregaria* and can be used as a contact bioinsecticide (see photo).

The figure shows the success of male locusts in locating targets of different colours. Solitarious locusts show a higher differential response to light in the red region of the spectrum, whereas yellow light is more attractive to gregarious-phase locusts



Collaboration in locust research

Currently the programme has a collaborative agreement on semiochemicals research with the Pheromone Group of the Department of Biological Sciences, Lund University, Sweden. There is also a joint effort on some aspects of desert locust neurophysiology with Prof. S. Yagi of the Tropical



Schistocerca gregaria nymph infected with *Beauveria bassiana*. Locust mortalities of 80–90% occur within 8–14 days after contact with the fungus.

Agricultural Research Centre, Ministry of Agriculture, Forestry and Fisheries, Tsukuba, Ibaraki, Japan. The Programme is currently developing a joint proposal on electronic tracking of locusts and grasshoppers with the Applied Physics Laboratory, Johns Hopkins University and the Rangeland Insect Laboratory, Bozman, Montana, USA. A Memorandum of Understanding between ICIPE and the Government of Sudan regarding field research on the desert locust was signed in 1991 and has since been implemented.

The Programme received many requests for locust material from laboratories and institutions around the world. These include: Oxford University, University of East Anglia, UK; Jomo Kenyatta University, Kenya; University of Oldenburg, Germany.

Reports of the LRP research projects are to be found in Part II of this publication.

Some definitions

Semiochemicals: Chemical signals produced by one organism which produce a behavioural or physiological response (e.g., mate location, food location, phase change, etc.) in another organism.

Pheromone: A semiochemical message produced and received by members of the same species. Sex pheromones and aggregation pheromones are two examples.

Kairomone: A signal produced by one organism which elicits a beneficial response in a recipient organism of a different species.

Volatiles: Low-molecular weight chemicals that readily diffuse and become air-borne.

Solitarious: A phase shown by certain insects (e.g., locusts), characterised by thinly dispersed populations and non-social life style.

Gregarious: A life style phase characterised by high-density populations, synchronised sexual maturation and mating, communal egg-laying and long-distance mobility.

Recession zone: An area occupied by solitary-living locusts between plague outbreaks.

Phase marker: A chemical substance which provides an accurate measure of the phase of the insect.

Livestock Pests — lowering animal productivity

Proboscis of an infected tsetse fly (*Glossina morsitans*) showing the disease-producing *Trypanosoma congolense*. The parasites complete their life cycle in the hypopharynx of the fly, where they transform into forms infective to mammals. When the fly feeds, these forms are injected along with its saliva and begin a new cycle in the animal host (40x, phase contrast)

In Africa's largely agrarian economies, the livestock sector contributes at both the micro- and macro-economic levels. The Livestock Pests Research Programme (LPRP) targets two pests which are major constraints to the livestock industry on the continent: tsetse and ticks.

TSETSE — AT THE BITING EDGE OF PRODUCTIVITY

TSETSE

The tsetse fly (*Glossina* spp) is the vector of two devastating disease complexes, human trypanosomiasis (sleeping sickness) and the animal disease (nagana). The causative agent is a parasite, *Trypanosoma*, which enters the human or animal host when the fly bites. The range of the fly covers about 10 million square kilometres (about 30%) of the African continent.

Trypanosomiasis is the most important animal disease in Africa, as evidenced by the low numbers of ruminants in the tsetse-infested sub-humid and humid zones. Although the sub-humid zone extends over 40% of sub-Saharan Africa, it currently carries only 25% of this region's livestock population and produces only 20% of the total ruminant meat and milk production.

The costs of tsetse control are enormous, with an estimated US$ 7 million spent in one year alone in fighting the pest in four countries of the Kagera River Basin (Tanzania, Uganda, Rwanda, Burundi). Chemical spraying, other than being expensive, is often ineffectual in controlling flies.

ICIPE's tsetse control strategies

The most effective means of controlling tsetse and trypanosomiasis incorporates the use of traps in conjunction with other IPM techniques. The ICIPE strategy here is to make use of environmentally sustainable and appropriate technologies. Evidence shows that suppression of the tsetse population by up to 99% of pre-control levels can occur when traps are used, either alone or in combination with baits. As well as reducing the number of flies, a substantial decline in trypanosomiasis disease levels may result.

In spite of improvement in trap and target design, however, it has become clear that in most cases tsetse can-

ICIPE technician John Kiilu demonstrating the construction of the NG2G tsetse trap to Maasai in the Aitong region of the Maasai Mara, Kenya. When baited with cow urine and acetone, the traps achieve reasonable control of important pests such as *Glossina pallidipes* at densities of only 2–4 traps per km^2

ICIPE technician James Likhanga with visiting scientist Jan Zdarek, feeding laboratory-reared tsetse flies on an immobilised black rhinoceros in Nairobi National Park. The flies are used to diagnose trypanosome infections in rhino and other species to assess the role of wildlife as disease reservoirs for livestock. Studies are also underway to assist the Kenya Wildlife Service in managing disease in endangered species such as the black rhinoceros

not be completely and permanently eradicated from their habitat. The reasons for this are still unclear, but re-invasion from adjacent fly-infested regions is one suspected cause; other mechanisms, as yet undefined, may also be in operation here.

The ICIPE's tsetse control programme has concentrated on improving trapping strategies. Intensive research over the past year has focused on *Glossina fuscipes fuscipes*, which does not respond well to conventional trapping methods. The usual odour attractants such as phenols, ketones and octenol derived from cow waste products have not proved effective for this species. However, when filtered monitor lizard and fresh hippo dung were tested, there was a significant increase in *Glossina fuscipes fuscipes* catches.

The residual tsetse which resist trapping survive and eventually assist in recovery of the fly population to pre-control levels. Therefore, the behaviour of tsetse around traps has been studied to determine how the fly approaches and enters, or avoids, the trap. It appears that flies who enter traps do so because they are trying to avoid a collision within the trap components. The kind of fly and the numbers of each species caught in a given trap design have been found to depend on the time of day, the sex of the fly, its hunger status, its age, and the height of the trap above the ground. The optimum trap design is being determined for *G. brevipalpis*, including a modification of the NGU trap developed by the ICIPE. (This species of fly has proven difficult to catch in existing trap designs). New trap designs for catching *G. pallidipes*, which avoids the common biconical trap, include increasing the number of entrances.

Wildlife are preferred on the tsetse menu

The feeding behaviour of tsetse and the importance of wild animals as reservoir hosts for trypanosomes is another project at the ICIPE. Most tsetse species have preferred wild hosts, and usually avoid domestic animals and man, with the exception of *G. palpalpis*, which prefers the domestic pig. The most popular wild hosts include bush pig, bushbuck, giraffe, buffalo, rhino and elephant. There are many unknowns about fly feeding behaviour and its impact on wildlife and disease transmission.

Results so far suggest that it is the emission of volatile compounds from the bodies of the hosts, rather than their excretory products (dung, urine) which attracts the fly to the host for its bloodmeal. Oduor baits from four important wild hosts, rhino, elephant, warthog and hippo, are being explored. ICIPE's thrusts on the chemical ecology of tsetse include chemical communication among *Glossina* spp, and on kairomones and allomones, and how they affect such behaviour as host-seeking, larviposition, sexual attraction, etc.

Tsetse facts

- Sleeping sickness (human trypanosomiasis) has resisted elimination for over 70 years. It undergoes a quick resurgence during times of civil strife and economic hardships.
- Elimination of nagana (animal trypanosomiasis) could result in an increase of 147 million head of cattle in affected areas, providing an additional 495,000 tons of meat and 1.3 million tons of milk to the population annually.
- The tsetse immune system ensures that only about 2% of flies are infected with the disease-causing *Trypanosoma* parasite.

Tsetse reproduction and heredity

The reproductive cycle of this interesting insect is another topic of research. The tsetse is unusual, in that it does not lay eggs, but rather gives birth to a larva which hatches after a few hours. One female tsetse produces only a few larvae (7–10) in her lifespan, in contrast to the hundreds of eggs laid by many other insects. ICIPE scientists are raising female flies on a variety of bloodmeal sources (rabbits, goats, eland, waterbuck) to determine if one is superior for producing larger and healthier pupae for mass rearing procedures.

Climatic conditions can affect segments of the tsetse population. Certain genotypes are susceptible to sub-optimal (hot/dry or cool/dry) conditions. However, heavy trapping carried out by ICIPE over a four-year period shows that more than 80% of the alleles remain unaffected.

Host animal defense systems

Some host animals have chemical substances in their blood which facilitate the trypanosome infection in the fly and make it a better disease vector. If these blood factors can be fully identified, then strategies to counteract them could be used in limiting the number of infected flies that are capable of passing on the trypanosomes in a given region. ICIPE is presently working to identify and develop methods to counteract these blood factors. Differences in infection rates and the particular species of trypanosome parasite present in the fly are being studied for three important tsetse species, *G. brevipalpis, G. austeni* and *G. pallidipes,* in relation to the host animals available.The development of DNA probes to identify which *Trypanosoma* species is present in the flies has led to the discovery that *T. congolense,* an important parasite causing disease in livestock, is possibly a different 'species' than other trypanosomes.

TICKS — UNWELCOME PASSENGERS

TICKS

Global losses due to tick infestation of livestock are estimated at $7 billion, with about half of this in Africa alone. Although over 160 tick species exist in Africa, the two most important are *Rhipicephalus appendiculatus* (the brown ear tick) and *Amblyomma variegatum* (the spotted tick). About 90% of the estimated 200 million cattle in Africa are infested, often with several tick species. Ticks are concentrated in the savannah country covering over 15 million square kilometres of the 'food basket' of Africa.

Ticks produce several often-fatal livestock diseases. The most important of these are tick fever, East Coast fever, heartwater, and anaplasmosis. In addition to being vectors of disease, ticks can cause the emaciation and death of cattle by depleting their blood supply. Mortality is especially high among the higher producing exotic or 'grade' animals, and can approach 80–100% in some regions.

The emphasis of ICIPE's livestock tick programme is to develop alternative, environmentally sound technologies to suppress tick populations below levels where they can do harm. This is being done by a study of tick behaviour and ecology, the use of biocontrol agents, and the development of an anti-tick vaccine.

The tick trek

Much of the life cycle of the tick is concerned with maintaining its water balance, as it is parasitic for only about 3–5% of its lifetime. Tick activity in moving up and down vegetation and into the moist soil and its diurnal activity and feeding patterns are being studied so that rational control of these pests is possible.

Chemical cues provide clues for control

The current status of the chemical ecology of the brown ear tick, *Rhipicephalus appendiculatus* is being studied at ICIPE. Tick interactions with their habitat, their hosts and

RESEARCH HIGHLIGHTS

1. Hippo dung and monitor lizard urine were found to increase catches of *Glossina fuscipes fuscipes,* opening up the possibility of developing new odour baits for trapping this species.

2. DNA studies of *T. congolense* parasites from tsetse in Kenya have revealed the existence of a new genotype for which a diagnostic probe has been developed.

3. A reliable technique for isolation of trypanosomes from wild tsetse was developed from basic studies on the factors affecting the establishment of trypanosomes in the tsetse midgut.

4. Isoenzyme studies of *Glossina pallidipes* have revealed evidence for physiological adaptation of flies to different biotypes. There appears to be only minimal evidence for any genetic selection resulting from trapping programmes.

5. Studies of tsetse behaviour around traps have revealed the importance of designing traps with multiple entrances in order to improve trapping efficiency.

6. A parasitoid of ticks (*Ixodiphagus hookeri*) was isolated from the field and reared in the laboratory for possible future use as a biocontrol agent.

7. Domestic chickens were shown to be effective in reducing tick loads on cattle when the two are kept together.

8. Glycoprotein components of the cheliceral digits of *Rhipicephalus appendiculatus* have been shown to be capable of inducing partial protective immunity against feeding ticks.

with their various pathogens, predators and parasitoids offer possibilities for their control. The allomonal effects of plants (some of which may have larvicidal properties) are being considered. Various attractants have been isolated from the breath and body washes of the hosts and these are being tested in tick traps. In addition, tick pheromones known to modulate mate location, copulation, aggregation, and attachment to the host are known and are examples of interactions among individuals, which are being assessed as avenues for their control.

Tick biocontrol agents

Natural enemies of ticks with potential for use in their management are being investigated at the ICIPE. A parasitic wasp, *Ixodiphagus hookeri*, attacks 63% of the *A. variegatum* ticks in one area of Kenya. A method has been developed for rearing this parasitoid in the laboratory in preparation for a future mass release programme. Domestic chickens are efficient natural tick predators, and the chicken/cattle ratio for effective tick control is being determined. Recent studies have demonstrated a drastic reduction of infestation in experimental animals.

The tick immune system

Lectins are natural protective proteins found in tick fluids, which help it resist attack by pathogens. Certain sugars that block lectin activity and make the tick less resistant to bacterial attack and which could be incorporated into biological control agents applied onto the ticks, have been identified by ICIPE scientists.

Tick vaccine development

Tick control by conventional methods, such as the application of chemical acaricides, are beyond the reach of most Third-World farmers. In Africa, about 92% of cattle have no access to acaricide treatments, due to high costs of importing the chemicals themselves and to the costs of construction and managing of the diptanks (for effective tick control, cattle ideally need to be dipped twice weekly). The tick-borne diseases induced in the host animals can sometimes, but not always, respond to treatment with drugs.

Tick facts

- One female tick can cause a weight loss of 4 g in the host bovid during the 1–2 weeks it is attached to the animal.
- Several thousand ticks can infest a single animal, causing severe blood loss.
- Over US$ 720 million is spent annually in Africa on importing chemical acaricides for tick control.
- Tick resistance to the common acaricide BHC developed within 18 months of its introduction in South Africa and Australia.

The development of a vaccine to protect the ticks' target hosts is a strategy that has been under development at the ICIPE over the past decade. The approach used at the ICIPE is to try and identify a protein antigen produced by the tick itself which can be injected into cattle and other tick hosts to induce antibodies against the tick antigen. If the cattle-blood antibodies can then be passed back into the tick *via* its mouthparts during the time it is feeding on the cattle, the antibodies may produce a fatal reaction within the body of the tick, resulting in its death.

Studies over the past year show that partial protective immune responses of animals immunised with solubilised extracts of fully fed *R. appendiculatus* are similar to those produced by extracts from cheliceral digits (the long front 'arms') of the same tick species. Another part of the tick being examined for the presence of antigens is the gut. Injection of the higher molecular weight gut polypeptides (long chains of amino acids) have been shown to produce a much higher immune protection in cattle than the lower molecular weight fractions. Immunoblot analysis has shown these larger molecules to be greater than 60 kDs.

Reports of the LPRP research projects are to be found in Part II of this document.

Medical Vectors — retarding human development

The Medical Vectors Research Programme (MVRP) activities in 1992 centered on two of the most important tropical diseases: malaria and leishmaniasis. The Programme's emphasis is to develop control strategies against the vectors and reservoirs of malaria and leishmaniases appropriate for the arid and semi-arid areas, where these diseases cause loss of human life, and retard development through debilitating illness.

SANDFLIES — MINUTE VECTORS OF DEFORMITY

SANDFLIES

The sandfly is a tiny (6 mm) blood-sucking insect which is the vector of a parasitic disease, leishmaniasis. The protozoa, *Leishmania* spp, is transmitted to man and other animals at the time of feeding. An estimated 12 million cases of leishmaniasis exist worldwide, with about 400,000 new cases recorded yearly. The disease is found in over 80 countries, and is on the increase in the developing world. In Africa, the exact extent of this widespread disease is unknown, due to the difficulties in its diagnosis.

Leishmaniasis occurs in three forms: (i) the visceral form, called kala-azar, which affects the spleen and liver, and is fatal within 6 months – 1 year if left untreated, (ii) the cutaneous form, which affects the skin, leading to permanent scarring and disfigurement from the lesions, and (iii) mucocutaneous leishmaniasis, which produces lesions that resemble the cutaneous form, but may later spread to the mucous membranes of the nose, mouth and pharynx, causing severe disfigurement and suffering. The vocal cords can be damaged, and death from bronchopneumonia can easily occur.

Due to the high cost of treatment of these diseases, and the general unavailability of the required imported medicines, a more rational approach to the prevention of leishmaniasis is through the control of its vectors.

Understanding sandfly ecology

ICIPE's strategies for the control of sandflies is through a basic understanding of their behaviour and ecology, and through the application of a simple technology which lowers the sandfly population in leishmaniasis-endemic areas. The epidemiology of the disease is being researched in several foci. Control of the disease is made more complicated by the presence of the parasite in both domestic and wild animal reservoirs, so these intermediates are also under study in the MVRP.

Trapping technology is an essential ingredient of sandfly population monitoring, and ICIPE scientists have in the past two years developed a new design of trap, the updraft suction trap that allows collection of live flies for study and breeding in laboratory colonies, as opposed to the standard downward suction light traps. This new trap is effective in catching flies in outdoor sites, as well as indoors, and is constructed of low-cost, locally available materials. The trap is also effective for mosquitoes.

ICIPE scientists collect tiny (6 mm) sandflies adhering to the 'ICIPE sticky trap'. The trap is made of plastic sheeting coated with castor oil and used for monitoring of sandfly population density. Here, the sticky trap is mounted on a traditional dwelling in a semi-arid region of Kenya

RESEARCH

1. A larvivorous fish common in Africa, *Tilapia zilli*, has proven to be an effective control measure for mosquito larvae in ponds. Furthermore, the *Tilapia* is a popular and delicious source of dietary protein.

2. Six strains of *Bt* bacteria toxic to the larvae of three important mosquito vectors (*Anopheles, Aedes* and *Culex* spp) have been identified and registered.

3. *Anopheles gambiae* has been strongly implicated as a potential new vector of *Leishmania* parasites.

4. In field trials, the *Mbu cloth* technology was found to lower the prevalence of malaria by 73% when employed in a community exercise.

Mass culture and characterisation of *Leishmania* parasites isolated from sandflies were undertaken by the Molecular Biology Research Unit in collaboration with the MVRP. The sandfly vectors of *Leishmania donovani* in Kenya have been found to be *Phlebotomus martini, P. ciliae, P. vansomerinae* and *Sergentomyia garnhami*, while *P. duboscqi, S. ingrami* and *P. martini* have been found to be vectors of *L. major*. Using the updraft trap, these flies have been found most frequently near animal burrows and in termite hills.

The host animals of sandflies range from lizards to the domestic dog, with each species having its preferred host. Most phlebotomine sandflies prefer termite hills and animal burrows for breeding, where they feed on the resident lizards and rodents. The breeding sites of *S. garnhami* in the kala-azar endemic area of Kitui, Kenya have only recently been identified. Baseline information on the breeding ecology of the flies is necessary before effective anti-vector control measures can be employed, particularly if the immature stage is the target.

Leishmaniasis facts

- The cost of treatment of a case of kala-azar averages US$ 150 for a course of 30 daily injections. Left untreated, the disease is fatal within 6–12 months.
- One village in war-torn southern Sudan reported 60,000 cases of leishmaniasis in late 1992.
- In Bihar, India, an estimated 250,000–300,000 people suffer from the disease.

The *Mbu cloth* technology: Two vectors for the price of one

'Mbu' is the Kiswahili word for mosquito. The *Mbu cloth* is a piece of cotton, about 9 m x 1.5 m, impregnated with the pyrethroid insecticide, permethrin. The insecticide used is non-toxic to mammals and can persist for up to 6 months, after which the cloth needs re-treatment. The *Mbu cloth* has proved effective in controlling both sandfly and mosquito vector populations. An ICIPE study over a 26-month period in the Baringo District of Kenya, an endemic focus of both visceral and cutaneous leishmaniasis, showed that communal use of the *Mbu cloth* by installation in 2000 houses resulted in an average reduction of the sandfly population by 52–73%. In particular, *P. martini* and *P. duboscqi*, the vectors of the visceral and cutaneous diseases, respectively, were reduced by 76% and 85%, compared to control houses. The cloth also reduced the general level of sandfly feeding, and the disease has not been reported in the experimental area since the introduction of the technology.

Further refinement of the *Mbu cloth* continued this year, and monitoring of the efficacy and persistence of the insecticide was done. Socio-economic and anthropological studies were carried out to assess the acceptability and sustainability of the cloth. Monitoring of possible insecticide resistance of the sandflies was carried out, and the colour preference of the vector investigated.

MOSQUITOES — MAKING A COMEBACK

MOSQUITOES

Malaria is the most important parasitic disease affecting man in the tropics. Several other important diseases transmitted by mosquitoes include encephalitis, filariasis, dengue and yellow fever. The causative agents of malaria are protozoan parasites, *Plasmodium* spp, which are transmitted to man when the mosquito bites and injects its saliva.

Malaria is a major cause of mortality and morbidity, with a reported 2 billion people at risk of the disease, and reported cases between 200–400 million annually. The disease occurs in 102 countries worldwide, and results in an estimated 2 million deaths a year, half of these in Africa alone. About 90% of malaria-caused deaths occur in children.

HIGHLIGHTS

5 Preferred breeding sites for disease-carrying sandfly species have been identified using trapping techniques developed at the ICIPE. The species of *Leishmania* parasites carried by the flies have been identified.

6 Populations of two species of sandflies responsible for transferring visceral and cutaneous leishmaniasis (*Phlebotomus martini* and *P. duboscqi*), were reduced by 76% and 85% in houses fitted with the *Mbu cloth* in field trials involving over 2000 dwellings.

7 Characterisation and differentiation of three closely related sandfly species has been done by chorionic sculpturing of their eggs, using scanning electronmicroscopy.

The incidence of malaria continues to increase in Africa, particularly in semi-arid regions which are undergoing development under increasing human population pressure. Construction of dams, irrigation schemes, mining and the digging of quarries have all served to introduce the water required for mosquito egg-laying and larval development.

ICIPE's long term goals include development of strategies to control the mosquito vector, particularly in arid and semi-arid areas, through an understanding of the insects' biology, ecology, behaviour and bionomics, and through the application of a simple technology developed in the Medical Vectors Programme, the *Mbu cloth*, described above.

The *Mbu cloth* lowers malaria prevalence

A recent ICIPE study has shown that introduction of 2000 of the *Mbu cloths* in a community of 10,000 in Baringo District, Kenya, has resulted in significantly lower rates of malaria prevalence, with an overall reduction of 73% in the treated areas. Malaria was implicated as the major cause of spleen enlargement (splenomegaly) of children in the area.

Mosquitoes succumb to fish and bacteria

Mosquito larvae are susceptible to a variety of predators, and ICIPE scientists have identified a voracious larvivorous fish, *Tilapia zilli*. In clear water ponds, this delicious fish was found to significantly reduce larvae by 88–100%. However, when the water was turbid or contained aquatic weeds, the predatory efficiency of the fish was lowered. Catfish were observed to kill the *Tilapia*. Introduction of *Tilapia*, both as a mosquito control agent, and as a source of high-quality edible protein, is therefore recommended.

A mosquito-toxic bacterial biological control agent has been discovered by an ICIPE expert. Over eight strains of *Bacillus thuringiensis israelensis* have been isolated and identified from mosquito habitats such as mud and water, and from infected larvae. The bacteria have proved toxic to all major vectors (*Anopheles, Aedes* and *Culex* mosquitoes), and acts as a stomach poison to the larvae. Pilot-scale testing has shown that a powdered formulation is effective in controlling mosquito breeding.

Can mosquitoes transmit parasites mechanically?

The possibility of the *mechanical* transmission of parasites by mosquitoes has been examined by MVRP scientists. When feeding through its mouthparts, the *Anopheles* mosquito continually ejects droplets of blood from its anus. Mosquitoes were fed on mice infected with trypanosomes. The droplets of blood ejected by the feeding mosquito were analysed and found to contain live, virulent trypanosomes. Furthermore, these parasites were found to survive in the stomach contents of the mosquito for up to 24 hours post-feeding. These observations lead to the speculative conclusion that it may be possible for such live protozoal parasites to be introduced into the host by mechanical means, such as scratching of the bite or breaks in the skin.

Malaria facts

- An especially virulent parasite, *Plasmodium falciparum* is spreading into habitats previously ignored, such as highland areas. The parasite is now resistant to many commonly used anti-malarial drugs and death can occur within a few days of appearance of symptoms.
- About 80% of the population of Africa live in areas with little or no malarial control programmes.

BCERU — the chemical connection

The Behavioural and Chemical Ecology Research Unit (BCERU) is a newly formed unit to consolidate the growing collaboration between the former Sensory Physiology Research Unit and the chemistry section of the Chemistry and Biochemistry Research Unit into a seamless grouping with a mandate to undertake research in areas of chemical and behavioural ecology pertinent to ICIPE's core programmes. The primary tasks of the new Unit are to:

- study behavioural elements such as host-seeking and selection, mate-seeking and mating, oviposition, and aggregation;
- describe the mediating cues and to identify the semiochemicals implicated in the above behaviour;
- elucidate the semiochemical basis of the phase dynamics and phase characters of locusts;
- elucidate factors that regulate interactions between different trophic levels;
- develop semiochemicals for pest monitoring and manipulation.

The research projects undertaken by BCERU chemists and physiologists provided specialist input into the following core programmes:

Crop Pests

Chilo partellus. Studies relating to the chemical ecology of this stemborer during the year comprised of reassessment of the role of sex pheromone components of the pest and examination of selected behaviours together with the semiochemicals mediating them.

Contrary to a previous report, neither of the two major components of the *C. partellus* female sex pheromone blend (*Z*-11-hexadecenal and *Z*-11-hexadecen-1-ol) was effective in attracting males of this species in Africa, when dispensed alone. Likewise, the commercial Trece Pherocon cap baited with the major component, was ineffective. After work in BCERU, optimisation of the synthetic pheromone composition and a refined release method is now at hand. When the two compounds are dispensed separately but in very close proximity to each other, very high trap catches (83% of those caught in traps baited with two virgin females) can be obtained. This finding will provide a basis for the development of a controlled-release, long-performance dispenser for more widespread use in *C. partellus* monitoring, essential in the integrated management of this pest.

The relative feeding preference of *C. partellus* larvae on three maize cultivars was shown to correlate negatively with amounts of allomones present in the cultivars. Identification of these allomones will be undertaken later.

Banana weevil. Attraction of banana weevil to the host plant was shown not to be due to the major pseudostem-derived airborne terpenoid hydrocarbons identified last year. The active components have now been traced to the minor oxygenated terpenoid fraction, and identification of these is in progress. Locating the probable active components of the male-produced aggregation pheromone of the weevil and

identification of the intricate blend of feeding allelochemicals will be reported in detail next year.

Maruca testulalis. A study undertaken by BCERU on antennal morphology of *M. testulalis* has revealed four sensilla types in both the females and males. Moreover, antennae of both sexes were stimulated by emanations from cowpea leaves, flowers and green pods; moths (particularly virgin and mated females) oriented toward the cowpea odours in a wind tunnel at different phenological stages of the plant. Further observations are expected to draw more light on the biological significance of these results.

Tsetse-related research

Tsetse research focused on three fronts: (i) search for additional kairomones, particularly from the bodies of host animals; (ii) structure-activity studies of phenolic kairomones; (iii) larviposition behaviour of selected tsetse species and establishing the role, if any, of chemical signals.

The objectives are to identify a broader range of tsetse semiochemicals that can enhance the efficiency of existing traps and those that are attractive to different tsetse species or useful in specific physiological states of the flies. As mentioned in the earlier report of the Livestock Pests Research Programme, tsetse have preferred hosts, and studies of allomones are expected to throw some light on tsetse's indifference to certain animals. These chemicals are expected to find use in the management of low density fly populations. Progress has been registered on each front.

A new technique for the collection of air-borne volatiles from the bodies of host animals has been developed. This has been shown to be much more selective than solvent washings, which contain large amounts of non-active compounds of varying volatilities which mask the active components in our chromatograms. A structure-activity study of phenolic compounds with respect to *Glossina pallidipes* was completed, providing a much clearer idea of the structural requirements for the attractiveness of 3- and 4- substituted phenols for this tsetse species. Several promising analogues are now being evaluated in the field and a similar study has been initiated for *G. m. morsitans* to elucidate the requirements for attractancy of phenolic compounds for this insect and, hopefully, to discover some effective attractants for this species. Lastly, air-borne volatile collections from the larvae of *G. m. morsitans* and *G. m. centralis* were shown to be attractive to gravid females. Identification of the active components (by GC-EAD and GC-MS) is at hand. If they prove to be potent attractants, these compounds may provide a means of targeting gravid females for trapping.

Locust semiochemicals

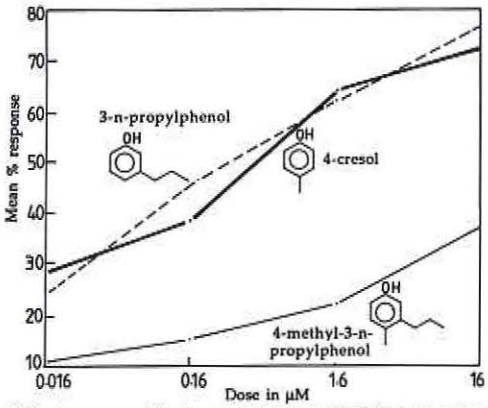
The groundwork for understanding the role of semiochemicals in some of the key behavioural traits associated with the gregarious phase of the desert locust (*Schistocerca gregaria*) has been laid. Noteworthy results during the year are outlined below:

- Demonstration of the existence of two distinct aggregation pheromone systems for the two stages of the gregarious phase of the insect; identification of the pheromone systems is at an advanced stage.
- Demonstration that oviposition aggregation is associated with a volatile chemical signal(s) from the egg-froth; a volatile collection from the egg-froth has demonstrated a significant attraction to ovipositing females.
- Demonstration of the maturation-accelerating effect of volatiles from live mature adult males or immature adults in a 2-storey bioassay chamber. Similar demonstration of the effect of trapped volatiles from mature adult males and identification of constituent components are underway. Preliminary indications are that some or all of the adult aggregation pheromone components may also serve to accelerate maturation of the young adult.

Volatile substances emanating from the bodies of host animals serve to attract tsetse for feeding. The screen figure shows a gas chromatogram of cattle body volatiles collected by a new technique developed by ICIPE scientists

Tick-related research

Exploratory research has implicated a number of semiochemical signals that may mediate behaviours of the brown ear tick, *Rhipicephalus appendiculatus*. These



Olfactory sensitivity of *Glossina pallidipes* to three phenolic compounds. The low EAG response shown to be 4-methyl-3-n-propylphenol, which combines the structural features of the other two compounds shown in the figure (both powerful tsetse attractants) suggests that the fly perceives each of these two compounds separately

include host location and recognition, and feeding site location by the adult. These activities may involve both kairomones from host animals and pheromones from feeding ticks of the same species. A more detailed behavioural study on the orientation responses of *R. appendiculatus* (which feeds inside the ear) *and R. evertsi* (which feeds in the anal regions) is underway. The findings to date show clearly that whereas the former species is repelled by anal cattle washings, it is attracted by ear washings. The reverse is true for *R. evertsi*. Thus, feeding site location by these species appears to operate by a push-pull mechanism probably enhanced by signals emitted by successfully feeding species-related ticks. Further studies are expected to throw more light on this. Isolation and identification of the semiochemicals mediating this feeding behaviour has been initiated and could open up the possibility of developing sampling tools for these ticks off-the-host.

Tick-repelling plants. Last year, we reported on tick-repellent properties of the essential oils of two plants, including one which belongs to the family Capparidaceae. The identification of the chemical constituents of these plants is underway, with the ultimate objective of locating the active components. The essential oil of *Cleome monophylla* has been identified and the repellency activity of some of its constituents confirmed.

RESEARCH HIGHLIGHTS

1. An improved dispensing technique for *Chilo partellus* sex pheromone components has been developed, and has proved successful in trapping African populations of this species.

2. Some of the volatile compounds emanating from banana which attract the pest *Cosmopolites sordidus* have been identified as oxygenated terpenoids. The aggregation pheromone and feeding allelochemicals of the weevil are close to elucidation.

3. The antennae of a major cowpea pest, *Maruca testulalis*, have been shown by electron microscopy to consist of four types of sensilla which respond to cowpea odours.

4. A new technique for collecting the air-borne volatiles emitted by host animals has been developed. The technique has proved superior to simple body washings, which contain numerous impurities which mask the insect-attracting components.

5. Thirteen synthetic phenolic compounds have been tested for their attractivity to the tsetse *Glossina pallidipes*, leading to a better understanding of the structural requirements for increasing the biological activity of odour baits for this species, which avoids the common biconical trap.

6. Potential tsetse lures produced by the larvae and active toward gravid females have been demonstrated.

7. Locust semiochemicals regulating such key processes as aggregation, group egg-laying behaviour and synchronised maturation, are well underway to being identified.

8. The feeding behaviour of two *Rhipicephalus* species of ticks and the semiochemicals controlling feeding site location are under investigation.

Infection of ticks. In collaboration with scientists from ILRAD in Nairobi, membrane feeding techniques for ticks developed in BCERU have been further improved and shown to be an effective means of transmitting *Theileria parva* infection to nymphal ticks. This technique will enable the study of factors affecting *T. parva* transmission without the complication of host/*T. parva* interactions, and may find use in the maintenance of ticks as well as *Theileria* parasites.

Bioinsecticides

An ARPPIS scholar from Ethiopia interested in understanding the scientific rationale for traditional use of some plant materials in post-harvest protection, is evaluating three *Ocimum* species and their essential oils against three common storage pests. Ground leaves of the plants and the essential oils have shown varying degrees of protection against the pests. Further evaluation of these materials and identification of the active components is continuing.

Reports of the research projects of BCERU are to be found in Part II of this publication.

MBRU — getting down to the molecular level

The newly-formed Molecular Biology Research Unit (MBRU) was created by amalgamating the biochemistry section of the former Chemistry and Biochemistry Research Unit and the former Cell Biology Research Unit. The primary task of the new Unit is to undertake research in areas of arthropod molecular biology and biochemistry pertinent to the broader goals of the Centre's programmes. In particular, the Unit performs the following:

- biochemical studies on target arthropods aimed at understanding structure-function relationships and the production of bioactive products;
- use of molecular biology techniques for taxonomic studies, improvement of selected genes, understanding of genes, and large-scale production of bioactive products;
- histological, ultrastructural and cyto-chemical studies on target organisms;
- establishing insect cell lines for the study and production of microorganisms, including pathogens.

During the past year, MBRU research centered on three of ICIPE's target pests: tsetse, ticks, and the desert locust. In addition to its research activities, the Unit provides Centre-wide services in light microscopy, and scanning and transmission electron microscopy. Additional services are also provided in photography, photofinishing and production of transparencies.

Tsetse-trypanosome relationships

Interrupting the life cycle of the trypanosomes. In order to complete their life cycle within the tsetse fly, the trypanosomes must undergo three transformations, each of which can result in high mortalities to the parasites. When the bloodstream parasites enter into the insect's midgut, they must transform into procyclic forms better suited for survival in this harsh environment. Very few parasites (less than 1%) survive this step. The midgut contents are highly proteolytic in nature, and contain trypsins and trypsin-like enzymes. In addition, there are lectins, agglutinins and lysins.

A factor in the midgut of tsetse that promotes the differentiation of bloodstream trypanosomes to procyclics has been identified as a trypsin-like enzyme. During purification of midgut trypsin, a lectin capable of agglutinating trypanosomes is also obtained. It is proposed that both the lectin and trypsin activities reside in the same molecule. *In vitro*, glucosamine inhibits trypsin/lectin activity and trypanosome differentiation. Rigorous studies in the MBRU aimed at addressing the hypothesis that the lectin and trypsin are in fact the same molecule are underway.

Genetically typing the flies. The work on developing microsatellite markers has been initiated only recently. Microsatellites are dinucleotide or other simple repeating sequences which are widely distributed in the genomes of diverse species. Variations in length of the microsatellites can be detected by PCR amplification and high resolution genetic maps can be generated. Microsatellites can be used in identifying economically important genes such as those responsible for a certain behaviour or responses, say the ability to detect a specific odour such as might be present in a trap bait. If it can be shown that behavioural resistance to traps by certain species is genetically controlled, then this opens the possibility of new vector control strategies. It may explain, for instance, why *Glossina f. fuscipes* is not attracted to the odour baits commonly used in tsetse traps. Microsatellites can also be used for taxonomic

RESEARCH DIRECTIONS

1. A DNA probe for identifying *Leishmania* parasites has been developed. The probe has been used to identify *L. major* in the sandfly *Sergentomyia garnhami*, implicating this fly as a vector of cutaneous leishmaniasis in Kenya. Two probes that are specific to *L. tropica* and *L. donovani* have been developed.

2. A bloodmeal-induced chimeric molecule (trypsin-lectin) has been isolated and found to be important in differentiation of bloodstream trypanosomes into procyclics. Specific antibodies are being used to determine the levels of the protein in wild-type tsetse species. The information gleaned will be used to explain inter- and intra-species differences in susceptibility of tsetse flies to trypanosome infections.

3. Studies on the endotoxins of three isolates of *Bacillus thuringiensis* indicate differential toxicities against mosquitoes, tsetse and the stemborer, *Chilo partellus*.

4. DNA microsatellite markers are being developed to study the basis of behavioural (and insecticidal) resistance of tsetse to specific traps and odour baits. The markers will be used in tsetse population analysis. Isolation and characterisation of the olfactory genes is underway. A genomic library of *Glossina m. morsitans* has been constructed as part of this work.

5. A rapid technique for determining the genetic variations within and between tsetse populations is being developed, using the RAPD-PCR technique. The DNA sequence variation of the mitochondrial cytochrome b gene in wild tsetse is under study.

6. A practical, efficient method for mass infection of tsetse with a DNA virus (as an alternative sterilant to radiation) is being developed.

purposes, as a marker for classifying members of the same species or the same population.

A genomic library of *Glossina pallidipes* has been made and screened for microsatellites using a (GT)n probe. Efforts are currently underway to sequence the positive clones. This information will allow the preparation of suitable primers to be used in PCR (polymerase chain reaction) amplification for obtaining adequate quantities of the gene fragment for further studies. This may ultimately result in the isolation and characterisation of the genes responsible for olfaction.

Probing the parasites. Research on the development of DNA probes for use in characterisation of *Leishmania* parasites is continuing. A probe is itself a relatively short piece of DNA with a specific selected sequence of nucleotides. Such a probe can be labelled with a marker and used to identify a complementary nucleic acid sequence in a highly sensitive manner. So far, at least two probes have been developed that are specific to *Leishmania tropica* and *L. donovani*. While more probes for differentiating other *Leishmania* species are being sought, there is a concurrent effort to characterise these probes, for example, by nucleotide sequence analysis. This will enable the preparation of suitable primers (templates) for use in PCR-assisted rapid analysis of field isolates of the parasites.

Identifying *Bt* strains and their toxins

The bacterium *Bacillus thuringiensis* (*Bt*) is an insect pathogen that is widely being studied and used as a biological control agent. *Bt* produces a toxin which binds to the midgut lining of the insect, causing disruption of the midgut cells and eventual death. In MBRU, the characterisation of endotoxins of *Bacillus thuringiensis* is progressing apace. Using three isolates as examples, reliable biochemical and molecular biology methods for strain identification have been perfected. Furthermore, the genes encoding the endotoxins of two isolates have been identified and cloned. Sequencing of these genes is now underway. Specific recognition sites (receptors) that bind the endotoxins in the midguts of susceptible insects have been identified and work is underway to characterise them.

A virus to control tsetse

Work on the tsetse DNA virus is progressing rapidly. A study of the mating of infected, sterile males has shown that sterile and non-sterile males show equal mating success. A method for mass infecting tsetse with the virus by dipping of the larvae has been developed and appears to be effective. Future studies will include characterisation of the virus, establishment of a method for its mass culturing and assessment of its use in SIT (sterile insect technique) programmes for tsetse control.

Reports on the research projects of the MBRU are found in Part II of this document.

BMRU — from design to analysis

The Biomathematics Research Unit (BMRU) supports ICIPE's core programmes through the Unit's services, research and training activities. Services to the Centre's research programmes and units includes consultancy on design and analysis of experiments, as well as on presentation and interpretation of results. The Unit also provides computer hardware procurement, maintenance and repair services to all the ICIPE offices, and computer software services, which includes data base development, slide production and graphics. Other services provided by the Unit include the preparation and digitisation of climatic and vegetation maps using the Geographic Information System (GIS). This service is particularly important for the monitoring of pest movement, migration and distribution.

The Unit's research activities are based on the premise that there is a continual need for improved biomathematical methods in pest management in the presence of unstable biological environments. The BMRU has continued to undertake research in the areas of modelling of insect populations, epidemiological modelling, and in the development of standardisation indices and efficient statistical analysis procedures. In addition, BMRU has also been involved in collaborative research with the various research programmes and units of the ICIPE.

RESEARCH ACTIVITIES

- ***Analysis of field scores.*** A fundamental problem in the analysis of field scores is that the score for any plot, except the first, is usually dependent on the score of the immediate previous plot, giving rise to groups of serially correlated data. Serial correlation, when ignored, leads to under-estimation of the error variance, and consequently leads to incorrect inferences. Two methods of analysing such trials have been developed by BMRU.

- ***Yield conversion.*** Mathematical relationships between crop yield from experimental and farmers' fields have been studied. Two methods of yield conversion from experimental to larger plot sizes have been proposed. One of these methods is based on the soil heterogeneity factor, while the other is farmers' management level-based.

- ***Yield loss from pest infestation.*** A series of non-linear models has been examined with regard to their capability to describe yield loss *versus* pest infestation relations. Initial studies have shown that the allometric model fits very well to cowpea yield loss and *Maruca* infestation data.

- ***Resistance classification.*** Classification of crop varieties for resistance based on yield loss experiments usually focuses on percent yield loss comparisons with only passing reference to the actual potential yield. A method of classification based on simultaneous consideration of both the percent yield loss and actual yield potential of the varieties has been developed. The method seeks to minimise percent yield loss while maximising yield potential.

In the area of training, consultation services to the students of ICIPE's African Regional Postgraduate Programme in Insect Science (ARPPIS) have dominated the consultancy time of BMRU's staff, taking up about 39% of all service time. These services include project supervision; teaching (Statistics, Biomathematics and Computer Programming); advising on design and analysis of experiments, and on presentation and interpretation of results. Many students in relevant disciplines from institutions within Kenya have also had the opportunity of undergoing industrial training in the BMRU this year.

The reports of BMRU research projects can be found in Part II of this document.

Consultancy activities

Biostatistics continues to occupy a significant portion of BMRU's consultancy activities, particularly on data management and data analysis with the ARPPIS students. Non-conventional types of analyses like repeated measures analysis of variance, survival

analysis and discriminant analysis, have been used more frequently this year.

The Unit recently acquired new statistical software to facilitate its work. SYSTAT software is proving to be extremely useful because of its graphical interface and menu-driven comments. The time series package SAS/ETS for estimating parameters in ARIMA model and performing time series analysis and the latest version of STATISTIX have also been acquired. The latter has new capabilities such as multi-way analysis of variance, linear programming and time series analysis.

Collaboration with national agricultural institutions in the area of biostatistical services increased during the year and consumed about 30% of BMRU service time.

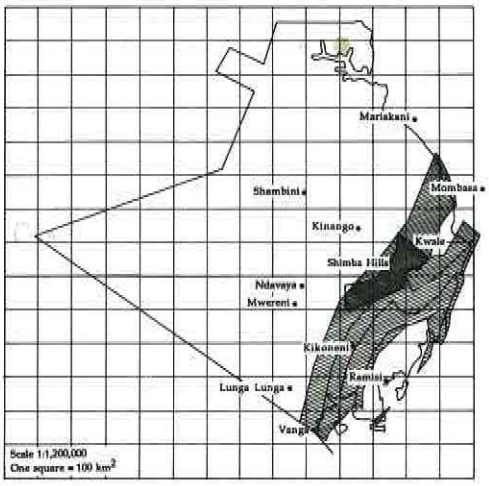
Strengthening computing power

After the completion of a library, a local area network was installed which links up six computers in the library, five of which are XT PCs and one AST 286 as server.

The computing power of the Centre was strengthened with the addition of four powerful computers installed in the Kwale and Kilifi research stations in May, and at the SSIRU office in Duduville in November. A new remote weather station was also installed in Shimba Hills during the year for tsetse research work.

Printing quality was improved on in 1992 after the installation of four Hewlett Packard (HP) III laser printers in ICIPE/WAU, PDU, IBIRI and BMRU, and two HP IIs in the library and finance offices.

The computing section of BMRU has continued to provide software consultancy as well as slide production and graphic services to the Centre. With the acquisition of several colour monitors, more scientists have been able to produce their own slides. In order to increase further the computer literacy level of ICIPE staff, the BMRU has decided to hold computing courses in 1993.



Map produced by the GIS technique showing study areas in high-potential zones of Kwale District. The lined area shown here straddles three agro-ecological zones and was selected on the basis of specified criteria for soil quality and pH, and amount and reliability of rainfall. Socio-economic data will be incorporated into the map at a later stage in the study, which will provide data on pest levels and crop yields in relation to pest management technologies. The shaded area is the Shimba Hills

Geographic Information Systems activities

The objective of the GIS section is to build geographic databases covering ICIPE research sites. The primary sources of data are the 1 : 50,000 topographic maps produced by the Kenya Government (Survey of Kenya), from which physical features are extracted, and climatic data from satellites such as NOAA. In addition, climatic data from ICIPE's weather stations in the various sites is incorporated. Other data built into the databases are related to the relevant research activities, such as position of participating farms, crop yield, borer numbers, species, position of tsetse traps, trap catches by species, etc. The first site selected for building the database is on the Kenyan Coast covering Kwale and Kilifi Districts (see map).

BTRU — biotechnology for pest control

Biotechnology activities in ICIPE started by the setting-up of a Biotechnology Task Force in late 1989. The Biotechnology Research Unit (BTRU) was created during the restructuring of ICIPE in 1992. The primary objective of the new Unit is to perform insect-related biotechnology research in collaboration with relevant research programmes and units in the Centre.

The 1989 Task Force identified a number of important biotechnology research projects across the board within the Centre's areas of study. The development of *Bacillus thuringiensis* (*Bt*)-based insecticides was given top priority. In 1989/90, a 'Pilot Study For Evaluating the Feasibility of Utilising *Bacillus thuringiensis* as a Biological Insecticide against Flies in Tropical Countries' was initiated.

Bt biopesticides for pest control

In March 1992, ICIPE acquired a 15 litre volume fermenter. During the past year, the Unit has produced 1.5 tonnes of *Bt* for field application against filth flies. In a collaborative effort, 8 litres of *Bt* produced for the Crop Pests Research Programme is now being tested in the field. Work on formulation of *Bt* strains active against the tsetse fly is now underway. The Unit has come up with a preliminary *Bt* tsetse formulation which can be sprayed directly on cattle. The activities for *Bt* research work planned for the new Unit include: isolation and identification of insecticidal *Bt* strains and their pathogenicity to target pest insects; evaluation of biosafety aspects; quality control of strains and toxins; study of persistence of toxicity in the field; determination of optimal process conditions and fermentation using locally available raw materials; formulation properties of the bioinsecticides, including incorporation of UV screens; development of modes of application; exploring plant seed inoculation with specific *Bt* strains against root-attacking insects; microscopic studies on the mode of action of *Bt*; exploring the possibility of combining *Bt* (for pest control) and rhizobium (N_2-fixation) inoculation of plant seed.

Microbes and methane

Other future areas of interest where the Unit could become involved are microbial production and modification of phenolic attractants, culture of insect intestinal microorganisms, and methane production by insects. The Unit is presently developing the modalities and logistics of setting up an ICIPE Pathogen Bank.

Buffalo urine phenolics

For the control of tsetse flies, the microbial aspects of phenolic attractants present in buffalo urine will be studied in close collaboration with the Behavioural and Chemical Ecology Research Unit (BCERU) and the Livestock Pests Research Programme (LPRP). Activities will centre around isolation of bacteria from urine which are involved in the production and/or modification of phenolic compounds; simulation of processes involved in batch and continuous fermentation; investigation of possible involvement of minor microorganisms in the release of target-derived precursors of the attractants; investigation of whether protein-derived amino acids might be precursors of the active compounds; further microbial modification of active compounds into structural analogues with possibly higher activity or stability in the field.

Reports on the research projects of BTRU in 1992 are to be found in Part II of this document.

Scientists from the Biotechnology Research Unit adjust the 15 litre fermenter for production of *Bt* and other bioinsecticides. The Unit has developed a *Bt* formulation which can be sprayed directly on cattle as a protection against tsetse. Other *Bt* strains are being used to control filth flies in latrines

IABU — breeding insects for research

The Insect and Animal Breeding Unit (IABU) is an essential pivot in the research efforts of the ICIPE. The Unit produces and supplies quality experimental insects and small mammals to the core research programmes and units on a continuous and sustainable basis. The Unit is organised into three sections:

- phytophagous arthropod rearing (stemborers, pod borers and locusts)
- haematophagous arthropod rearing (tsetse and mosquitoes)
- small mammals breeding (rabbits, rats, mice and hamsters)

Concurrently with production and supply, the Unit undertakes research and development projects aimed at improving rearing techniques for efficient production systems. These include (i) testing of rearing techniques and diets, for developing standard rearing procedures, and (ii) developing methods to assess the quality and biological performance of the insects and small laboratory mammals reared, with the aim of developing a quality control protocol. In addition to its research activities, the Unit serves to train scientific and technical personnel from national and international institutions in insect rearing and animal breeding techniques, and to offer consultative services in insectary management and design.

Research is needed to sustain productivity

A new system of costing the production and supply of crop pests was devised, so that a user requesting an early developmental stage or egg stage of the insect will not be charged the same as for the adult stage. Procedures for the artificial rearing of *Maruca testulalis* and *Busseola fusca*, including development of a semi-synthetic diet appropriate for each pest, were refined.

The difficulties in rearing tsetse were further investigated, and the effect on reproduction of the fly of administering a broad-spectrum antibiotic to the host rabbits was found to be detrimental.

Maintaining the health of the host rabbits was not overlooked, and feeding of New Zealand white rabbits with a coccidiostat did not adversely affect the general health of the rabbits, nor the tsetse (*G. m. morsitans*) fed on them.

An award-winning method for rearing *Busseola fusca*

In an important development this year, Mr. F.O. Onyango of the Unit was awarded the ICIPE Medal for Innovative Research for 1992. In presenting the award to Onyango, the selection panel noted that, "The maize stalk borer *Busseola fusca* has been recognised as a major pest of maize and sorghum in many countries of tropical Africa. Hitherto, research on this important agricultural pest has been hampered by the occurrence of a six-month long diapause in the last larval stage, as well as the lack of an artificial diet for rearing the insect continuously in the laboratory. Mr. Onyango devised a functional medium D2/88, making it possible for the first time to rear 15 successive diapause-less generations of *B. fusca* without loss of vigour or reproductive potential." The method is now used routinely at the ICIPE to rear and supply the insect for research on a continuous basis. The technology has been successfully adopted in Zambia by the national programme networking with the ICIPE; the ICRISAT station at Bamako in Mali has similarly requested training for their personnel. Within Kenya, the Unit supplied experimental *B. fusca* eggs for artificial infestation to the Kenya Agricultural Research Institute (KARI), Kitale as well as offering consultative services to the Kenya national programme in the design of a functional insectary for rearing *B. fusca*.

1992 IABU production and supply

Chilo partellus. At the Mbita Point Field Station (MPFS), 60 million egg equivalents (MEQ) were produced, and 19 MEQ distributed. From the Duduville labs, about 8.5 MEQ were supplied.

Maruca testulalis. About 2.8 MEQ of this pest were supplied in 1992.

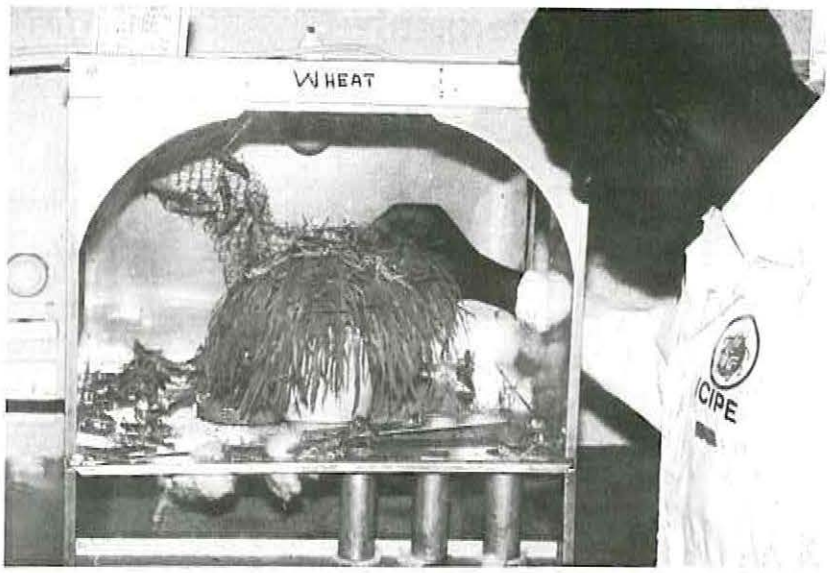
Busseola fusca. Production of this stemborer has increased 10-fold since 1990. The quantity supplied in 1992 was 1.2 MEQ.

Schistocerca gregaria. The crowded colony is now in its 17th generation, and a total of 26,000 locusts were provided for research this year. For the isolated (solitarious) locusts, a total of 1254 were supplied in 1992.

Glossina morsitans morsitans **and** ***G.m. centralis.*** User demands for both species of tsetse were met this year without difficulty. The colony of *G.m. morsitans* is maintained at 9000 producing females, while that of *G.m. centralis* is kept at about 7000.

Glossina pallidipes **and** ***G. fuscipes.*** Both these species are proving difficult to raise because of their reluctance to mate and their high mortality in the lab. About 30,000 pupae have been obtained from wild flies collected around Lake Victoria; these are being used as the nucleus for a colony at Duduville.

Small mammals. Outbred colonies of laboratory rats, rabbits, Swiss mice and hamsters, and inbred strains of balb/c mice are maintained and supplied for feeding the haematophagous arthropods and for other research work. In 1992, the numbers of these mammals supplied were 1845, 1770, 1149, 324 and 894, respectively.



IABU technician preparing green feed and wheat germ for gregarious-phase desert locusts. The aluminium tubes containing moistened sand, shown in the bottom of the cage, are used by the females for egg-laying. Solitarious locusts are reared separately in individual cells in rooms maintained at a constant negative pressure, to prevent chemical communication between the two phases.

Details of the research projects undertaken by IABU are to be found in Part II of this Report.

SSIRU — the social science interface with research

The present emphasis made on the development of socio-economic research in the ICIPE derives from the Centre's basic mission to develop technologies appropriate for the needs of resource-poor farmers in Africa and elsewhere in the tropics. This basic goal gives rise to many questions concerning the research clientele. What are the characteristics of resource-poor producers? What type of production problems do they face? What are their technological needs? What are the possibilities for the adoption, management and sustainability of IPM/IVM technologies? These are the kind of questions which can only be addressed through socio-economic research and which the Social Science Interface Research Unit (SSIRU) attempts to answer.

The ICIPE is, moreover, committed to the development of technologies which are economically viable, socially compatible, environmentally sound, and sustainable. In order to ensure that the desired technological qualities are realised, social and natural scientists must work closely in various phases of the R&D process, including the specification of technological needs and objectives, the technology design process, and monitoring and evaluation.

Interactive and participatory R&D

SSIRU seeks to promote socio-economic research which is characterised by interactive, collaborative and participatory approaches. A key factor to the successful adoption and diffusion of IPM/IVM technologies is the participation of the farmer clientele at appropriate levels and stages of the R&D process. Farmer participation is expected to be greatly increased in some of the new research projects currently under implementation (see box). The broad areas of SSIRU research are as follows:

- studies of production and social systems and technological needs;
- adoption, impact and sustainability studies;
- studies of community organisation, mobilisation and management potential;
- studies of indigenous knowledge and technology;
- economic analyses.

Research activities and collaborative projects

- Adaptive Research on Community-Based Management of Tsetse and Trypanosomiasis in Lambwe Valley (in collaboration with LPRP)
- Interactive Socio-Economic Research for Bio-Intensive Pest Management Technology Development (ISERIPM), in Coast Province
- Kwale and Kilifi Adaptive Research Project (with CPRP and LPRP)
- Socio-Economic Aspects of the Tsetse Research Project in Nguruman and in Coast Province (with LPRP)
- Socio-Economic Aspects of the Ticks Research Project on Rusinga Island, Homa Bay District, (with LPRP)
- Socio-Economic Aspects of the Problem of Ticks in the Homa Bay District Mainland (with CPRP)
- Socio-Economic Aspects of Tsetse Research Project in Coast Province (with LPRP)
- Socio-Economic Research Relating to the Application of the Mbu Cloth Technology in Baringo District (with MVRP)

Profiling the farms, the farmers and their needs

Among the studies which fall under the theme of production and social systems is the Socio-Economic Diagnostic Survey of Kwale and Kilifi Districts. This study was undertaken in collaboration with CPRP and LPRP as well as the Kenya Agricultural Research Institute (KARI). The study has produced data relating to

production conditions, practices and problems, and will form the basis for the adaptive research activities involving IPM and IVM technologies.

Food production practices and the cropping calendar is the theme of another study in Lambwe and Kibiri areas of South Nyanza. One general finding thus far is that adoption of new methods of production is significantly related to awareness of recommendations made by extension workers and to the wealth of the farmers.

A study which falls under the same general theme, concerning the feasibility of using chicken as predators of livestock ticks on Rusinga Island, revealed some basic information having a direct bearing on the practicability of this approach. The study shows an incongruity in the shelter arrangements of cattle and chickens which would need to be rectified in order to increase the interactions between livestock and fowl if predatory efficiency is to be enhanced.

A study relating to the Adaptive Research Project on Community-based Management of Tsetse and Trypanosomiasis generated benchmark data on the study community from a sample of 311 homesteads. One encouraging finding is that, given the relatively large herds kept by the homesteads in the Lambwe Valley and the community's reasonable economic capacity, the mobilisation of resources for the management of the tsetse trapping technology is unlikely to present a problem.

Farmers in Lambwe Valley in western Kenya learn to construct a tsetse trap in the SSIRU/LPRP adaptive research project on community-managed tsetse trapping technology. The farmers were given a short course on the biology and ecology of the fly in order to increase their understanding and interest in the control strategy

Mobilising the community

Another activity pertaining to the above Project concerned itself more directly with the issue of mobilisation and training of the study community for the adoption and management of the tsetse trapping technology. Out of the planned training programme for 40 farmers, the first batch of 14 participated in a 5-day training exercise designed to impart basic scientific knowledge on the problem of tsetse and trypanosomiasis, trap construction and maintenance, and other topics designed to enhance the skills, as well as the interests, of the participants (see photo). The trainees then returned to their communities to carry on with the mobilisation and training of their neighbours. Monitoring of the training and transfer activities by SSIRU has revealed that the entire exercise is being undertaken with remarkable competence and success. Monitoring and evaluation are important aspects of research which will continue along with other interactive socio-economic and biological research activities in progress in Lambwe.

Diffusing IPM technologies

On the theme of adoption, impact and sustainability, an assessment was made by SSIRU on the capacity of the extension services in South Nyanza District for diffusion of IPM technologies. On the basis of the level of training and knowledge of extension workers of IPM and on the ratio of extension agents to farmers, there seems to be little prospect for wide diffusion of IPM technologies in the study area.

Economic analysis

Under the theme of economic analysis, one SSIRU study sought to estimate the costs and benefits of alternative treatment regimes against ticks and tick-borne diseases in use on Rusinga Island. One preliminary finding of this study is that the treatment consisting of an improved diet produces the highest weight gains, while the internal treatment of tick-borne diseases, when used alone, produces the lowest liveweight increase of all the treatment regimes.

More details about the objectives, methods and results of SSIRU studies outlined above can be found in Part II of this Report.

Institution-building Interactive research and Information

IBIRI — mandate for building technological capacity

The Institutional Building, Interactive Research and Information Programme (IBIRI), was established during the re-structuring of ICIPE in September 1992. Its creation, by the amalgamation of the former project-focused IBIRU (Institutional Building and Interactive Research Unit) with the more service-oriented LIDS (Library, Information and Documentation Services), gives the IBIRI a unique position as a medium for technological capacity building. The IBIRI aims to develop and execute strategies for strengthening the capacity of national agricultural programmes in pest and vector management, and to enhance and facilitate ICIPE's own research and development programmes, training activities and collaborative arrangements. The Programme pursues the above goals by:

- *developing and implementing educational programmes for training scientific and technical manpower as well as user communities;*
- *facilitating interactive technology development, validation, packaging and demonstration;*
- *establishing and coordinating capacity-building networks of African countries and institutions;*
- *providing an effective information and documentation back-up, specialised in the fields of insect pest and vector biology and management;*
- *maintaining a dynamic communication and information system for the exchange of information on insect science.*

Education and training

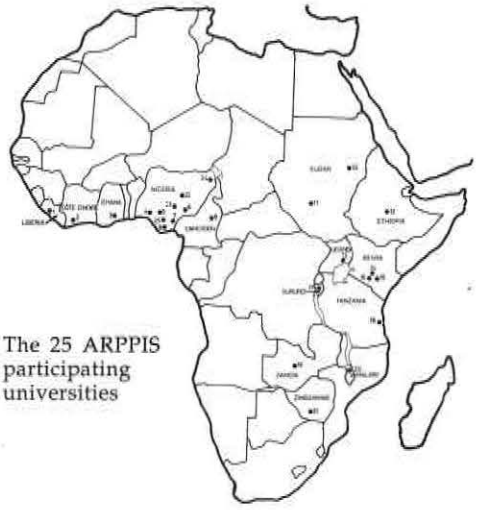
When it was established in 1970, the ICIPE was given a twin mandate: (i) to undertake basic research in integrated control methodologies for arthropod pest management, and (ii) through training and collaboration, to strengthen the scientific and technological capacities of developing countries.

The ARPPIS PhD Programme

The keystone of ICIPE's education and training activities is the ARPPIS programme. The African Regional Postgraduate Programme in Insect Science (ARPPIS), established in 1983, is a unique collaborative PhD research and training programme between the ICIPE and African universities. ARPPIS is a living example of effective South-South regional collaboration between a specialised research institution, the ICIPE, and African universities for capacity-building in environmentally sustainable insect pest management. Between 1983–1992, 112 PhD scholars from 22 African countries have enrolled in ARPPIS. Of these, 57 scholars have graduated and continue to work in Africa as university lecturers or researchers with national and international agricultural research systems. Sixteen scholars from 10 countries joined the 1992 Class, including for the first time, a student from Mali. Currently, 40 scholars (1990–1992 Classes) continue with coursework, research, data analysis and thesis writing at the ICIPE.

Thus far, a total of 25 universities in Africa have joined ARPPIS as Participating Universities (see map). Each university sends one representative to the ARPPIS Academic Board, which is charged with the policy and management of all academic

matters. A Board of Studies ensures the implementation of Academic Board policies and oversees curricula implementation, monitors students' progress, conducts examinations, and approves students' research projects and supervisors. The Board of Studies is chaired by Dr. V.O. Musewe, Programme Leader of IBIRI. 1992 saw the departure from ICIPE of Professor Z.T. Dabrowski as the Academic Coordinator of ARPPIS and the Ag. Head of the former IBIRU.



The 25 ARPPIS participating universities

At all stages of training, the ICIPE works in close collaboration with the universities, thus strengthening their capacity in postgraduate science education. As a centre of scientific excellence, the ICIPE can offer, in these days of economic deprivation, what has come to be unique facilities for research and practical training. Therefore, the ARPPIS students generally carry out their research at ICIPE headquarters at Duduville or at one of ICIPE's allied research stations. The participating universities contribute their wealth of experience and expertise by appointing one or two of their faculty to work in collaboration with an ICIPE staff supervisor. Courses are taught by international experts drawn from the participating universities, ICIPE, and other research organisations. Students are awarded their PhDs from their registering universities, which frequently are outside their country of origin. Six scholars originating from Sierra Leone, Chad, Sudan (2), Uganda and Nigeria were awarded the PhD in 1992.

The ARPPIS MSc Programme in Tropical Entomology

While ARPPIS scholars pursue their PhD studies at ICIPE, postgraduate training in insect science at the MSc level under the ARPPIS MSc Sub-regional Programme is planned for implementation in four centres around the Continent: University of Zimbabwe, Harare (Southern Africa); University of Ghana, Legon (Anglophone West Africa); Addis Ababa University, Ethiopia (Eastern and NE Africa), and D'Schang University Centre, Cameroon (Francophone Africa).

The Southern Africa Centre at the University of Zimbabwe is the first of the four to take off, and admitted its first class of seven students in March, 1992. The University of Ghana is at an advanced stage in planning the curriculum and enlisting faculty for the Programme, and plan to admit their first students in 1994. The Universities of Addis Ababa and D'Schang are at the preliminary stages of planning.

Complete reports of the ARPPIS Programme are to be found in Part II of this document, along with reports on other of IBIRI's training activities.

Professional development training

ICIPE played host to a total of 21 post-doctoral fellows and eight visiting scientists in 1992. The ICIPE Training Attachment/Internship Scheme enrolled 27 interns for the year, including scientists from the Netherlands and USA. Due to financial constraints, there were no visits to ICIPE under the Third World Academy of Sciences (TWAS)/ICIPE Research Associateship Scheme.

ARPPIS PhD students from Chad, Somalia and Sudan gather round Dr. Mohamed of LPRP to learn the technique of removing ticks from a dragging cloth, used to assess tick populations

Specialist training courses

Another aspect of training at the ICIPE where the Centre has the opportunity to share its facilities and expertise is through the mode of short courses offered by the research programmes and units around specialised themes. A few of those offered in 1992 include Insect Mass Rearing for IPM/IVM (IABU), Training Courses for Field Staff of Kwale and Kilifi Adaptive Research Project (SSIRU), Taxonomy and Identification of *Cotesia* Stemborer Parasitoids (ICIPE/WAU), Ticks Management, Tsetse Management. Participants for these courses are drawn from universities and national agricultural research and extension services from around the world.

Meeting the people. Prof. T.R. Odhiambo, Director of ICIPE is introduced to farmers participating in the adaptive research project at the Kenya Coast

Outreach and collaboration

The fundamental research undertaken by ICIPE scientists reaches fruition when it is translated into practical applications in integrated pest management systems that contribute to improved food production and health. The Pest Management Research and Development Network (PESTNET) was established in 1986 under the auspices of ICIPE to strengthen the national agricultural research and extension services (NARES) in the areas of insect science and pest management through interactive technology development, training and exchange of information.

PESTNET collaborative activities currently span 18 African countries, with resident scientists stationed in Somalia, Zambia, Burundi, Uganda, Tanzania and Rwanda. Several West African countries are slated to join in the near future, and research institutes presently collaborating with ICIPE in the Phillipines will form the basis of PESTNET expansion into the Southeast Asia region. A resident scientist is soon to be sited in Mexico, thereby opening the door for collaborative ventures in integrated pest management in Latin America.

Working with the NARES, PESTNET scientists conduct research on insect pests and methodologies for their control. The information generated is then disseminated through the Pest Management Documentation and Information Systems Service (PMDISS) to member countries and *via* the PESTNET newsletter, *Network News*.

The Kwale-Kilifi Adaptive Research Project is a prime example of the kind of interactive outreach which ICIPE promotes. In this project, the Kenya Agricultural Research Institute (KARI) is the executing agency and ICIPE serves as the implementing agency. The project aims to transfer the technologies devised by ICIPE in the management of crop and livestock pests for the purpose of increasing food production and cash income of small holders in this region. Tsetse trap technology is also being disseminated, as trypanosomiasis (nagana) is a major threat to livestock in this area, which includes the Shimba Hills Game Reserve.

A socioeconomic diagnostic survey conducted in 1992 of 180 farmers has profiled the farms, the farmers and their needs (see report from SSIRU and BMRU). In testing IPM technologies for local suitability, the research team has identified pest resistant maize, cowpea and sorghum genotypes with potential for local adaptation. Agronomic practices, suitable for the agro-ecological zones of the study area are being evaluated. The social acceptability of these IPM components and of an improved design of tsetse trap are being assessed.

On-the-job training has been provided for the technical and support staff, who have also attended courses on adaptive research methodologies. The target farm community are being trained in evaluating pest resistant varieties and cultural practices for IPM. KARI officials have benefited from training courses on tsetse management, and two are being sponsored for PhD training under project support.

Results of PESTNET interactive research projects are reported in Part II of this Report under Crop Pests Research. Results of the Kwale-Kilifi Project appear in Part II under IBIRI.

A farmer (in brown jacket) from Shimba Hills who was trained in tsetse trap construction emerges as a local trainer for other farmers in the Kwale-Kilifi Adaptive Research Project, an outreach activity of ICIPE and KARI

Information and communication

Providing a firm information resource base for research is the task of the Information Resource Centre (IRC). Commissioned in April 1991, the IRC maintains a computer database which serves not only ICIPE users, but also the member countries of PESTNET. The database carries information on document acquisitions, personnel, institutions and projects, and can be accessed through a local area network (LAN). Over 1000 records have been entered, using the UNESCO-sponsored software CDS/ISIS.

ICIPE is the central datapoint for the PMDISS (Pest Management Documentation and Information Systems and Service). PESTNET national coordinating centres have started submitting their data to the central database, and in return receive the quarterly PMDISS bibliography. ICIPE is linked to the CGNET through the E-mail facility. The Centre regularly submits data to AGRIS, the International Agricultural Information System of FAO, and in return receives the AGRIS database on CD-ROM and as the printed AGRINDEX.

Other services rendered by the IRC for ICIPE staff include the publication of an in-house *Library and Documentation Bulletin*, computer searches from CD-ROM databases, interlibrary loans, and document supply. The library continues to expand its collection, and 300 books and 600 reprints relating to pest management were acquired this year, in spite of financial constraints. A total of 7000 books and 200 journal titles now fill the library shelves at Duduville and Mbita Point Field Station.

The Communications section of IBIRI is responsible for organising information exchange activities, such as exhibitions, technology demonstrations, workshops, seminars, and the Annual Research Conference (ARC). The 1992 ARC was a departure from ICIPE's traditional format. This year, the conference was organised around a specific theme, 'Insect Behaviour and Chemical Ecology in IPM'. Another new feature was the inclusion of a discussion forum on each of the sub-themes on phytophagous (plant-eating) insects, haematophagous (blood-sucking) insects, and the chemical ecology of the desert locust. An important discussion forum between ICIPE scientists and the local donor representatives provided a unique opportunity for frank discussion of pertinent issues in research and funding. (A list of the many interesting seminars presented this year can be found in Part II of this Report.)

Editing of ICIPE's scientific publications is done through the office of the science editors. Over 75 scientific manuscripts were edited, as well as reports and proceedings of workshops, seminars and meetings. The Centre's major publicity tools, the *Annual Report*, the *Dudu* newsletter, and *Network News*, are edited and published in collaboration with the ICIPE Science Press. ICIPE is the head office of the international journal, *Insect Science and its Application*, of which 6 issues were published in 1992. The end of 1992 marked the retirement from ICIPE of the Principal Science Editor, Dr. M.F.B. Chaudhury, who has served the Centre for 17 years, first as an insect physiologist and Programme Leader of the Sensory Physiology Unit, and laterly as editor.

ICIPE Science Press

The ICIPE Science Press (ISP) continues with the production of high quality journals, books, scientific illustrations and posters. The Press covers the entire gamut of production procedures, including conceptualisation, design, layout, typesetting, and printing. Over 80% of ISP's printing needs are now handled in-house. Although ISP equipment and staffing levels are modest for the volume of work it receives, the Press has managed to meet most deadlines this year. A University Student Attachment Programme has helped to bridge the staffing gap. A few of the titles published this year include the *1991 Annual Report* (ISBN 92 9064 040 5), *Insect Science and its Application* (6 issues of Volume 13), and *Maintaining and Servicing of Scientific Equipment in Africa* (ISBN 92 9064 049 9).

ICIPE Governing Council †

Member	Country	Date of Appointment	Nominating Body, Term
1993 Retirement Class			
Dr. Michael Ashburner***	U.K.	1990	SGI, I
Prof. Shellemiah Keya**	Kenya	1993	HC, I
Dr. Benjamin Kipkorir*	Kenya	1993	HC, I
Prof. C. Safilios-Rothschild*/**	Greece	1990	SGI, I
Dr. Moise Mensah*	Benin	1993	SGI, I
1994 Retirement Class			
Prof. Peter Esbjerg** (Chairman, PC)	Denmark	1991	SGI, I
Prof. Toshitaka Hidaka**	Japan	1988	SC, II
Prof. Fotis Kafatos**	Greece	1991	SC, I
Dr. John W. Meagher**/*** (Chairman, NC)	Australia	1991	SGI, I
Prof. Jacob L. Ngu***	Cameroon	1991	SGI, I
1995 Retirement Class			
Dr. William T. Mashler* (Chairman, GC)	USA	1989	SGI, II
Prof. Dr. H. Rembold** (Vice-Chairman, PC)	Germany	1989	SC, II
Dr. A.R. Sutherst**	Australia	1989	SGI, II
Dr. Moctar Toure* (Vice-Chairman, GC)	Senegal	1989	SC, II
Ex-Officio Member			
Prof. Thomas R. Odhiambo (Director, ICIPE)*/***			

Notes

Each term lasts three years: I, first term; II, second term

HC Kenya Government nominee
SGI Sponsoring Group for the ICIPE (SGI) nominee
SC Nomination from the scientific community
* Member of the Executive Board
** Member of the Programme Committee (PC)
*** Member of the Nominating Committee (NC)
**** To maintain a rotation schedule, any term of a member completed by another member is excluded from that member's tenure.

† as of 31st December 1992

Part II

Reports of Research, Training and Support Units

Part II—Contents

1

Crop Pests Research

(Includes reports of the Crop Pests Research Programme and of PESTNET projects in Kenya and Zambia).

CROP LOSS ASSESSMENT AND ECONOMIC INJURY LEVELS

The assessment of crop losses caused by insect pests and the determination of the minimum damage that a crop can endure before it shows economic damage due to infestation by insect pests are vital factors in the management of such pests. It is on the basis of information on crop loss assessment (CLA) as well as economic injury levels (EIL) that proper utilisation of pest control strategies can be planned. When phenological stages of the crop are synchronised with levels of insect populations that inflict economic damage, then pest control measures need be applied only where necessary, thereby minimising unnecessary applications.

1.1 ASSESSMENT OF GRAIN YIELD LOSSES IN SORGHUM DUE TO THE STEMBORER, *CHILO PARTELLUS* (SWINHOE)

K. V. Seshu Reddy, K. O. Sum and D. O. Nyagol

An experiment was conducted at MPFS with the objective of quantifying the magnitude of yield losses in three sorghum cultivars and of working out the relationship between insect pest infestation and actual grain yields.

Three sorghum cultivars, LRB-5, LRB-8 and Serena, were planted in 4 x 5 m plots at a spacing of 60 cm between rows and 15 cm between plants. Each plot consisted of six rows and in half the rows (3 rows) tillers were removed while in the other half, tillers were left intact. The plants in each plot were artificially infested with newly hatched *C. partellus* larvae using a camel hair brush at densities of 2, 4 or 8 larvae at 21, 28, 35 or 42 days after crop emergence (DAE). For each variety, one plot was set as control by covering with mosquito net soon after crop emergence to prevent external infestation. This was a four-factor experiment with three replications in a randomised complete block design, with cultivars forming the main plots while tillers (removed or not), DAE and larval densities were the sub-factors.

A factorial ANOVA performed on the resultant data showed that plant height was significantly dependant on cultivars, larvae and crop stage at the time of infestation, but was independent of tiller removal. The stage of the crop at the time of infestation was important in determining the ultimate plant heights irrespective of the cultivars. It was observed that the plants which were infested at younger stages, especially at 21 DAE, resulted in significantly lower heights. In general, infestation with higher densities resulted in stunted growth, however, the influence of larvae had a very significant interaction with crop stage. A given larval density infested to younger plants resulted in more stunted growth compared to the same density administered to older plants of the same cultivar. Similar trends were also observed with the other parameters *viz*, percent stem tunnelling and grain yield losses.

Grain yield losses due to the stemborer *C. partellus* infestation were strongly influenced by the cultivars, DAE and infestation levels. Of the three test cultivars, there were highest losses in Serena (81.7%), followed by 67.9% in LRB-5 and 66.3% in LRB-8 when the plants were infested with 8 larvae/plant at 21 DAE and tillers removed. However, in the plots where tillers were left intact and infested with 8 larvae/plant, at 21 DAE the percent grain yield losses in Serena, LRB-5 and LRB-8 were 74.6%, 76% and 17.6%, respectively. Serena and LRB-5 had the highest tillering rate with an average of 2 tillers/plant. Of the tillers that grew, 75% formed harvestable heads in Serena and 70% in LRB-5. In contrast, LRB-8 had very low tillering ability with an average of 0.5 tillers/plant with only 36% developing into harvestable heads.

With respect to crop growth stage (DAE), grain yield losses were found to be higher in the younger

plants (21 DAE) when subjected to the same kind of treatment than in older stages, irrespective of cultivars, treatment to tillers and larval densities. An attempt made to establish the relationship between pest attack and grain yield resulted in generally significant linear relationships of the form $Y = a + bx$ for all the cultivars.

PEST POPULATION MONITORING THROUGH PHEROMONAL TRAPPING

The surveillance of pest populations is a major component of IPM, for it is through such monitoring of pest numbers that possible pest outbreaks can be forecast. The efficient application of certain key agents for pest control, such as the timely release of predators and parasitoids or spraying of insect pathogens, directly depends on surveillance of pest populations.

1.2 DEVELOPMENT OF A PHEROMONE-BASED TRAPPING SYSTEM FOR MONITORING OF *CHILO PARTELLUS* POPULATION

*S. A. Lux**

Research on pheromonal biology of *C. partellus* was initiated at the ICIPE some years ago to develop effective tools and tactics for utilising the female sex pheromone in IPM. This work is a collaborative project between the ICIPE (CPRP and BCERU) and research teams from the Universities of Lund and Uppsala (Sweden).

The two major components of *C. partellus* female sex pheromone, (Z)-11-hexadecenal (ALD) and (Z)-11-hexadecen-1-ol (ALC), were tested extensively in previous years. However, contrary to the results published previously (*J. Chem. Ecol.*, 1979, 5, 153–163), neither of them when dispensed alone was effective; the best results achieved with the blend of the two did not exceed 50% of the effectiveness of using virgin females as bait. Analysis of information available to November 1991, led us to conclude that there was little chance that important pheromone components still remained unknown. Therefore, it was hypothesised that the low attractiveness of traps baited with synthetic pheromone may be due to an erroneous dispensing technique resulting from inadequate understanding of *C. partellus* male behaviour. We therefore set out in 1992 to (i) verify the biological significance of the two major components of the pheromone, (ii) to determine the basic conditions for effective dispensing of the pheromone, and (iii) to prove that field monitoring of the *C. partellus* using the two-component pheromone blend is feasible.

1.2.1 *An effective dispensing technique for* Chilo partellus *pheromone*

Effect of increase of the pheromone load on efficiency of the rubber septa dispensers. The effect of varying concentrations of the two components (10:1 ratio) dispensed from separate rubber septa placed roughly 1–3 cm apart was tested. The distance between the two rubber septa was not strictly controlled. The concentration of the aldehyde varied from 100 µg to 10,000 µg per septum.

The best results (40% of effectiveness as compared to two virgin females) were obtained with traps baited with the two components at the lower concentrations, ALD:ALC = 100 µg :10 µg or 300 µg:30 µg.

Results indicate that the performance of the trap cannot be improved by increasing the pheromone emission rate.

It was observed that males approaching the pairs of dispensers used in the above experiments seemed to get confused at a distance of 20–30 cm from the sources of the pheromone components. This confusion was not observed in males approaching calling females. On the other hand, males were less confused when the dispensers were put very close together to simulate a single release point for the blend.

These observations strongly support the hypothesis about possible error in the dispensing system. Therefore, a simple dispenser was constructed, allowing very close but separate release of both components.

Construction of an experimental dispenser. The dispenser was constructed from two pieces of filter paper and a piece of polyethylene foil. Both pieces of paper were separated by a piece of polyethylene foil and assembled together by a paper clip. Such a dispenser was used for further experiments and was also used for field monitoring of *C. partellus* at the Coast. Release characteristics of the pheromone blend (rate and ratio) were quantified in field conditions at the Kenya Coast (see also BCERU section in this Report), so the release parameters necessary for effective trapping were roughly assessed.

The paper dispenser was designed to be used only for biological studies and was not meant to be recommended for practical use in its present form. For large-scale applications, a precise yet more handy and durable slow-release dispensing system still remains to be developed.

Testing the experimental paper dispenser baited with the two-component blend. The experiment was conducted in the screenhouse and two types of baits were used: (1) eight traps baited with virgin females and (2) eight traps equipped with the new dispenser. Traps were arranged alternately. Females as well as dispensers were changed daily. The experiment was conducted in three replicates (three screenhouses) simultaneously and was run for 22 nights.

The experimental dispenser made from filter paper (with separated components, but released closely) performed similar to virgin females (82% compared to the trap baited with two virgin females). The difference between virgin females and dispenser was not significant.

Distance between pheromone components as a factor confusing males approaching the trap. The experiments were set using delta traps with four types of baits: (1) new dispenser with pheromone components released very close to each other, (2) similar dispenser made

with filter paper, but components separated by 3 cm, (3) dispenser made from two rubber septa separated by 3 cm, (4) two virgin females. Each experiment lasted 3 days. Virgin females were replaced with new ones every day but dispensers with synthetic pheromone were exchanged after 3 days. The experiments were arranged on the basis of a Latin square design (4 x 4), conducted in screenhouses and on artificially infested fields at MPFS. Screenhouse experiments were replicated more than 40 times and field ones 20 times.

Similar experiments were also conducted on fields naturally infested at the Kenya Coast (Mtwapa, Kaloleni, Kilifi). The experiment was conducted on three fields concurrently and was replicated 20 times.

Separating the release points of the pheromone components resulted in consistent three-fold decrease of catches. During the first day, the dispenser made from filter papers (with separated components, but released closely) performed similar to virgin females (screenhouse, 78% and field, 116%, compared to virgin females). Although during the next two days the effectiveness of the paper dispenser decreased considerably, even after three days it was still 30% as attractive as virgin females. The effectiveness of the rubber septa dispenser also decreased in almost the same ratio as that of the filter paper, which suggests the occurrence of similar deteriorating mechanisms of the pheromone components irrespective of the dispenser material. After three days of the experiment the rubber septa dispensers performed consistently worse than the filter paper dispensers and never reached the effectiveness of virgin females.

The results indicate that the distance between release points of the components is a factor responsible for confusing males approaching the trap.

1.2.2 *Biological significance of the two major components of the pheromone*

Comparison of attractiveness of virgin females versus the two main pheromone components dispensed singly and as a blend. The experiment was conducted in screenhouses in the same arrangement of traps (4 x 4) as was described before. Four types of baits were used: (1) two virgin females, (2) the new dispenser baited with 100 µg of the aldehyde (ALD) and 10 µg of the alcohol (ALK), (3) the same dispenser, but baited only with 100 µg ALD (the second square of filter paper left clean), (4) the same dispenser, but baited only with 10 µg ALK. Female moths as well as dispensers were changed daily. The experiment was conducted in three replicates (screenhouses) simultaneously and was run for 44 nights.

The results show that the performance of the dispenser baited with the two major components was comparable to virgin females. The dispenser baited with both components was more attractive than the dispenser baited with the aldehyde or alcohol alone (80%, 34%, 28%, respectively when compared to virgin females). The addition of the alcohol did not decrease the attractiveness of the dispenser.

It was concluded that both the major components of the pheromone do play an important biological role, and that the two act synergistically, contrary to the antagonism reported previously.

Testing commercially available bait (Trece Pherocon cap) for Chilo partellus. The Trece Pherocon cap (commercially available from Pest Management Supply Inc. Amherst, MA, USA) was tested in screenhouses. Four types of baits were used: (1) two virgin females, (2) Trece Pherocon cap (3) the paper dispenser baited with 100 µg ALD and 10 µg ALK, (4) the paper dispenser baited with 300 µg ALD and 30 µg ALK. Females as well as dispensers were changed daily, and Trece Pherocon caps were changed after 5 days. The experiment was conducted in three replicates (three screenhouses) simultaneously and was run for 10 nights. The results show that both the dispensers (100:10 and 300:30) performed similarly as virgin females (115% and 123% compared to virgin females) and no significant difference was found between them. The Trece Pherocon cap, commercially sold for trapping *Chilo partellus*, was found to be very inefficient (19% compared to virgin females). Chemical investigation revealed that the Trece Pherocon cap is baited with ALD alone (about 500 µg/cap). The bait was found to be very ineffective when used in Kenya. Therefore, development of a new bait, based on both major pheromone components remains essential.

1.2.3 *Field monitoring of* C. partellus *using a synthetic blend of the pheromone components*

Monitoring was performed at the Coast in two locations (Mtwapa and Kilifi) from March 1992 till the end of the year. In each location two fields (50 x 50 m) were selected, one with sorghum and the other with maize. On each field 9 delta traps were placed (distance between traps was 20 m). Traps were baited with synthetic pheromone components and the dispenser made from filter papers (as described above). Dispensers were changed and catches recorded every third day. Monitoring was started about one month before planting in order to get information about the off-season level of population. The experiment was conducted in cooperation with the ICIPE-WAU project, who made destructive sampling on the same fields to record infestation by immature stages.

The results show that before planting, *Chilo* population was very low; very distinct and statistically significant peaks were recorded just at the planting time. Although during 1992 the *C. partellus* population was unusually low (which was confirmed by recording the plant infestation by immature stages), the data obtained are biologically viable and statistically significant.

The results indicate that field monitoring of *C. partellus* with traps baited with synthetic blend of the two major pheromone components is feasible and there is no longer any need to use unhandy and unreliable virgin females.

S.O. Paye and P.O. Agolla provided technical assistance

PLANT RESISTANCE TO INSECTS AS AN IPM COMPONENT

Research in this area is aimed at the development of strategies for efficient utilisation of plant resistance in maize, sorghum and cowpea against their major insect pests, particularly the cereal stemborers *Chilo partellus* and *Busseola fusca*, the legume pod borer *Maruca testulalis*, the cowpea aphid, *Aphis craccivora* and cowpea flower thrips, *Megalurothrips sjostedti*. The activities undertaken include elucidation of components, mechanisms and genetics of resistance in the target crops against the target pests, and improvement of crop cultivars so as to combine pest-resistance/tolerance with other desirable agronomic characters, including yield.

1.3 COMPONENTS AND MECHANISMS OF RESISTANCE IN SORGHUM TO STEMBORERS

K. N. Saxena, A. M. Nour, F. D. O. Odawa and S. M. Otieno

Two major advances were made in this area: firstly, studies were intensified to gain information on the nature and levels of resistance/tolerance in selected sorghum genotypes to the stemborer *Busseola fusca*, previous studies having been on the stemborer *Chilo partellus*. Such a study would lead to identification of sorghum genotypes showing cross resistance to the two borer species. Secondly, the sorghum hybrids developed at the ICIPE, incorporating the borer-resistance traits from the lines previously identified as resistant/tolerant to *C. partellus*, were subjected to more detailed analysis.

1.3.1 Components of resistance to B. fusca

Eleven genotypes, 6 open pollinated lines and 5 hybrids, were evaluated for resistance or susceptibility to the three major types of damage by the stemborer: leaf lesions, deadheart and stem tunnelling. The genotype IS 1044 showed highest resistance to all three types of damage, their scores being the lowest among the genotypes tested. The hybrid HYD-8 (1441A x IS 1044) was as highly resistant to deadheart and stem tunnelling as IS 1044. The lines IS 18363, ICS 3 and ICS 4 were highly susceptible to all three types of damage, whereas Serena (IS 18520) was similar to IS 18363 in its susceptibility to deadheart and stem tunnelling but less susceptible to leaf damage.

1.3.2 Mechanisms of resistance in sorghum to B. fusca

These mechanisms were elucidated in respect of behavioural nonpreference and antibiosis for three sorghum genotypes: IS 18520 (Serena) (susceptible), IS 18363 (susceptible) and IS 1044 (resistant).

The stemborer showed a strong nonpreference for oviposition, orientation and feeding for IS 1044, whereas these responses for the remaining two genotypes were quite high. Similarly, the development of the insect on IS 1044 was much poorer — reflecting antibiosis — than on IS 18520 or IS 18363. Thus, both nonpreference and antibiosis mechanisms are involved in the resistance of IS 1044 to *B. fusca*, as was also previously reported for *C. partellus*.

1.4 COMPONENTS AND MECHANISMS OF RESISTANCE IN MAIZE TO *CHILO PARTELLUS*

K. N. Saxena, S. O. Ajala, P. M. Chiliswa and G. O. Asino

The major advances during the year included information on (i) chief components of resistance to *C. partellus* in newly received maize materials from CIMMYT and ICIPE, and (ii) mechanisms of resistance to *C. partellus* in three maize genotypes developed at the ICIPE.

1.4.1 Components of resistance in maize genotypes from CIMMYT and ICIPE

Sixty-three maize genotypes received in 1992 from CIMMYT and 17 being developed at the ICIPE were evaluated for resistance or susceptibility to *C. partellus* and for agronomic characteristics including grain yield. A resistant check (MP 704) and two susceptible checks (Inbred A and hybrid 511) were also included in the tests for comparison. Each plant was artificially infested with 20 neonate larvae and assessed for leaf lesions damage (% leaves with lesion score ≥ 4.0 on 1–9 scale), deadheart (% plants showing the symptom), and stem tunnelling (% of stalk length).

The stem tunnelling was quite low in almost all the genotypes including the checks. However, leaf damage ranged from nil to 31.4% and deadheart ranged from nil to 39.7%. The values below or equal to 5% were regarded as very low (high resistance), > 50 ≤ 10.0 as low, >10.5 ≤ 20.0 as medium, > 20.0 ≤ 30.0 as high and > 30.0 as very high (low resistance).

The resistant check MP 704 showed very low levels of leaf damage as well as deadheart, reflecting high resistance to these two types of damage. On the other hand, certain other genotypes, e.g., ICIPE's entries 008 and 082, showed high levels of both these damages, reflecting their high susceptibility to the borer. Among the materials from CIMMYT, 13 entries showed very low levels of leaf damage and deadheart, resembling MP 704 in their high resistance to the pest. Of these 13 entries, six had a much higher grain yield (above 6 tonnes/ha) than the remaining, including MP 704.

Among the 17 ICIPE materials, five showed low or very low levels of the two types of damages, but only one (entry 032) gave grain yield above 6 t ha^{-1}. Thus, the above mentioned six materials from CIMMYT and one from ICIPE show promise for further development for IPM programmes.

1.4.2 Mechanisms of resistance in new maize materials

Three maize genotypes (ICZ 3, ICZ 4, ICZ 5) developed during the past two years were studied for the role of

nonpreference and antibiosis in their resistance to *C. partellus*. As for sorghum, the insect's oviposition, orientation and feeding responses to the test genotypes were compared with the checks MP 704 (resistant), Inbred A (susceptible) and hybrid 511 (susceptible) for understanding the role of non-preference. Larval development and adult fecundity were compared on the above genotypes to elucidate the role of antibiosis.

As regards nonpreference, the insect's ovipositional response to the test genotypes was much lower than that to the susceptible hybrid 511 in a choice situation. However, in a no-choice situation, the test genotypes received fairly high egg-laying. The orientational nonpreference of the larvae was observed for MP 704 but not for other genotypes tested. With reference to antibiosis, this was observed in MP 704 for larval development and in ICZ 4 for adult fecundity as well as for survival.

The above information provides the basis for further elucidation of the biophysical and biochemical characters of the test genotypes for improvement of their pest-resistance and agronomic characters.

GENETICS OF PLANT RESISTANCE TO INSECTS

1.5 COMBINING ABILITY OF RESISTANCE TO THE SPOTTED STEMBORER, *CHILO PARTELLUS* IN MAIZE

R. S. Pathak and S. M. Otieno

During the past years, our genetic studies included only the best known resistant and susceptible genotypes such as ICZ1-CM (R), ICZ2-CM (R), MP 701 (R), MP 702 (R), MP 704 (R), and Inbred A (S). Recently some additional genotypes have been evaluated in the Programme. It was therefore decided to evaluate the potential of these genotypes for genetic improvement.

Damage scores for parents showed MP 704, MP 701, MP 702, ICZ 2-CM and ICZ1-CM to be the top resistant genotypes, in that order. The correlations between parental means and their general combining ability (GCA) estimates for leaf-feeding ($r = 0.937^{**}$), deadheart ($r = 0.894^{**}$), stem-tunnelling ($r = 0.832^{**}$) and number of holes per metre plant height ($r = 0.942^{**}$) were highly significant, which suggests that initial selection of the parents for hybrid combinations may be largely based on the damage score of the genotype. These results emphasise the value of GCA as a selection criterion in a resistance breeding programme.

1.5.1 Germplasm enhancement in maize and sorghum

The F_4 and BC_2F_3 populations of maize resulting from crosses between resistant (ICZ1-CM, ICZ2-CM and MP 704), and susceptible (Inbred A) genotypes were developed on white grain colour background of Inbred A. These populations were improved through a recurrent selection programme using half-sib, full-sib within and intermating between populations. All selections for resistance to *C. partellus* were done under artificial infestation while the recombination of selected progenies was done under uninfested conditions. The resultant C_1, C_2 and C_3 populations showed a good improvement in resistance to *C. partellus*. Their yield potential is yet to be tested.

The germplasm enhancement in sorghum included the resistant parents IS 1044, IS 12308, IS 2205, IS 2269 and tolerant cultivar Serena. They were crossed to a common male sterile line TX624 to obtain F_1, F_2, BC_1F_1, and BC_1F_2. Selection for resistance to *C. partellus* was initiated in the mixed seed planted in 1990. Two cycles of selection under artificial infestation have been completed. The results indicate that not much progress has been made in broadening the genetic base of the population for resistance. Most of the plant types resemble those of IS 1044 and/or Serena. It was noted with concern that there was little or no contribution in gene exchange from IS 12308, IS 2205 and IS 2269 due to their breeding limitations; the line IS 12308 was found to have functional male sterility, IS 2269 does not accept pollen when used as a female, and IS 2205 has long glumes that ensure selfing and limits the shedding of pollen. It was therefore decided to make individual plant selection from these populations for variety development through progeny-row evaluation.

1.6 INHERITANCE AND LINKAGE STUDIES USING ISOENZYMES AND MORPHOLOGICAL TRAITS IN APHID RESISTANT/SUSCEPTIBLE COWPEA CULTIVARS

S. G. Mwangi, R. S. Pathak, E. Osir and K. Ampong-Nyarko

Screening for resistance is mainly done through aphid infestation of the test materials. Infestation levels often are erratic in the field. The present study was undertaken in a bid to identify markers for aphid resistance.

Crosses were made among eight aphid-resistant (ICV 10, ICV 11, ICV 12, TVu 310, IT82E-25, IT84S-2246-4, IT87S-1394, and IT87S-1459) and two susceptible (ICV 1 and TVu 946) cowpea cultivars. Preliminary results on aphid resistance confirmed earlier reports that resistance is qualitative (monogenic) and is dominant to susceptibility. Work continues on relationships among morphological traits and aphid resistance and on isoenzyme variations of the test materials.

PLANT RESISTANCE TO INSECT PESTS

1.7 NONPREFERENCE MECHANISMS OF COWPEA RESISTANCE TO *APHIS CRACCIVORA*

S. Oghiakhe

Experiments were carried out to determine the involvement of nonpreference as a mechanism of resistance in cowpea to *Aphis craccivora* using two

resistant cultivars, ICV 12 and TVu 310 and two susceptible cultivars, ICV 1 and TVu 946. A total of 10 adult aphids starved for 2 h were released at the centre of a plastic pot containing the plants of the test cultivar equidistant to each of the cultivars. The plastic pots were covered with a cylindrical metal frame (90 cm x 27 cm dia.) fitted with a white cotton mosquito net.

The results showed that after 24 h and 72 h, the total number of adults and nymphs on the resistant cultivars were significantly lower ($P < 0.0001$) than the numbers found on the susceptible cultivars. The susceptible cultivars, ICV 1 and TVu 946 were thus more preferred for settling and oviposition. This clearly shows the involvement of nonpreference (or antixenosis) as a mechanism of resistance to aphids in cowpea.

Such information is useful in formulating control measures and selecting the methodology and cultivars for resistance breeding. Further studies are in progress to elucidate the involvement of other resistance mechanisms in the resistance of cowpea to this pest.

1.8 ANTIBIOSIS MECHANISM OF RESISTANCE IN COWPEA TO THE LEGUME POD BORER, *MARUCA TESTULALIS*

S. Oghiakhe, F.O. Onyango, J. Obara and P. Odawa

Studies carried out in the laboratory to determine the involvement of antibiosis in cowpea resistance to the legume pod borer, *Maruca testulalis* using plant parts from four cowpea cultivars with known levels of resistance/susceptibility to *M. testulalis* revealed that the larval development period ranged from 11.4 days in flowers of IT82D-716 to 14.4 days in terminal shoots of the same variety. On each variety terminal shoots produced the longest larval period, followed by flowers and pods in the resistant TVnu 72 and TVu 946. On the susceptible IT82D-716 and ICV 1, terminal shoots were followed by pods and flowers, respectively.

Percentage pupation ranged from 70% in the control to 100% in the flowers of the highly resistant TVnu 72. Pupal weight was lowest on terminal shoots of ICV 1 (45.6 mg) and highest on fresh pods of TVu 946 (49.4 mg). With the exception of IT82D-716, plant parts that produced the shortest larval period also produced the highest pupal weights. Terminal shoots gave the lowest growth index on all cultivars. The highest growth index on terminal shoots was obtained in the order, TVnu 72 > ICV 1 > TVu 946 > IT82D-716. Growth indices obtained in the order of decreasing suitability of flowers were TVnu 72 > IT82D-716 > TVu 946 > ICV 1. On fresh pods, growth indexes were in the order, TVnu 72 > ICV 1 > IT82D-716 > TVu 946.

Results show that the highly resistant wild species, TVnu 72 was the most suitable for larval development followed by IT82D-716, ICV 1 and TVu 946. This clearly indicates that antibiosis does not play any significant role in cowpea resistance to *M. testulalis*. Further work is in progress to determine the involvement of other mechanisms of resistance (e.g., non-preference or antixenosis, tolerance) and morphological factors in order to formulate effective control measures for *M. testulalis* in cowpea.

1.9 TIME OF DAY FOR SAMPLING FLOWER THRIPS *MEGALUROTHRIPS SJOSTEDTI* (TRYBOM) (THYSANOPTERA: THRIPIDAE)

S. Oghiakhe and S. K. Firempong

Accurate and precise sampling information is crucial to decision making in pest management. This calls for a sampling method that is reliable, efficient, quick and cost effective. Nothing is known regarding the best time of day to sample thrips for resistance and/or population studies on cowpea. This information is important because many insects, including thrips, show diel fluctuations in activity. The present study was therefore undertaken to determine the best time of day to sample this pest on cowpea.

Seasonal variation was observed in the best time of day for sampling thrips on cowpea at Mbita Point Field Station in western Kenya. Thrips population in the Station are usually much higher during the short rains than in the long rains. In the short rainy season, 1030 h is the best time while the next best is 1330 h and *vice versa* for the long rainy season. The effect of agro-meteorological factors on thrips population at different time of sampling will be determined.

1.10 IMPROVEMENT AND DEVELOPMENT OF MAIZE FOR RESISTANCE TO STEMBORERS

S. O. Ajala, P. Chiliswa and P. O. Onong'

Maize improvement activities for the period under review were carried out with the active participation of a collaborating entomologist. Since maize breeding activities are continuous, the year under review consolidated results from previous efforts.

1.10.1 Improvement in levels of resistance

A second cycle (C_2) of a mass selection procedure to increase on levels of resistance to *C. partellus* attack in each of five maize populations described earlier (*ICIPE Annual Report* 1990) was completed. Evaluation of the original (C_0), C_1 and C_2 from the populations for possible gains to selection revealed that, in general, the ratings and measurements associated with leaf feeding and stem tunnelling were decreasing with selection. If gains/cycle were to be considered, Poza Rica 7832 seemed to be more responsive to selection than the others for both leaf feeding and stem tunnelling.

Results from this study show that mass selection as practised on the populations reported herein, is an effective method of increasing levels of resistance to leaf and stalk feeding by larvae of *C. partellus*. However, to increase on gains/cycle, a form of progeny (S_1) testing may be needed before recombination, however,

an additional season will be required to complete a cycle.

1.10.2 Relative contributions of C. partellus *damage parameters to grain yield reduction*

In a previous report (*ICIPE Annual Report* 1991), we highlighted phenotypic correlations and correlations among GCA effects for three damage parameters of leaf feeding, deadheart and stem tunnelling. This inter-relationship and its effect on grain yield loss was further investigated using 145 maize genotypes arranged in three groups. For the three groups, stem tunnelling was consistently the most important damage parameter contributing to grain yield loss, its main effect being through reduction in ear number. Perhaps the effect of stem tunnelling on yield reduction could result from disruption in fluid flow occasioned by damage to vascular bundles, thus starving and stunting the plant, reducing ear number and consequently, reducing grain yield. Observation from this study contradict earlier opinions that leaf feeding is the most important damage parameter causing grain yield loss in maize (Ampofo, J.K.O. 1986. *Environ. Entomol.* 15, 1124–1129).

The practical application of this result would aid in arriving at a functional criterion to measure tolerance to the pest. Other studies are, therefore, being initiated to effectively arrive at a functional definition of tolerance to *C. partellus* attack.

1.10.3 Line extraction

A pedigree nursery for developing resistant lines is usually maintained every season. In addition to this, 56 *C. partellus*-resistant S_4 lines were top-crossed to a broad based tester, ICZ 3 and evaluated. An opportunistic high incidence of downy mildew (*Perenosclerospora sorghi*) at the Mbita location aided further screening/selection. The performance of the top-yielding 15 entries are shown in Table 1.1. Ten of the top-yielding entries were common to both locations and except for entry 115, downy mildew infection were relatively low. An average yield of 7 t ha^{-1} was considered desirable. A nine-parent *C. partellus* resistant synthetic population is, therefore, feasible. However, artificial screening of the lines and/or synthetic population generated from them will be necessary for exact pathogenic level(s) to downy mildew.

1.10.4 Development of resistant germplasms

The genetic base of IC-90-W1 (ICZ 3) was broadened by the inclusion of resistant selections from Pop 10, ER 29 SVR and MMV 600. The new population thus created, IC-92-W1 (ICZ 5) gave comparable yield to ICZ 3 but has a higher level of resistance to the maize streak virus. The change in name from IC-90-W1 and IC-92-W1 to ICZ 3 and ICZ 5, respectively, became necessary in order to itemise, register and simplify the use of the germplasms.

Table 1.1 Grain yield (t/ha) of top 15 maize entries for each of three locations and across locations in western Kenya

Mbita			Ungoye		Across	
Entry	Yield	DMR[1]	Entry	Yield	Entry	Yield
141	8.12	3.44	154	11.32	154	8.89
5	8.06	0.00	115	11.02	115	8.83
234	7.65	5.02	159	10.45	159	8.80
8	7.61	7.99	277	10.13	8	8.57
32	7.60	3.25	8	9.53	5	8.49
189	7.40	9.69	9	9.26	32	8.23
132	7.38	0.00	274	9.22	277	8.18
159	7.14	8.10	166	8.98	189	8.11
144	7.10	6.43	6	8.95	274	8.09
11	7.04	6.88	5	8.91	234	8.06
274	6.95	0.00	32	8.85	166	7.95
166	6.92	3.10	189	8.83	11	7.85
115	6.64	15.18	164	8.80	132	7.80
279	6.58	0.00	28	8.71	141	7.76
154	6.47	6.68	11	8.65	6	7.71
Lsd	0.36	1.64		0.24		0.22

[1]Downy mildew resistance (DMR) levels were estimated as the proportion (%) of plants in the row showing the symptom, Lsd = Least significant difference at $P = 0.05$.

1.11 IMPROVEMENT AND DEVELOPMENT OF RESISTANCE IN SORGHUM CULTIVARS AGAINST STEMBORERS

A. M. Nour and P.O. Ollimo

The objectives of the sorghum improvement project are to develop and improve the level of stemborer resistance in high-yielding sorghum cultivars. The work on sorghum improvement during the current crop season covers the following activities.

1.11.1 Variety improvement: Assessing the yield potential and stemborer resistance of advanced sorghum genotypes

Twenty stemborer-resistant advanced lines, together with two local checks, were tested in a preliminary field trial for yield potential and stemborer resistance. The experimental design and the other detailed procedures were outlined in previous ICIPE reports. Leaf damage, percentage of deadheart, percentage of stem tunnelling and larval and pupal population density were considered in selection for resistant cultivars.

Preliminary results showed that eight derivatives, namely (LRB 6 x LRB 5)-51-1-4-1, (LRB 6 x LRB 5)-51-1-5-1, (LRB 6 x LRB 8)-126-1-2-1, (LRB 6 x LRB 8)-195-2-2-1, (LRB 5 x IS 1044)-356-1-1-1, (LRB 5 x IS 1044)-365-2-1-1, (LRB 8 x IS 1044)-6-2-1-1 and (LRB 8 x IS 1044)-27-1-1-1, gave comparatively lower scores for deadheart and stem tunnelling than the standard check Serena. Among these 8 derivatives, the first four have an average grain yield ranging from 3.3 t ha^{-1} to 4.5 t ha^{-1} compared to 3.6 t ha^{-1} for Serena and 3.4 t ha^{-1} for IS 1044.

1.11.2 Developing multiple resistance to stemborer and shootfly

The objectives and the techniques developed for screening for multiple insect resistance were outlined in the 1990 *ICIPE Annual Report*. During the short rains of 1991, 208 F_3 progenies were selected as having various combinations of resistance to stemborer and shootfly. These selections were further tested during this season as F_4 progenies. The criteria for selection were the same as above.

Preliminary results indicated that out of 208 progenies, 25 were selected as promising families which combine a high level of resistance (≤ 10% deadheart) to both stemborer and shootfly. Families which combine resistance for both pests and at the same time have high yield potential include (LRB 6 x IS 5469)-178-1, (LRB 8 x N-13)-141-2 (IS 1044 x IS 5469)-429-2, (IS 1044 x IS 2269)-479-6 and (IS 1044 x IS 2269)-493-4.

1.11.3 Incorporation of stemborer resistance/tolerance into sorghum hybrids: Assessing new hybrids for resistance and grain yield

During the short rainy season, 23 sorghum hybrids were developed using male sterile lines as females and resistant/tolerant lines as male parents. These hybrids, together with Serena and IS 1044 as checks, were evaluated under artificial infestation in single row replicated trials. The results show that seven hybrids scored a percentage of deadheart ranging from 8 to 23%, and for stem tunnelling from 27 to 40%, compared to the standard check Serena, which scored 50 and 47% for deadheart and stem tunnelling, respectively. For the other two parameters (foliage damage and larval and pupal population density) the differences were not significant from Serena. Hybrids which combine stemborer resistance and at the same time have high yield potentials include (1424A x LRB 5), (Tx624A x Gadam Elhamam), (2219A x IS 1044) and Tx623 x LRB 5).

1.11.4 Assessment of advanced sorghum hybrids

In this trial 10 sorghum hybrids, previously identified as elite promising hybrids together with five varieties (2KX-17, IS 1044, Seredo and Ochuti from Kenya, and Gadam Elhamam from Sudan), were evaluated for stemborer resistance and grain yield, at both Mbita Point Field Station and Ungoye Field Site. The common variety Serena was included as a check variety.

Based on the percentage of deadheart and the percentage of stem tunnelling, four hybrids were selected with an average score ranging from 0.5 to 1.4%, and from 8.7 to 11.6% for deadheart and stem tunnelling, respectively. The check variety Serena scored 10.3 and 11.6% for the same parameters. On the other hand, six hybrids gave grain yields ranging from 6.67 t ha^{-1} to 7.96 t ha^{-1}, compared with 6.35 t ha^{-1} for the standard variety Serena. Among the varieties, only Seredo and Gadam Elhamam gave grain yields almost equal to that of Serena.

CULTURAL PRACTICES FOR PEST MANAGEMENT

Research in this area aims at identifying and utilising the cultural practices that may lead to a reduction of insect numbers, and may therefore be incorporated into an integrated pest management strategy. Over the last seven to eight years, the major activity on cultural practices has centred on intercropping, which led to the identification of cereal/legume intercrops as a combination that reduces pest population on both crops. In this report we present the work carried out this year on cropping systems for pest management.

1.12 CROPPING SYSTEMS FOR PEST MANAGEMENT

K. Ampong-Nyarko, K. V. Seshu Reddy and K. O. Sum

The objectives of this project are to determine appropriate cropping patterns that drastically reduces pest incidence, to fine tune recommendations about intercropping and other cropping patterns, and to increase agronomic productivity and economic profitability of intercropping.

1.12.1 Compatibility of crop combinations for intercropping

An intercropping experiment was planted in the short rains of 1991 to fine tune recommendations on intercropping. There were seven combinations comprising maize monocrop, sorghum monocrop, maize and bean, maize and cowpea, sorghum and bean, sorghum and cowpea, sorghum and maize.

Differences in stemborer density and percent of plants attacked were not significant between the various cropping patterns. However, there was an indication of cowpea being more effective in reducing stemborer attack in both sorghum and maize than bean. For example, at 4 WAE the number of stemborers per 10 plants in maize and bean intercrop was 13 ± 4.7, whilst the maize cowpea intercrop was 4.3 ± 1.3. Similarly, the borers in sorghum were 6.3 ± 1.2 and 4.0 ± 2.0, respectively. Also the number of borers in the maize sorghum intercrop was 64% higher for the sorghum than for the sorghum monocrop, but was about equal in both the maize intercrop and monocrop.

1.12.2 Effect of plant density and different intercropping combinations on insect attack and yield

In the long rains of 1992 an intercropping experiment was planted at MPFS to determine the effect of plant density and different crop combinations on borer attack and grain yield. In both maize and sorghum intercropped with cowpea, closer intra-row spacing gave the least borer attack at both plant densities of 55,555 and 111,111 plants/ha. Grain yields were, however, confounded by *Striga* infestation on the site but observations indicate that cereal grain yield in the

intercrop that equals the monocrop cereal yield are obtainable under the 90 x 10 cm spacing.

1.12.3 Strip cropping

The objective of the strip cropping experiment was to determine the optimum strip width that reduces insect pest incidence and maximises yield. In a preliminary experiment planted in the short rains of 1991 at Ungoye Field Site, there was no significant difference in the number of larvae and pupae for 2, 3 or 4 rows of sorghum alternating with similar rows of cowpea compared with the standard single alternate row arrangement. The number of flower thrips in 1, 2, 3 and 4 alternating rows averaged 23 thrips/flower compared to 31 thrips/flower in 5 rows, 39 thrips/flower in 6 rows and 42 thrips/flower in the cowpea monocrop.

1.12.4 Plant density in strip cropping

In the short rains of 1992 another strip cropping experiment with emphasis on agronomic productivity was conducted at MPFS. The treatments consisted of 2, 3, 4, 5, rows of sorghum alternating with similar rows of cowpea at two plant densities of 111,111 and 74,444 plants/ha. Three common farmers' intercropping practices, sorghum and cowpea in alternate hills in the same row, row planting of sorghum and cowpea in the same hill, and random planting of sorghum and cowpea in the same hill, were included as controls. Once again, 2–4 rows of sorghum alternating with cowpea were confirmed to be most effective in reducing stemborer attack and damage. There was no difference in borer incidence and damage between the plant densities used. At 7 WAE the farmer practices suffered more borer damage than the strips of 2–4 rows. The strip cropping has a potential to improve yields of companion crops and increase efficiency of field management.

1.13 INFESTATION OF *PHASEOLUS VULGARIS* (L) BY BEANFLY *OPHIOMYIA* SPP (DIPTERA : AGROMYZIDAE) AND ITS MANAGMENT BY CULTURAL PRACTICES

J. Kayitare and K. Ampong-Nyarko

The beanfly is a major constraint to the production of beans, a widespread leguminous crop in equatorial and sub-equatorial Africa, especially in East Africa (Kenya, Tanzania, Uganda, Rwanda and Burundi). Beanfly incidence causes yield losses averaging 47–87%. The control methods used against the pest are based primarily on chemical insecticides. Cultural practices as a pest management tool is a much-ignored area of research that needs to be explored in this field. Consequently, studies on five cultural practices (soil fertility, intercropping, plant density, planting time and weeding regime) on beanfly infestation as a possible management strategy were carried out.

Two species of beanfly, *O. phaseoli* and *O. spencerella* were identified in Oyugis, where *O. spencerella* was dominant. The increase of nitrogen levels increased beanfly infestation by 12–66%. The fertilized plants were more succulent and had more nutrients, and therefore offered better conditions to beanfly fecundity and development. However, the infested plants in fertilized soils compensated for the damage and grew quickly to pass the critical stages; and thus, the beanfly infestation had less effect on grain yield. In the case of no nitrogen being applied, beanfly infestation reduced the yield by 48%. Therefore, a balanced fertilizer use reduces beanfly damage and increases grain yield.

The study of intercropping of bean and maize as a possible management strategy revealed that intercropping increased beanfly infestation compared to pest levels in pure stands of beans. The microclimatic conditions created by intercropping of beans and maize were favourable for the beanfly occurrence. Therefore, the monocropping of beans appeared to be a better cropping system for the reduction of beanfly incidence.

Increase of beanfly was observed in wider spacing than in closer spacing of beans. The optimal plant density seemed to be the density that also gave the least beanfly occurrence.

Early planting reduced beanfly infestation. Rainfall and temperature accounted for different rates of beanfly population increase in successive plantings.

The effect of weeding regimes on beanfly infestation did not pinpoint an optimum weeding period which could reduce beanfly infestation. However, it was observed that weeds-free and weeding three weeks after plant emergence produced a good yield.

Parasitoids regulate beanfly population in nature. Six species of parasitoids were identified, with *Opius phaseoli* being the dominant species. They were density-dependent and reduced beanfly population by 26%.

The experimental results indicate that the use of balanced fertilizers, an appropriate cropping system, optimal plant density and early planting time were good cultural practices that can form a part of IPM to reduce beanfly incidence.

1.14 FUNCTIONAL MECHANISMS IN CROPPING SYSTEMS

K. V. Seshu Reddy, K. Ampong-Nyarko, K. N. Saxena and K. O. Sum

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

1.14.1 Establishment of mechanisms for low pest incidence in cropping systems

A field experiment of sorghum, maize and cowpea intercrop to determine the ovipositional behaviour of *Chilo* in intercropping was planted in the short rains of 1991 at MPFS. At 7 WAE gravid female *C. partellus* moths were released into the caged plots. *Chilo partellus* moths oviposited on all the crop species in the intercrop. The number of egg masses laid were 40% on cowpea, 31% on maize and 28% on sorghum. The egg batches

were found on both the abaxial and adaxial sides of cowpea leaves, and occasionally were found on the stems.

Screenhouse experiment. In the first screenhouse experiment treatments consisted of intercropping of cowpea (cv ICV 2) and sorghum (cv Serena), and plant age (3, 4, 5, 6 WAE). The arrangement was single alternate row, with a standard spacing of 45 cm x 20 cm for sorghum and cowpea. There were four replicates, one row per replicate. At weekly intervals starting from 3 WAE of the crop, 80 gravid *C. partellus* moths from a culture maintained on an artificial diet were released at dusk in the screenhouse. At 3 WAE there was no significant difference between the number of egg masses deposited on the cowpea and the sorghum. The egg masses on cowpea accounted for 41% of the total eggs deposited. This trend was maintained for the other periods but the total number of egg masses reduced with plant age. The ovipositional preference values for sorghum were positive for all stages of growth, but negative for cowpea.

1.14.2 Hatchability and survival of C. partellus *neonate larvae on cowpea*

The objective of the experiment was to determine the hatchability, survival and ability of neonate larvae on cowpea to locate the sorghum host. Two rows of cowpea at 20 cm interrow spacing were planted and sorghum plants were placed at six distances (20, 40, 60, 80, 100 and 120 cm) away from cowpea rows. About 150 cm were left between plants to avoid crossover of larvae between treatments. At 3 WAE egg masses of *C. partellus* at the blackhead stage were deposited on leaves of the cowpea and the sorghum plants. After 7 days, the sorghum plants were examined for foliar damage and dissected for stemborer larvae. The experiment was repeated three times. *Chilo partellus* eggs were able to hatch on cowpea but the number of larvae that arrived on the sorghum host reduced with increasing distance. Whilst an average of 8 larvae arrived per plant in the 20 cm distance, only 0.7 larvae arrived at 120 cm. There was a highly significant correlation between distance and the number of larvae arriving on sorghum. In conclusion, *C. partellus* is able to oviposit on cowpea in an intercrop. The eggs are able to hatch but the inability of some neonate larvae to arrive on the sorghum host leads to reduction of insect pest numbers in intercropping. This could be one of the mechanisms that leads to low insect pest incidence in intercropping. As this observation was made under the screenhouse conditions, its widespread occurrence in nature is being established.

1.15 ROLE OF OTHER CULTURAL PRACTICES IN IPM

K. Ampong-Nyarko, K. V. Seshu Reddy and K. O. Sum

The objective of this project is to identify other cultural practices that may be beneficial or detrimental to target insect pests and have potential for use in IPM.

1.15.1 Effect of fertilization on stemborer incidence

An experiment to study the effect of nitrogen and phosphorus and their interaction on stemborers was undertaken in the short rains of 1991 and the long rains of 1992 at Ungoye. Treatments consisted of factorial combinations of four levels of nitrogen (0, 45, 90, 180 kg N/ha) and two levels of phosphorus (0, 50 kg/ P_2O_5). There was a significant interaction between nitrogen and phosphorus. In the absence of phosphorus, stemborer incidence increased with increasing nitrogen levels but increase in nitrogen levels did not increase stemborer incidence when phosphorus was applied. The application of nitrogen together with phosphorus will enable the benefits of nitrogenous fertilizer to be realised without worsening the stemborer problems.

1.15.2 Non-crop vegetation and incidence of insect pests

The role of early season weeds on the incidence of insect pests was investigated under field conditions at Ungoye in the long rains of 1992. Treatments consisted of factorial combinations of five weeding regimes (no weeding, weed free, weeding once at 3 WAE, weeding once at 5 WAE, weeding twice at 3 and 5 WAE) and two cropping patterns (sorghum monocrop, sorghum and cowpea intercropped). In the monocrop the presence of weeds drastically reduced the borer incidence (16% incidence for no weeding compared to 50% in weed-free). Weeding once at either 3 or 5 WAE also reduced the pest incidence. Borer infestation in the two weedings was just as high as the weed-free, but in the intercrop the presence of weeds had little beneficial effects in suppressing the borer incidence.

1.15.3 Trap crop

An experiment was planted at Ungoye Field Site in the long rains of 1992 to determine the possibility of using a tolerant/susceptible established maize variety H-511 as a trap crop. The treatments consisted of ICZ 3 as main crop with either H-511 planted all round it or with one row of it alternating with 4 rows of ICZ 3, monocrops of each variety and an intercrop of ICZ 3 and cowpea. Borer incidence was low but the indication is that H-511 failed to protect ICZ 3 from stemborer attack as there was no significant difference between the ICZ 3 monocrop and ICZ 3 in the trap crops. The lowest incidence of borer of 10% was recorded in the intercrop compared to the 22% in trap crops and monocrops.

1.15.4 Residue management

An experiment on the integrated management of crop residues was initiated in the long rains of 1992. Treatments consisted of no tillage with sorghum stalk *in situ*, ploughing with sorghum not removed and sorghum mulch removed and ploughed. Differences between treatments were not significant but the least number of stemborers was recorded in the ploughed treatment with the stubble removed. The number of

thrips was significantly lower in no tilled plots (4 thrips/flower) and highest in ploughed with stubble removed (14 thrips/flower).

BIOLOGICAL CONTROL FOR PEST MANAGEMENT

Natural enemies play an important part in the regulation of pest numbers in the field. In the Crop Pests Research Programme, biological control activities have centred on pre-release studies on the larval parasitoid *Cotesia flavipes*, and field evaluation of certain insect pathogens: *Beauveria bassiana, Metarhizium anisopliae, Nosema marucae,* and *Bacillus thuringiensis*. Part of this work is reported here.

1.16 INTEGRATION OF *BACILLUS THURINGIENSIS* AND *NOSEMA MARUCAE* WITH A CHEMICAL INSECTICIDE DIPTEREX (TRICHLORPHON) FOR THE CONTROL OF CEREAL STEMBORERS

M. O. Odindo, Z. Ngalo, E. Ngugi, P. Amutalla, T. Onyango, B. Ouma and M. Yogo

In previous reports, it was shown that the local isolates of *Bacillus thuringiensis* as well as the microsporidian *Nosema marucae* can effectively control the spotted stalk borer, *Chilo partellus* when sprayed alone on either sorghum or maize infested with the pest. High increase of yields and reduction of plant damage have been recorded in both screenhouse and field trials.

When insect pathogens are applied at sublethal dosages, then insect mortality and pest control will only be partial, and considerable damage is caused to the infested plants. Similarly, a reduced level of chemical insecticides will not give complete protection to the crop. However, such low levels of a chemical insecticide may act as a stress-causing factor, which lowers the resistance of an insect to disease. Therefore, simultaneous application of a sublethal dosage of a pathogen and a low level of a chemical insecticide may give a sufficiently high level of crop protection, and assist in the conservation of the environment. This factor was investigated in the studies carried out during this reporting period.

Twelve rows of sorghum (var. Serena) were planted in the screenhouse at 50 cm between rows and 15 cm between plants. At 3 weeks after plant emergence, all the plants were infested with 1st instar *C. partellus* larvae at 20 to 25 larvae per plant, placed directly inside the leaf whorl. The larvae were allowed to settle on the plants for 24 h and then the plants were treated as follows:

Rows 1 & 2 (T_1) : Dipterex, 1 g/plant (recommended rate of application)
Row 3 & 4 (T_2) : *Nosema marucae* (concentration 1 x 10^8 spores/ml; recommended rate of application)
Row 5 & 6 (T_6) : Infested control (no pathogen/chemical)
Row 7 & 8 (T_4) : *Bacillus thuringiensis* 0.5% aqueous suspension + 0.5 g/plant Dipterex
Row 9 & 10 (T_3) : *Bacillus thuringiensis* 1% suspension (recommended rate of application)
Row 11 & 12 (T_5) : *Nosema marucae* 1 x 10^6 spores/ml + Dipterex 0.5 g/plant.

There were 3 replicates.

The plants were assessed every 2 days for foliar damage. At 5 weeks after plant emergence, all the plants were sampled and dissected in order to recover any surviving insects as well as dead insects. The level of stem tunnelling, number of entry and emergence holes and height of plants were also recorded.

The records showed that the full level of *Bacillus thuringiensis* and *N. marucae* and Dipterex resulted in the lowest foliar damage on infested plants. Foliar damage was highest on infested non-treated plants. The pathogen/chemical insecticide combination also gave a high level of protection and stem tunnelling was low in protected crops.

The results indicate that the sublethal dosages in combination with a reduced level of Dipterex gave a level of protection equivalent to full levels of pathogen and chemicals. Further investigations will be carried out in the field in order to evaluate the application of these pathogen/chemical insecticide combinations.

1.17 PATHOGEN PRODUCTION FOR PEST MANAGEMENT IN SMALL-SCALE FARMS: *IN VITRO* PRODUCTION OF *NOSEMA MARUCAE*

M. O. Odindo, M. Y. Oriwo, T. Anyango Odero, P. A. Amutalla, E. Ngugi, Z. Ngalo Otieno and T. Onyango

In previous reports, we have noted that the microsporidian *Nosema marucae* can be used adequately and effectively in the control of the spotted stalk borer, *Chilo partellus*. In order to make the pathogen available for crop protection, and to ensure its widespread use, we have investigated some factors pertaining to its production, especially at small-scale farm level.

1.17.1 Rearing Chilo partellus *larvae for pathogen production*

Larvae were reared in medium-size plastic lunch boxes (16.5 x 6.5 x 11 cm) covered with a fine wire mesh to facilitate efficient air circulation in the containers. Fifty newly emerged larvae were put on young sorghum stems and leaves placed in the boxes. The larvae were changed onto fresh sorghum leaves and stems every alternate day. Larvae were also reared on an artificial diet composed mainly of cocobeans and ground sorghum leaves. Larvae reared on the artificial diet were not changed, until required for pathogen production.

1.17.2 Preparation of inoculum

The inoculum for infecting borer larvae was prepared from freshly dead *C. partellus*. The insect cadavers were macerated in 20 ml sterilised distilled water, and the suspension purified by several passages through fine muslin cloth and alternate low- and high-speed centrifugation (2000 and 5000 rpm). The purity of the pathogen was checked at each stage of centrifugation using a phase-contrast compound microscope. The final concentration was adjusted to 1.2×10^7 spores/ml, which was used for pathogen production.

1.17.3 Inoculation of C. partellus *larvae*

Larvae for pathogen production were removed from rearing containers and dipped into a glass Petri dish into which about 0.5 ml of the pathogen inoculum had been pipetted. They were left in the pathogen suspension for 2 to 3 seconds, then transferred onto freshly cut sorghum stems which were placed in 8 cm diameter plastic Petri dishes. Ten larvae were reared in each Petri dish and stacked in batches in a shelf inside a temporary rearing shed. The diet was changed every 2 days when larval cadavers were also harvested. Records were taken on mortality, pupation, and adult emergence.

Microsporidian spore content in the dead larvae was verified by randomly selecting 25 cadavers, macerating in 10 ml distilled water, and determining spore concentration in a Neubauer chamber counter.

1.17.4 Yield of spores and pathogen storage

Over a three-year production period, larval mortality varied from 91.9 to 99%, and spore yield range was 1.3×10^6 to 4.9×10^8 spores/larva. Spore production in adults was low however. The larval spore content was equivalent to 8.2×10^7 to 3.1×10^{10} spores/g larval body weight. The larval cadavers were stored in plastic Petri dishes on shelves within the pathogen production sheds.

1.17.5 Adaptation of microsporidian production for small-scale farming

The production system used here is suitable for small-scale units, which can be easily adapted for rural communities. *Chilo partellus* larvae are hardy and are easily reared in re-usable plastic lunch boxes, on a natural diet of sorghum leaves and stems. A fairly modest system producing 10,000 3rd instar larvae per day, with a mean spore yield of 1×10^8 spores/larva would produce pathogens sufficient for more than 900 ha in a year. The efficacy of *Nosema* has been clearly demonstrated. Several production units of the type described here, if they were to be set up in the areas where *C. partellus* is a major factor, would revolutionise pest management in cereals in the tropics.

1.18 POTENTIAL OF ENTOMOPATHOGENIC HYPHOMYCETES (DEUTEROMYCOTINA) FUNGI FOR THE CONTROL OF THE STEMBORER *CHILO PARTELLUS*

N. K. Maniania, R. O. Okello, R. R. Oluoch and T. A. Odero

Strains of entomopathogenic fungi (Hyphomycetes) were demonstrated to be pathogenic towards eggs and larvae of the stemborer *Chilo partellus* in the laboratory (1989 *ICIPE Annual Report*). We report here the results of field tests to evaluate the potential of selected fungal strains, and to study the influence of host plants on the microorganism.

Field experiments were conducted at Ogutu's farm at Mbita, South Nyanza, Kenya, during the short-rains of 1990–91, and the long-rains of 1991 to evaluate the potential of the entomopathogenic hyphomycetes *Beauveria bassiana* (Balsamo) Vuillemin (2 strains) and *Metarhizium anisopliae* (Metschnikoff) Sorokin (2 strains) for biological control of the stemborer *C. partellus*. Each maize plant was artificially infested with either two 12 h-old egg masses (short-rains experiments) or with one blackhead-stage egg mass of *C. partellus* two weeks after plant emergence. Treatments consisted of two applications of aqueous conidial suspensions of $2.3–5.0 \times 10^{12}$ conidia/ha (first treatment), and of 1.0×10^{12} conidia/ha (second treatment).

No significant effects of fungus treatments on 12 h-old egg masses were found, except in the case of *B. bassiana* isolate ICIPE 35 which killed 30% of egg batches. Compared to the controls, there was a significant reduction in the number of *C. partellus* larvae, level of leaf damage, and stalk tunnelling in treated plots. The performance of the different fungal species and fungal isolates was similar. When treatments and artificial infestations were in synchrony, one application of pathogens could significantly reduce the stemborer populations.

1.19 INFLUENCE OF SORGHUM HOST PLANT CULTIVARS ON THE ACTIVITY OF THE ENTOMOPATHOGENIC FUNGUS *METARHIZIUM ANISOPLIAE* AGAINST *CHILO PARTELLUS*

N. K. Maniania, K. N. Saxena and R. O. Okello

The influence of three cultivars of *Sorghum bicolor* (ICS 3, ICS 4 and IS 1044) on the activity of the fungus *Metarhizium anisopliae* on the stemborer *Chilo partellus* was investigated in the field and laboratory during 1991 and 1992.

The results of the field experiments showed that application of *M. anisopliae* to all three sorghum cultivars infested with egg masses at the blackhead-stage, resulted in a significant decline in *C. partellus* larval population density at all concentrations tested relative to the controls. There was no effect of either the cultivar ICS 3 or ICS 4 on the efficacy of *M. anisopliae* against the stemborer larvae during the two seasons, although with the cultivar IS 1044, the larval population density under treatment with a dose of 1.0×10^{12} conidia/ha was significantly higher in 1991 and lower in 1992 than on other two cultivars.

An increase in the fungal concentration was generally followed by a reduction in the larval population density and subsequent damage to the

Table 1.2 Mortality and time-mortality responses of third-instar larvae of *Chilo partellus* reared on three sorghum cultivars and exposed to a dose of 3.0×10^7 conidia ml^{-1} of *Metarhizium anisopliae*

Sorghum bicolor Cultivar	Total mortality[1]	Mortality caused by fungus[1]	Lethal time 50% LT_{50} (days)[2]
ICS 3	65.3 ± 2.4^a	51.5 ± 7.0^a	7.9 ± 0.1^{ab}
ICS 4	66.9 ± 8.5^a	47.7 ± 8.9^a	9.8 ± 2.2^a
IS 1044	77.7 ± 7.3^a	72.3 ± 10.2^a	4.9 ± 0.7^b
Artificial diet	80.5 ± 5.5^a	70.5 ± 8.1^a	5.1 ± 0.9^b

[1]Angularly transformed percentage of larval mortality; mean ± SE. Means were corrected for control mortality using Abbott's formula.

[2]Lethal time for mortality caused by fungus only. Means followed by same letter are not significantly different ($P = 0.05$).

host plants. However, significant differences between the effects of different concentrations were found only during 1991.

Larvae fed on different cultivars and inoculated with the fungus at a dose of 3.0×10^7 conidia ml^{-1} in the laboratory, did not vary in their susceptibility to the pathogen. Also, differences between total larval mortalities and mortalities caused by the fungus (noted by the presence of fungus on the cadaver) were not significant. However, the LT_{50} was shorter in cultivar IS 1044 than in cultivars ICS 3 and ICS 4 (Table 1.2). Compatibility of fungus with cultivars is, therefore, an important consideration for using fungi for biological control of the stemborer.

1.20 CLASSICAL BIOLOGICAL CONTROL OF *CHILO PARTELLUS*

W. A. Overholt

The ICIPE and the Department of Entomology, Wageningen Agricultural University, are jointly implementing a collaborative project on biological control of crop pests. The project has initially focused on biological control of the spotted stemborer, *Chilo partellus*. This pest was selected as a target because of its economic importance and its status as an introduced species in Africa.

Chilo partellus was first reported in Africa from Malawi in the 1930s, and has since spread to most countries in eastern and southern Africa. One pest management strategy that has been successfully used against many introduced pests is classical biological control, whereby natural enemies of a pest in its aboriginal home are introduced into the area the pest has invaded, thus re-establishing the pest/natural enemy relationship. The objective of the project is to introduce exotic parasitoids of *C. partellus* into Africa from its aboriginal home in Asia.

One promising exotic natural enemy of *C. partellus* is *Cotesia flavipes*, a small braconid wasp that we have imported into Kenya from Pakistan. *Cotesia flavipes* is a gregarious endoparasitoid that attacks medium and late instar stemborer larvae in the plant stems. The female parasitoid oviposits in the host and eggs eclose after about 3 days. The emerging parasitoid larvae feed internally for 10–12 days and then exit the host by chewing through the integument. Once outside the host, the parasitoid larvae spin cocoons and pupate. Adults emerge about 6 days later.

Cotesia flavipes has been used in biological control programmes in many areas of the world, including Africa, against *C. partellus* and other stemborer species. The project is following a systematic approach to the introduction of *C. flavipes* by conducting intensive studies on its adaptability prior to making releases. The host range, host finding mechanisms, biology, and taxonomy of *C. flavipes* are currently being investigated in the laboratory. Through these studies, we hope to gain insight into the key factors influencing establishment.

The introduced pest, *C. partellus*, is only one species of a complex of stemborers found in maize and sorghum in Africa. The project is currently screening *C. flavipes* against these other stemborers to determine their acceptability for parasitisation and suitability for parasitoid development. Results of our work suggest that while all the stemborers we have examined are acceptable to *C. flavipes* for oviposition, only some can be successfully parasitised. This acceptability/suitability dichotomy may have been a factor in earlier failures to establish *C. flavipes*.

In some areas of eastern Africa, indigenous stemborers are more important than *C. partellus*, particularly at higher elevations. Presently, the only possibilities for classical biological control of native pests are through the use of natural enemies from closely related pests in other areas of the world, or through the redistribution of natural enemies within a pest's endemic range. To investigate the possibilities for the classical biological control of indigenous stemborers, we are currently organising collaborative arrangements with the Plant Health Management Division of the International Institute for Tropical Agriculture (IITA) at Cotonou, Benin and the Biological Control Facility of Texas A&M University. With Texas A&M, we plan to investigate the 'new association' hypothesis in classical biological control. The new association hypothesis asserts that natural enemies from species closely related to the target pest may actually have a greater potential for establishment and regulation of the target pest than its co-evolved natural enemies.

The ultimate test of *C. flavipes* will begin during the long rains of 1993 when parasitoid releases will be initiated on the Kenya Coast. For the past year the project has been collecting data on stemborers and their natural enemies at eight locations on the coast. The release of *Cotesia flavipes* at three of these locations will allow the evaluation of local establishment, and monitoring of dispersal from the release sites. The following section provides additional details into the various lines of research the project is following in pre-release studies.

1.20.1 Population studies on stemborers at the Kenya Coast

In order to establish a baseline of information prior to the release of exotic parasitoids, population dynamics studies are being conducted on stemborers and their natural enemies on the Kenya Coast. Fields of maize and sorghum planted during both the short (planted October 1991) and long rains (planted April 1992) were sampled weekly at Mtwapa and Kilifi to determine the abundance of stemborers and their natural enemies, and their seasonal phenologies. The incidence and fate of *Chilo* spp eggs was monitored twice weekly at Kilifi during the long and short rains. Additionally, 6 farmers' fields were sampled every two weeks along a transect from the Tanzanian border to Malindi.

Sampling at Kilifi indicated that during the first two weeks of the short rainy season more eggs were oviposited in maize. However, over the entire season far more eggs were found in sorghum. Maize may be a more attractive site for oviposition during the initial stages of plant growth, whereas sorghum apparently remains attractive during the entire season. This is likely to be due to the continual availability of vegetative plant material in sorghum through tillering. Successful eclosion was recorded in ca. 30% of eggs during the short rains and about 50% during the long rains. Parasitism of eggs was higher during the short rains than in the long rains, suggesting that parasitoid densities build up during the year and make a greater impact on stemborer populations during the short rains.

The results of sampling at Kilifi were similar to those found in 1991. *Chilo partellus* was the dominant species in sorghum and maize during both growing seasons, usually accounting for > 90% of the total borer population. *Chilo orichalcociliellus* and *Sesamia calamistis* were also found but collectively accounted for < 10% of total stemborers. *Eldana saccharina* and *Busseola fusca* were quite rare in both crops on all sampling dates. Partial ecological life tables have been constructed for maize during the short rains and the second *C. partellus* generation of the long rainy season. The highest mortality in both seasons occurred during the egg stages with > 58% generational mortality in both the rainy seasons. Parasitism of small larvae was quite rare, although high mortality due to 'disappearance' suggests that predators may be an important factor. Generational parasitism of medium and large instar larvae was also low during the short rains, but increased slightly during the long rains. No pupal parasitoids were recovered during the short rains and parasitism of pupae was quite low during the long rains. These results suggest that parasitism of larvae and pupae is typically low and justifies the introduction of exotic parasitoids in an attempt to add mortality factors to fill the apparent ecological voids.

1.20.2 Seasonal synchronization of C. flavipes *with* C. partellus

To become established in a new geographic area, an exotic parasitoid must be seasonally synchronised with its host. As an adaptive survival mechanism, *C. partellus* aestivates as a late instar larva in response to the senescence of maize at the end of the rains. Aestivation is broken with the onset of the next rains, the larva pupates, and the emergent moth begins the search for suitable host plants. The exotic parasitoid, *C. flavipes*, must have a mechanism to survive during the periods when the host is aestivating. This could either be through entering a diapause itself, having the ability to locate and parasitise diapausing *C. partellus*, or locating non-aestivating hosts. These possibilities are being actively investigated in the field at the Kenya Coast and in the laboratory.

Aestivating and non-aestivating *C. partellus* larvae were exposed to *C. flavipes* in the laboratory. Parasitoids readily oviposited in aestivating larvae in an artifical laboratory environment. Parasitoid developmental time from oviposition to adult emergence was not different in aestivating and non-aestivating larvae, indicating that the parasitoids probably do not enter diapause in response to the host condition.

Field cage studies have been initiated to investigate the host-finding ability of *C. flavipes* for aestivating and non-aestivating larvae. Female *C. flavipes* are introduced into cages containing plants infested with either aestivating or non-aestivating larvae. Preliminary results suggest that *C. flavipes* is unable to locate aestivating hosts.

Sampling of wild perennial grasses at several sites on the Kenya Coast was initiated in 1992. Preliminary results indicate that *Sorghum arundinaceum*, *Pennisetum purpureum* (napier grass), and *Panicum maximum* are attacked by *C. partellus* throughout the year and the majority of the larvae do not aestivate. In particular, *S. arundinaceum*, which harboured the greatest number of *C. partellus*, may serve as a reservoir of non-aestivating host larvae available for parasitisation during the dry season. The presence of non-aestivating hosts in these wild host plants may allow the continual reproduction of *C. flavipes* during the non-cropping seasons.

1.20.3 Host finding behaviour of Cotesia *spp parasitoids*

The ability of a natural enemy to locate a suitable host in a complex environment, even where host densities are low, is critical to the successful establishment of a natural enemy in a new environment. Studies are being conducted in a tritrophic context to investigate the mechanisms involved in host habitat location and host finding of *C. flavipes* and *C. sesamiae*. Experiments conducted in a Y-tube olfactometer indicated that uninfested maize plants were significantly more attractive to parasitoids than a control (empty pot of soil). When infested plants were compared to uninfested plants in a choice test, the infested plants were more attractive, suggesting that the presence of stemborers increases the concentration of attractive plant odours (synomones), or that additional chemical cues are present. Frass from several plant/borer complexes were all attractive to the parasitoids in no-

choice tests, but frass from *B. fusca* appeared to be less attractive than frass from other borers in a choice situation. Stemborers washed in distilled water were not attractive to parasitoids, indicating that compounds responsible for the parasitoid response are present on the surface of the larval body.

Work is currently focused on identifying the chemicals which mediate parasitoid behaviour, and the origin of these chemicals. Volatiles emanating from host plants and the plant/borer complex are being trapped and bioassayed for activity. Concurrently, gas chromotography and mass spectrometry (GC-MS) are being utilised to identify the compounds.

1.20.4 Acceptability and suitability of indigenous stemborers for C. flavipes

A complex of stemborer species occurs in maize, sorghum, and wild grasses on the Kenya Coast, and therefore when *C. flavipes* is released it will be faced with a choice in host selection. Results of host-finding studies suggest that the parasitoid responds positively to several host species. It is therefore important to determine the acceptability and suitability of these alternate indigenous stemborers for oviposition and development of *C. flavipes*. In laboratory experiments, *C. orichalcociliellus*, *S. calamistis*, and *B. fusca* were all found to be found to be acceptable for oviposition by *C. flavipes*. However, the suitability of the borers for development of parasitoid progeny varied. *Chilo orichalcociliellus* was as suitable a host as *C. partellus*. *S. calamistis* is less suitable than the *Chilo* spp, and *B. fusca* was not suitable. The results of this study imply that the success of *C. flavipes* to establish and regulate *C. partellus* may be limited in areas where *S. calamistis* or *B. fusca* are dominant.

1.20.5 Taxonomy of Cotesia *spp parasitoids*

It is currently believed that three ecologically similar species constitute the *'C. flavipes* complex'. All three species are gregarious parasitoids of stem boring pyralid or noctuid larvae that attack the stemborers once they have entered the plant stem. *Cotesia sesamiae* is native to Africa, *C. flavipes* is widely distributed from Australia to Pakistan, and *C. chilonis* is limited to Japan and China. These three species are extremely difficult and sometimes impossible to distinguish using characters relating to external morphology. These difficulties have partly confounded efforts by biological control workers to assess the impact of imported *Cotesia* spp on populations of stemborer pests. Morphological and biochemical studies are being conducted to clarify the systematics of the *C. flavipes* complex and to identify accurate methods to separate the species. Accurate identification of *C. flavipes* is essential for proper evaluation of establishment and impact following releases.

Previous workers found that the shape of the male genitalia could be used to distinguish *C. sesamiae* from *C. flavipes*. However, dissection and slide mounting of the genitalia is a tedious process which may not be practical when examining large numbers of recovered specimens. Morphometric studies conducted by the project on 16 characters from different populations of the *C. flavipes* complex from several areas of the world suggest that morphometrics may have use in separating the taxa. Furthermore, certain analyses suggest the possible presence of four taxa rather than three previously described.

Analyses have been conducted to determine the value of biochemical characters for separating the groups in the complex. Gel-electrophoresis using seven enzymes has been completed, but no diagnostic loci have been found which will consistently separate populations believed to represent the three species. Additional enzymes will be examined, but the initial results suggest that the three taxa may be closely related. Cuticular component analysis using gas liquid chromatography (GLC) has shown quantitative differences in the profiles of *C. flavipes*, *C. chilonis* and *C. sesamiae*.

Reciprocal crosses were made between all possible combinations of the three species to test whether the three species are biologically valid. Interspecific mating was observed between all combinations, but fertilization was only found between males of *C. sesamiae* and females of *C. chilonis*. The offspring of this cross were viable and produced both male and female progeny, suggesting that *C. sesamiae* and *C. chilonis* are not completely reproductively isolated.

1.20.6 Biological studies on C. flavipes *and* C. sesamiae

Cotesia flavipes and *C. sesamiae* have similar biologies and ecological requirements, and can essentially be considered to be ecological homologues. Both species attack the same stages of stemborers and there is overlap between the host ranges of the two species, with both successfully developing in *C. partellus*. Investigations are underway to identify biological differences which may suggest intrinsic or extrinsic superiority of one species over the other.

Studies have been initiated to determine the fate of parasitoid progeny when both parasitoids oviposit in the same *C. partellus* larva (multiple parasitism). Preliminary results suggest that regardless of whether *C. flavipes* or *C. sesamiae* parasitises the host larva first, *C. flavipes* is more successful in developing to the adult stage.

Investigations on the influence of temperature on the development of immature *C. flavipes* indicated that *C. sesamiae* developed more rapidly in *C. partellus* at 25 and 28°C, although there was no difference at 22°C. No *C. sesamiae* survived to the adult stage at 31°C and therefore no comparison between the species can be made. Survival of *C. flavipes* to the adult stage was higher than *C. sesamiae* at all temperatures.

The number of progeny per oviposition was significantly greater in *C. flavipes* than *C. sesamiae*. *Chilo flavipes* produced approximately three times more progeny per host than *C. sesamiae* when *C. partellus* was used as a host. The number of progeny per oviposition decreased dramatically for both species at 31°C.

1.20.7 Biologies of C. partellus *and* C. orichalcociliellus
The indigenous *C. orichalcociliellus* and the introduced *C. partellus* are ecologically very similar species. As recently as the late 1970s, they reportedly occurred in more or less equal numbers on the Kenya Coast. However, as discussed earlier, *C. partellus* was by far the dominant species during the long and short rainy seasons in 1991 and 1992. It appears that *C. orichalcociliellus* is being gradually displaced by *C. partellus*. Laboratory investigations on the biologies of the two species may provide insight into critical differences which have influenced the relative abundance of these two species.

Initial studies have been conducted to determine the number of larval instars and the duration of larval development for both species. When reared on *C. partellus* diet, *C. partellus* males went through fewer instars than *C. orichalcociliellus*, and a similar relationship was observed for females. The duration of larval development of *C. partellus* was significantly less than *C. orichalcociliellus* at 28°C.

Measurements of head capsules revealed no diagnostic differences between the two species in the first three instars. However, after the third moult, the head capsule of *C. partellus* was significantly larger than that of *C. orichalcociliellus*.

1.20.8 Genetic studies on C. partellus, C. orichalcociliellus, *and* C. partellus *parasitised by* C. flavipes
The genetic structure of *Chilo* spp populations in Kenya is being studied using allozyme electrophoresis. These investigations will provide insight into the intraspecific genetic variability of *Chilo* spp populations in Kenya. Furthermore, the identification of diagnostic loci for differentiating *C. partellus* from *C. orichalcociliellus* may be useful for separating the field collections of the two species. Finally, electrophoresis may also be used for estimating levels of parasitism due to *Cotesia* spp.

Collections of *C. partellus* have been made in different regions in Kenya and examined with electrophoresis. *Chilo partellus* has been sampled from western Kenya, and the coastal zone. *Chilo orichalcociliellus* has only been sampled from the coastal zone. Twelve enzyme systems have been examined for *Chilo* and *Cotesia*. Initial results indicate that certain allozyme patterns are characteristic of populations collected from different locations. One enzyme system has been found to be useful for quick differentiation of the two *Chilo* spp during all larval instars, including aestivating larvae which cannot be distinguished morphologically.

The potential of using electrophoresis as a rapid method for detecting parasitism by *Cotesia* spp has shown promise, although differentiating between parasitism by *C. flavipes* and *C. sesamiae* is not yet possible. Larvae parasitised by *C. flavipes* were electrophoresed alongside non-parasitised *C. partellus* and could be differentiated at 5 days after exposure.

BIOINTENSIVE PEST MANAGEMENT

R. C. Saxena

Growing concerns over the impact of agrochemicals on food safety and the environment necessitate that IPM should be practiced with minimum reliance on pesticides. This approach also takes into consideration the pest control needs of the resource-limited farmers in most developing countries, particularly in Africa, by emphasising biointensive pest management (BPM) (Fig. 1.1). In this framework, host plant resistance (HPR), comprising the use of pest-tolerant cultivars,

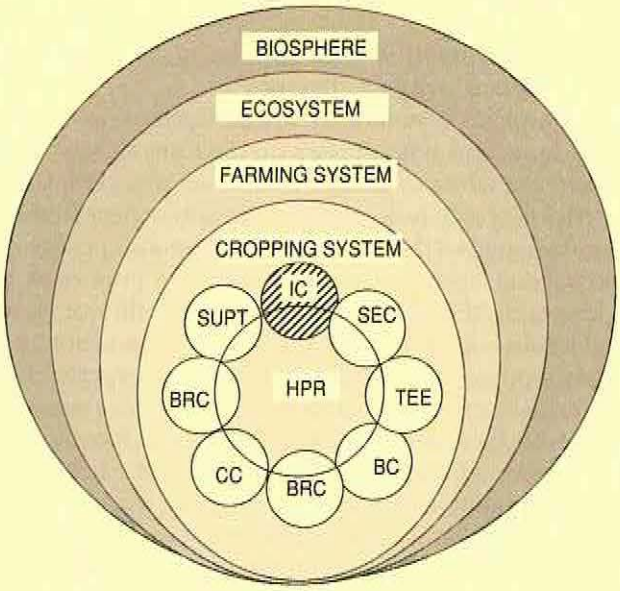


Fig. 1.1 BioIntensive Pest Management.

forms the hub and is driven by other pest management components: biological control (*BC*: predators, parasitoids, and microbials), botanical pest control (*BPC*: the use of derivatives of locally available plants with pest control properties), cultural control (*CC*: intercropping, companion-, and trap crops, improved landscape structure, adjustment of planting dates, crop residue management, etc.), bio-rational control (*BRC*: the use of pheromones, kairomones and allomones), and supportive tactics (*SUPT*: pest monitoring and surveillance with appropriate sampling tools and procedures, crop loss assessment, establishing economic injury levels, and thresholds for timely action). Insecticidal control (*IC*: use of synthetic insecticides) is used only as the last resort, when insect pest or vector outbreaks occur.

The menus selected for pest management have to be realistic and within the socioeconomic limits and capabilities (*SEC*) of the target farming community, and in harmony with existing cropping systems, farming systems, the ecosystem and eventually the whole biosphere. The target community has to be sensitised about the basic elements of environment conservation and biodiversity through training in

ecological education (*TEE*). In the event of nonavailability of pest-resistant cultivars, any other appropriate IPM component is ordained to play the pivotal role in conjunction with other pest management components.

1.22 BOTANICALS FOR PEST MANAGEMENT: NEEM SEED DERIVATIVES FOR MANAGEMENT OF COWPEA

*R. C. Saxena**

Derivatives of neem, *Azadirachta indica* have been used traditionally by small-scale farmers in Asia and Africa to protect crops from pests in the field and in storage. The plant's activity is based on many compounds which act as insect repellants, growth and reproduction inhibitors, among other activities. Research on neem derivatives and other botanicals has only recently been introduced into CPRP activities but it is planned that it will be incorporated into the biointensive integrated pest management (BPM) menus for control of cereal and legume pests. The neem tree is also widespread in many countries in Africa. We tested neem seed extract (NSE) and neem seed powder (NSP) for the management of cowpea insect pests in field trials conducted at the Mbita Point Field Station (MPFS) and at Ungoye Research Site during the long rains LR, (March to May 1992). A field trial was also conducted at MPFS during off season (July to October 1992).

During LR 1992, an early maturing cowpea cultivar ICV 2 was planted in 5 x 10 m^2 plots (60 x 15 cm spacing) as pure stands in five treatments, comprising high volume spray application of aqueous solutions of 1%, 2% or 3% NSE, or cypermethrin (0.049% a.i.); control plots were sprayed with water. Diammonium phosphate was applied at 200 kg/ha at planting time. The experiment was laid out as a randomised complete block (RCB) with four replications. At MPFS, the plots were sprayed at 38, 47 and 51 days after emergence (DAE); at Ungoye the plots were sprayed at 34, 42 and 52 DAE.

For the off-season cowpea trial at MPFS, the treatments comprised 3% NSE, NSP at 150 kg/ha, 3% NSE + NSP, cypermethrin, and the water-sprayed control. The experiment was designed as a RCB with four replications. Fertilizer was not applied during the off-season trial. NSP was applied basally at 30 DAE, while NSE was sprayed at 45 and 26 DAE.

At MPFS, pests were sampled initially per 20 cowpea hills at 33, 37, and 39 DAE using hand-held yellow wooden paddles, smeared with a thin coating of coconut oil. Thrips (*Megalurothrips sjostedti*) and the pod borer (*Maruca testulalis*) were sampled from 20 flowers per plot at 48 and 52 DAE. The pod-sucking bugs were recorded from rows 5 m long in each plot at 56 DAE.

In the off-season trial, thrips incidence was recorded by recording their number in 20 flowers per plot at 42, 47, 53, and 58 DAE. Yellow paddles were also used to sample the densities of predator spiders and wasps.

Cowpea grain yields (kg/ha) in all trials were sampled from a premarked 3 x 7 m^2 area in each plot. Data were analysed statistically using the Duncan's Multiple Range Test (DMRT).

In the trial conducted at MPFS in LR 92, thrips incidence was low at 33, 37 and 39 DAE, but increased during pod formation at 48 and 52 DAE in most treatments, except with insecticide. Neem treatments (2% and 3% NSE) significantly reduced the population of thrips larvae, compared with that in the control. In the trial conducted at Ungoye LR 92, thrips incidence was low at 33 DAE in all treatments, but increased several fold at 39 and 48 DAE in all treatments except insecticide. However, at 56 DAE thrips larval and adult populations were significantly greater in insecticide-treated plots than in plots sprayed with 3% NSE. NSE applications at 1 and 2% were not effective. In the off-season conducted at MPFS, thrips incidence was generally low in all sampling days at 42, 47, 53, and 58 DAE.

Table 1.3 Comparison of cowpea grain yield (kg/ha) in three plots treated with different concentrations of neem seed extract (NSE) and insecticide[1]

Treatment	Mbita (LR 1992)	Ungoye (LR 1992)	Mbita (off-season) (July–Oct. 1992)
NSE 1%	1783^{b}	466^{b}	869^{a}
NSE 2%	2089^{b}	717^{b}	798^{a}
NSE 3%	2289^{a}	1150^{ab}	941^{a}
Cypermethrin	2400^{a}	1683^{a}	988^{a}
Control (water spray)	1950^{ab}	433^{b}	693^{a}

[1] Within a column, means followed by the same letter are not significantly different at 5% level by DMRT. Averages of 4 replications. Diamonium phosphate was applied in trial conducted at Mbita and Ungoye during LR 1992, but not in the off-season trial conducted at Mbita.

During LR 92, cowpea grain yields at both MPFS and Ungoye sites in plots sprayed with 3% NSE were statistically equal to that in plots treated with cypermethrin (Table 1.3). There were no significant differences in cowpea grain yield obtained in various treatments and the control during the off-season trial, possibly due to low thrips incidence.

*E. L. Kidiavai, J. O. Ondijo,and D. Achiro provided technical assistance in this study

THE KWALE-KILIFI ADAPTIVE RESEARCH PROJECT

1.23 REPORT OF THE FIRST YEAR

S. Sithanantham, A. Oendo, M. Kiarie and I. Otieno

The people of Kwale and Kilifi districts in the Coast Province of Kenya are predominantly agriculturally oriented. The warm humid conditions together with the bimodal rainfall, tend to favour the multiplication and activity of most insects which include some

destructive pests of food crops especially maize, cowpea and sorghum. Maize and sorghum are known to suffer substantial yield loss while cowpea are attacked by several major insect pests, especially flower thrips, aphids, spotted (*Maruca*) borer and pod sucking bugs.

Since the technologies presently available for managing the pests are mostly unaffordable to the farmer and/or harmful to environment, there is the need to test (and if required refine) the environment-friendly and sustainable pest management technologies such as pest resistant cultivars and cultural practices.

The two major objectives of the project are to (i) increase food production and cash incomes of resource-limited farmers in Kwale and Kilifi Districts through increased knowledge and use of improved pest management practices of selected crops and livestock and to (ii) develop the IPM adaptive research capabilities of the Kenya Agricultural Research Institute (KARI), who are the executing agency (while the ICIPE is responsible for implementation).

This being the first year of the project, the emphasis was on understanding the local situation, building up the linkage with farmers and extensionists, and local testing of technologies for agroclimatic adaptation. In addition, relevant social science studies were carried out on farmers' perceptions, practices and attitudes.

1.23.1 Problem diagnosis/monitoring

The majority of the farmers were found to perceive pests as a source of substantial yield loss, but very few adopted any practice aimed at controlling them. On-farm monitoring of plots of maize and sorghum showed infestation by stalk borers to be substantial, especially in the short rainy season, confirming their importance as pests in the region.

1.23.2 Technology testing for local adaptability

Out of 16 stalk borer-resistant maize genotypes tested, five were identified as potentially adaptable. Among six pest-resistant cowpea genotypes evaluated, three were found to be locally adaptable. The suitability of 30 cowpea genotypes for intercropping with maize was assessed in the long rainy season. Many could grow satisfactorily and produce adequate leaves, but all produced very poor or no seed yield due to the high incidence of flower thrips and *Maruca* early in the season.

In sorghum, two genotypes were identified as locally promising out of four stalk borer-resistant entries examined. Early planting of maize, as another cultural practice, was shown to result in substantial reduction in stalk borer infestation, contributing significantly to enhancement in grain yield.

1.23.3 Technology refinement/acceptability

Consumer studies have been initiated for understanding the acceptance traits/criteria for varieties of maize and cowpea. The grain quality of the promising pest resistant genotypes of maize, sorghum and cowpea, especially their storeability, nutritional content and cooking qualities/taste are being investigated.

Based on the initial results and experiences, it is proposed to take the promising technologies to on-farm tests, so as to facilitate their joint evaluation by farmers, extensionists and scientists. It is hoped that these efforts will culminate in suitable refinements and promote the adoption of sustainable pest management technologies by the resource-limited farmers in the region.

See a summary of this project under Outreach on page 36, Part I of this Report.

UPLAND/LOWLAND RAINFED RICE IMPROVEMENT PROJECT

The Upland and Lowland Rainfed Rice Improvement Project started in the short rains of 1988/89 with the main objective of identifying suitable upland rice varieties for cultivation in western Kenya. The varieties are to have a high yielding potential, early maturity (90 to 120 days), good grain quality, resistance to major pests and diseases, good tolerance to local soils, ability to withstand low moisture, and resistance to weeds. The experimental material was obtained from IRRI and the African Upland Rice Observation Nursery.

Many promising lines have been identified and part of this work is reported here.

1.25 IMPROVEMENT OF UPLAND RICE

Z. Harahap, R. C. Saxena, K. Ampong-Nyarko and J. C. Olela

1.25.1 Advanced yield trial

Twenty upland rice varieties selected from 1991 short rains (SR) experiments were sown for advanced yield trials at Ungoye in the long rains (LR) 1992 on 18 March 1992 in rows 30 cm apart on 3 x 5 m plots in a randomised block design, replicated four times. Nitrogen (60 kg/ha) was top dressed at 40 days after emergence (DAE). Plots were not irrigated. The entries were moisture-stressed for almost a week from the time of seeding. Regular rains started about two weeks after seeding although scanty emergence had been recorded a week earlier. About 420 mm of rain was recorded during the 90 days of the cropping season. The five best entries IRAT 112 (1.3 t ha^{-1}), TGR 94 (1.3 t ha^{-1}), IRAT 229 (1.2 t ha^{-1}), ITA 257 (1.2 t ha^{-1}) and NO. 3290 (1.0 t ha^{-1}) matured in 82 to 98 DAE.

Maximum yield trial. The yield potential of top yielders, IRAT 112 and IAC 220/79 and early maturing IRAT 229 was retested at Ungoye LR 1992 and compared with their LR 1991 yield performance at the same site. The entries were sown on 20 March 1992 in rows 30 cm apart on 11 x 35 m plots in a randomised block design, replicated four times. Nitrogen (60 kg/ha) was top dressed at 40 DAE. Plots were sprinkler-irrigated once after seeding and four times after

emergence, the last being at one week before harvest (total irrigation comparable to 150 mm of rainfall). The natural rainfall was about 420 mm. The yields in LR 1992 were lower than in LR 1991 probably due to a delay in weeding, higher *Striga* infestation and uneven distribution of sprinkler irrigation (Table 1.4).

Table 1.4 Agronomic data of three upland rice varieties in maximum yield trials at Ungoye, LR 1992[1]

Designation	Height (cm)	Flowering (DAE)	Maturity (DAE)	Yield t/ha
IRAT 112	85	50	94	7.8 [a]
IAC 220/79	102	53	100	6.2 [a]
IRAT 229	85	49	88	3.8 [b]

[1] Total rainfall received from planting until maturity was 570 mm (natural rainfall, 420 mm and five times sprinkle irrigations, 150 mm). Means with the same letter are not significantly different at $P = 0.05$ by the Duncan's multiple range test. CV = 14.4%.

Varietal resistance to Striga hermonthica. Among 12 test entries, nine upland rice cultivars were identified as resistant, moderately resistant and moderately susceptible to *S. hermonthica* in field trials conducted at Ungoye and MPFS. The entries were grown in 3 rows 30 cm apart on 1.2 x 5 m plots in a randomised block design, replicated four times. The susceptible check IRAT 112, was grown alternately with the test varieties. At 81 DAE, *Striga* plants were uprooted plot-by-plot, sun-dried for 5 days and weighed. Varieties Tondano and IR 47686-4-2 had no *Striga* (highly resistant). IRAT 209 and UPR 103-80-1-2 had *Striga* dried matter less than 1 g/m^2 (resistant). ADT 31, Nam Roo and Mkosa Kabila were moderately resistant, while RPI 898-132-24-1 and IREM 190 were susceptible.

1.25.2 Preliminary screening of breeding lines for resistance to Striga hermonthica

Ninety-four lines derived from ICOX1 (Dourado Precoce/Ble Chai) and 48 progenies of outcrosses were planted in 1 m-long single rows (30 cm apart) at MPFS in LR 1992. The susceptible check IRAT 112 was sown at every 20 test lines. *Striga* plants were counted at 84 DAE. Lines with negligible *Striga* infestation were rated moderately resistant. ICOX1 progenies were either resistant or moderately resistant. A number of outcrosses showed drought tolerance and *Striga* resistance. These traits are being re-evaluated.

1.25.3 Selection for drought tolerance

A pedigree nursery of 1990 single panicles and 446 bulk selections were directly seeded in 1 m-long single rows for the pedigree and 5 m-long double rows for the bulk (30 cm apart) at MPFS at the end of March 1992. Plants were not irrigated. They were moisture-stressed because the rainfall was erratic. Soil cracked 2–3 cm deep in the field. At 90 DAE the total rains approximated only 436 mm (March 3.6 mm, April 127 mm, May 128 mm and June 145 mm). Drought spell durations were at 4, 15, 33, 54, 56 and 71 DAE. At 65 DAE when field soil moisture ranged from 3.5 to 10.4% at depths of 5, 10, 15 and 20 cm (average from 4 sites), several early lines derived from outcrosses of IAC 233/79, IRAT 112, ITA 257, IDSA 13 (IRAT 165), CNA 762069 and Ble Chai proved to be drought-tolerant and produced fairly good panicles at 75 to 90 DAE. Several ICOX1 progenies matured at 90 to 105 DAE. Due to recovery from moisture stress at night, morning scores were higher than ratings taken in the afternoon.

In another trial conducted at Ungoye, LR 1992, 115 lines were planted 3 rows each (5 m long, 30 cm apart). Delay in rains delayed emergence. Total rainfall of 420 mm was received in 90 days. The monthly rainfall distribution was March — 75 mm , April —165 mm, May — 135 mm and June — 23 mm. Fourteen lines were selected as drought-tolerant at Ungoye, LR 1992, most were progenies of ICOX1 and matured at 70 to 87 DAE.

1.25.4 Selection for tolerance to problem soils

Iron and Zn deficiencies were noticed at MPFS. Very few lines tolerated Fe and Zn deficiencies. Varieties IAC 272/78 and IREM 190 showed moderate tolerance. Several ICOX1 progenies tolerated Zn deficiency.

1.26 RAINFED LOWLAND RICE IMPROVEMENT

Z. Harahap, R. C. Saxena, K. Ampong-Nyarko and J. C. Olela

These trials were conducted at Kimira in Central Karachuonyo, Homa Bay District during LR 1992. Two observational nurseries, an advanced yield trial and a nursery for the demonstration plot were sown mid-February 1992. The first nursery comprising 250 entries (40 from ICOX1 progenies, 75 entries from Indonesia and 135 entries from LR 1991 selection) was sown in 5 m-long rows, 30 cm apart. The second nursery had 51 varieties/lines selected from LR 1991 trial, and 10 varieties from Indonesia which were planted on 3 x 5 m plots each at 30 cm apart in a randomised block design, replicated four times. Twenty-five promising varieties were planted under more upland conditions on a 0.5 ha plot. The varieties included all the adaptable, high yielding, early and drought-tolerant materials already tested by the ICIPE in western Kenya. The test materials were sown mid-February after a shower but suffered a month-long drought stress. Bird damage coupled with lack of rain after seeding added to the poor plant state.

Field conditions at Kimira were more representative of upland ecology with temporary submergence of 5 cm to 15 cm for two weeks at the maximum tillering stage. More rains came in between 75 and 95 DAE when some early varieties/lines were ready for harvesting. Upland rice varieties, such as IAC 220/79, IAC 233/79, GIC 165-80, BR 420-3-3-5, Tondano, Arias Baru and Laut Tawar, performed well. Two irrigated

varieties, Cisanggarung and Walanai also showed good growth. Varieties IR 42, IR 48, Pelita and Cisadane were not suitable for Kimira ecology. Swamp rice Alabio and Barito grew poorly. Upland rice variety IR 4725-B-B-5-2 was promising and had negligible bird damage, probably because of its erect and pointed leaves. More intensive trials, especially in the ecology with deeper submergence, are needed.

1.26.1 Pedigree nursery

These were selections from four previous trials tested for earliness, drought tolerance, *Striga* resistance, and problem soils. The selection included ICOX1 and 102 WARDA rice. Ble Chai or 47697-4-3-1 was planted as a check after every 10 entries which were sown in 1 m long rows (2 rows each, 30 cm apart).

Drought-tolerance studies. Three hundred and five entries being evaluated for drought tolerance, as well as other desirable agronomic traits are being planted in 3 m-long rows (2 rows each, 30 cm apart). They are still under observation.

Striga upland rice interaction. The promising upland rice varieties selected from previous trials conducted at Ungoye and MPFS are being tested for their reaction to *S. hermonthica* at MPFS during the season. They were planted on 1.2 x 5 m plots in a randomised complete block design, four replications each at 30 cm between the rows.

1.26.2 Results

Important characteristics to be included and improved for upland rice in a semi-arid ecology are high yielding ability, drought tolerance, early maturity (80–90 DAE), resistance to *Striga*, tolerance to Fe and Zn deficiencies and phenotypic acceptability including erect, pointed leaves to deter birds. IRAT 112, IAC 220/79, IAC 233/79, CNA 762069, GIC 165-80, IRAT 144, IAC 150/76, IRAT 283, IRAT 229 and IRAT 209 produced 7–9 t ha^{-1} under favourable conditions. Even under-minimal and erratic rainfall (420 mm) they produced 0.5 to 1.3 t ha^{-1}. These varieties should be included in the multilocation trials in western Kenya.

Ten upland rice varieties, IR 38547-B-B-B-7-2-2, IR 47255-B-B-B-5-4, IR 47697-4-3-1, IR 49255-B-B-5-2, B3913F-16-5-St-42, Ble Chai, Tondano, IR 47697-4-2, IRAT 209 and UPR 103-80-1-2 were resistant to *S. hermonthica*. Also, we have selected 30 *Striga* resistant breeding lines (ICOX1 progenies and outcrossed varieties). This reaction needs to be reconfirmed. Twenty lines maturing at 75 to 85 DAE were identified from outcrosses. IAC 272/78 and IREM 190 were tolerant to Fe and Zn deficiencies; 20 lines of ICOXI progenies and outcrosses were tolerant to Zn deficiency.

Kimira site had more upland-like conditions with frequent submergence of 5–20 cm for two weeks. Important varietal improvement traits for this ecology are high yield, drought and submergence tolerance, resistance to blast disease, earliness and plant type with erect, pointed leaves to deter birds. Thirty-five lines which performed well in this ecology were identified. Promising upland rice varieties such as IAC 233/79, GIC 165-80, IAC 220/79, Ble Chai, Nam Roo and Mkosa yielded 4.0 to 5.0 t/ha. Some introductions from Indonesia also performed well. Irrigated and swamp rice varieties such as IR 42, IR 48, Pelita I-1, Cisadane, Kapuas, Barito and Alabio performed poorly at Kimira. These need to be retested under deeper submergence. Sindano, a local check was susceptible to blast disease which devastated 50 ha rice in the surrounding area (at Kimira) during LR 1992. Blast resistance genetics should be incorporated into this breeding exercise. Water-logged and swampy areas in Kenya, which so far have not been utilised for food production, can be converted into productive lands by growing suitable rice varieties.

ICIPE-PHILRICE COLLABORATIVE RESEARCH PROJECT

The ultimate goal of the ICIPE/PhilRice research project on development of alternative IPM srategies for the yellow stemborer is to contribute to sustainable increase of rice production by small-scale farmers through reduction of losses to insect pests.

1.26 DEVELOPMENT OF ALTERNATIVE IPM STRATEGIES FOR THE YELLOW STEMBORER *SCIRPOPHAGA INCERTULAS*

H. Kumar

1.26.1 Population dynamics of the yellow stemborer

For adoption of integrated pest management strategies to combat stemborers, a critical monitoring of pest conditions is essential. Therefore, both adult and egg populations of *S. incertulas* were monitored during the dry season (DS) and wet season (WS) of 1992. The results show that the peak oviposition by the stemborer occurred in the fourth week of April, and declined until the third week of May. Oviposition by the stemborer increased again in the fourth week of May and declined to almost nil in the month of July.

The oviposition started again in the second week of August which culminated in a minor peak in the second week of September. Another peak oviposition was observed in the third week of October. Thus, during the period of 28 weeks for which egg-laying by *S. incertulas* was monitored, four ovipositional peaks were observed in April–May, May–June, August–September and October. The intensity of first and second peaks was stronger than that of the third and fourth.

The adults catches during the 28 week-period show that there were four clear peaks of flight activity by the yellow stemborer moths. The pattern of fluctuations of adult catches was almost similar to those of egg masses deposited by the moths. These observations show that the rice crop planted during the last week of June or first week of July would escape the attack against *S. incertulas*.

1.26.2 Evaluation of rices in the field under natural infestation for resistance to stemborers

The project objective excludes large-scale screening of rice varieties in order to avoid duplicating the work of other agricultural centres. Hence, the varieties selected for evaluation have been those found promising at various national and international centres. The rice varieties under evaluation are (i) those that combine adequate levels of resistance with acceptable yield and other desirable characters and can be used in IPM, and (ii) those that have a high level of resistance but poor agronomic characters and can serve only as sources of resistance.

Evaluation of rice varieties against the stemborer was done for overall borer-resistance and its major components in two stages:

Stage 1. The varieties were tested in replicated single-row plots under natural infestation with stemborer adults. These tests, though convenient for large scale screening, put different varieties close together. Consequently, their interaction, particularly the mixing of the sensory stimuli that they produce, may influence the behaviour of the pest and give a false picture of resistance. Hence, the varieties found promising at this stage were subjected to the next stage of testing.

Stage 2. This was done by planting each variety in multiple rows in larger plots to minimise or even avoid interaction among tested varieties. The parameters listed below were recorded.

Oviposition. Immediately after transplanting, each hill in a plot was carefully examined twice weekly and the number of egg masses recorded. The ovipositional preference/nonpreference by the moths on different rice varieties was compared.

Larval-pupal recovery. This was recorded at the time of harvest. For this study, almost 800 tillers were sampled. Each tiller was destructively sampled and the larvae/pupae of *S. incertulas* were recorded.

Percent deadheart. At five weeks after transplanting, each hill was examined and the number of healthy tillers and those showing deadheart were recorded. The percent deadheart was computed as follows:

$$\% \text{ deadheart} = \frac{\text{No. of deadheart in infested hills}}{\text{Total no. of tillers observed in infested hills}} \times \frac{\text{No. of infested hills}}{\text{Total hills observed}}$$

The percent deadheart was compared among the rice varieties.

Percent white heads. This was recorded at the time of harvest. Each hill was examined and of the productive tillers, those showing white head were counted. The percent white head were computed as described above for deadheart.

For each of the above parameters, the ratio of the value for a test variety to that for a reference (check) variety gives the relative index for that particular variety and resistance-component. The average of the relative indices of all four components gives the overall resistance level of the variety and is termed as overall resistance/susceptibility index (ORSI) relative to the reference.

The results (Table 1.5) show that the eight rice varieties which were subjected to first stage evaluation in single-row plots at the field station under natural infestation differed widely not only in ORSI but also in the way that individual components contributed to similar levels of ORSI. The varieties BPIRi 2, IR 60, and TKM 6 showed high ORSI values reflecting their susceptibility to stemborers. However, in BPIRi 2, the contribution of oviposition, larval survival and deadheart was greater and that of white head lower than for the variety IR 60. On the other hand, oviposition and larval recovery but not the deadheart contributed to the overall susceptibility of TKM 6.

The overall resistance/susceptibility index for IR 74 and IR 22 was equally low because of their high

Table 1.5 Relative differences in *Scirpophaga incertulas* infestation and damage to rice cultivars grown in single-row plots

Rice variety	Ratio of each parameter's value for a test cultivar to that of the reference check[1]				Overall resistance/ susceptibility index (ORSI)[2]
	Oviposition	Larval recovery	Dead-heart	White heads	
BPIRI 4	1.00 (2.7 ± 0.9)	1.00 (7.6 ± 1.9)	1.00 (14.6 ± 1.7)	1.00 (26.6 ± 2.9)	1.00
BPIRi 2	0.96	0.97	1.00	0.46	0.85
IR 36	0.89	0.91	0.80	0.97	0.89
IR 74	0.70	0.54	0.92	0.09	0.56
IR 66	1.44	0.67	0.92	0.99	1.00
IR 22	0.41	0.70	1.10	0.09	0.58
IR 60	0.63	0.93	0.86	0.98	0.85
TKM 6	1.85	1.20	0.49	-	1.18

[1]Reference check was BPIRi 4.
[2]Average of all parameter's values for each variety; the lower the (ORSI) value, the greater the resistance for that cultivar.

resistance to white head formation but very low resistance to deadheart formation. Resistance to egg-laying by *S. incertulas* was high in IR 22 but low in IR 74. Thus, varieties differed among themselves in terms of components of resistance.

Stage 2 evaluation showed that BPIRi 2, IR 36, IR 66 and IR 60 had almost equally high ORSI values. But the contribution of oviposition, larval survival and deadheart symptoms to the susceptibility of BPIR i 2 was greater than that of white head symptoms. In IR 36, IR 66 and IR 60, the resistance for each of the four components was equally low, resulting in overall susceptibility to stemborers. The variety IR 74 had the lowest ORSI value because of its high resistance to only one component, i.e., white head damage by the stemborers. Resistance to oviposition and deadheart was high but that to larval survival was low in TKM 6.

The observations also show that the variety TKM 6 had a high level of resistance to oviposition by stemborers in multiple-row plots but susceptibility to this component in single-row plots. This anomaly is possibly due to the fact that in single-row plots, the different varieties were put close to each other and thus the moths were unable to distinguish the sensory signals emanating from different varieties. On the contrary, in multi-row plots, the moths flying over the crop perceived distinct sensory signals from the varieties. Hence, they could select and oviposit on the preferred varieties only.

1.26.3 Mechanism of resistance in rice to the yellow stemborer

The objective of this study was to elucidate the plant related factors that determine the resistance or susceptibility of different rice varieties. This information can be useful to breeders for developing pest resistant varieties by incorporating the resistance-imparting or eliminating the susceptibility-imparting characters. The approach involves a two-stage investigation. In the first stage, the role of the insect's colonising responses are examined. The second stage examines the role of plant characters in governing the colonising responses of stemborer on rice varieties. During the current reporting period, study was initiated to elucidate the role of various colonising responses in determining resistance/susceptibility of certain rice varieties.

For this purpose, five rice varieties, namely IR 22, TKM 6, IR 60, IR 66 and IR 74 were selected. Seeds of each variety were sown in pots and seedlings were thinned to four/pot. The pots containing the seedlings were arranged in two separate sets. In the first set, five pots of each variety were arranged in a randomised complete block design in a galvanised iron tray containing water. At 7.5 weeks after planting, each tiller in a hill was artificially infested with 10 neonates of the yellow stemborer. To infest each tiller, the larvae were released on the second leaf from the base to simulate the emergence of larvae from eggs laid by stemborers on the leaves.

Forty-eight hours after the infestation, each tiller of a hill was destructively sampled. The number of larvae was recorded. The presence or absence of feeding lesions by the larvae on the plant was also recorded. A greater percentage of larvae moving from oviposition sites to the feeding sites on one variety than the other would reflect its suitability for the arrest of the larvae. In the second set, the five varieties were infested at 10, 20 and 40 larvae per tiller at 7.5 weeks after planting. Each pot with 4 hills was considered as a replicate. The treatments were replicated four times and the pots arranged in a randomised complete block design.

At 7 days after the infestation, the number of tillers showing deadhearts was recorded for each variety. The percent deadheart was computed on the basis of number of tillers showing deadheart and the number infested. At 15 days after the infestation, the percent deadheart was computed again for each variety. The tillers were destructively sampled and the number of larvae recovered from each variety was recorded. The larvae were kept in labelled glass vials and dried in an oven at 60°C for 24 h. The larvae were weighed to determine the biomass gained by them on each variety. A greater biomass gained by larvae on one variety than the other would reflect its suitability for the growth of the stemborers.

The results showed that when the varieties were infested with 10, 20 and 40 larvae/plant, the damage by the stemborer varied according to the variety and the infestation level. When infested with 10 larvae/tiller, at 7 days after infestation (DAI) the percent deadheart for IR 60 and IR 66 was lower than that for IR 22, IR 74 and TKM 6. At 14 DAI, almost 80–90 percent tillers of IR 22, TKM 6, IR 74 and IR 60 showed deadhearts. The incidence of deadheart on IR 66 was significantly lower than the remaining varieties. The larval survival on IR 66 was the lowest, followed by IR 74, TKM 6, IR 22 and IR 60. The biomass gained by the larvae was low for IR 22, TKM 6, IR 74 and IR 60, whereas it was high for IR 66.

When infested with 20 larvae per tiller, almost 90% tillers exhibited deadhearts for IR 22, TKM 6, and IR 74 at 7 DAI. Only 58% tillers showed deadheart for the variety IR 66. At 14 DAI, almost 100% tillers of all the varieties showed deadheart.

Larval survival was low for all the varieties. The biomass gained by the larvae was equally low for IR 22, TKM 6, IR 74 and IR 60 but was high for IR 66.

On infesting the rice varieties with 40 larvae per tiller, almost 100% tillers of each variety showed deadhearts. The varieties were completely destroyed. Larval survival was very low on all the varieties.

The observations given above show that the variety IR 66 possessed a moderate level of resistance against *S. incertulas* attack. No variety was resistant against high infestation by the borer. A low survival on IR 66 could be due to (1) high mortality of the larvae on this variety or (2) departure of the larvae from the plant because of its repellency or lack of attractancy. When the larvae were released on the leaves of the rice varieties for 48 h, a significantly low percentage of larvae established on the feeding site, i.e., stem, of

variety IR 66. Thus, a decline of the larval population occurred within the first 48 h during which the larvae move from their oviposition sites to the feeding sites on the rice plant. In view of this, it seems that a nonpreference type of resistance mechanism is responsible for low survival of larvae on IR 66. The antibiosis type of resistance mechanism does not seem to be operating with the resistant IR 66 because of a high biomass gained by the borer on this variety.

ICIPE-BMZ BANANA PROJECT

Among the key pests of bananas, the weevil *Cosmopolites sordidus* and a complex of nematodes are considered to be the most important agents in reducing banana yields and lowering the performance of the crop in the growing areas of eastern and central Africa. A few years ago, the ICIPE started a collaborative project on banana pests funded by the Federal Ministry of Economic Cooperation (BMZ) of the Republic of Germany to elucidate the factors responsible for the current decline of banana production in the East African region, especially those pertaining to the weevil, nematodes, and agronomic practices.

1.27 EVALUATION OF BANANA CULTIVARS FOR RESISTANCE/TOLERANCE TO THE BANANA WEEVIL *COSMOPOLITES SORDIDUS*

K. V. Seshu Reddy, M. C. Lubega, I. O. Mayoga and P. O. Ochanjo

The evaluation of twelve banana cultivars with different traits for resistance/tolerance was carried out based on the multiplication rate of the weevil and the extent of damage caused by it to banana rhizomes in the field. These cultivars include one roasting (Horn plantain — AAB); two beer (Mpologoma — AAA, Mutika — AAA), three cooking (Mbwazirume — AAA, Matumbo — AAB, Nakabululu — AAA) and six sweet (Bogoya pink — AAA, Nyoro — AAA, Kitembe — AAA, Sukali Ndizi Pink — AAB, Soth — AAB and Muraru — AA).

In the laboratory, three equal-sized rhizomes of about four months old were placed in a 60 litre plastic container for each cultivar and replicated four times. Ten females and 10 male adult weevils were released in each container and after two weeks the adults were removed. After a further 40 days, the rhizomes were sampled and the weevil population recorded based on the stages of development.

Among the 12 cultivars evaluated, the highest number (58.5) of insects developing and surviving at 54 days was observed in Mpologoma, a beer type of banana. The lowest survival rate observed was significantly different from that observed in the other cultivars except in the cooking types, Mbwazirume and Matumbo. In Soth, a sweet type, the average total population including larvae, pupae and adults observed was only 8.25.

At Ungoye Field Site, where the banana germplasm under the BMZ project is being maintained, the extent of damage caused by the weevil to the 12 cultivars was taken at the time of harvesting the bunches. This was done based on Visual Damage Rating (VDR) on a 1 to 5 scale, where 1 is no damage, 2 is 1–25%, 3 is 26–50%, 4 is 51–75% and 5 is 76–100% damage. It was found that the two beer cultivars had a VDR of 4 to 5, roasting and cooking cultivars 3 and sweet types 1 to 2. In Soth, Sukali Ndizi Pink and Nyoro, which are the sweet types, no damage was recorded.

It is evident from these studies that banana cultivar types are important in weevil development, survival and extent of damage caused. There seems to be no direct correlation between the genome grouping of a cultivar with the number of insects surviving or developing. However, the cooking as well as beer-type cultivars were found to be more susceptible to the weevil than the dessert types.

1.28 EVALUATION OF BANANA CULTIVARS FOR RESISTANCE TO THE LESION NEMATODE, *PRATYLENCHUS GOODEYI*

S. W. Waudo

Eighty-seven banana cultivars were screened for resistance against the lesion nematode, *Pratylenchus goodeyi* in five different tests. The tests were established at the Agricultural Research Institute, Maruku, Tanzania between September 1989 and May 1990. A completely randomised block design with four replications was used in all tests. Root damage due to the lesion nematode was assessed using a 0–4 rating scale, where 0 is no necrosis, 1 is 1–25, 2 is 26–50, 3 is 51–75 and 4 is 76–100% of a root being necrotic. Nematodes were extracted from roots using the maceration-sieving technique.

Banana cultivars differed significantly ($P = 0.05$) in their ability to support *P. goodeyi* in all the five tests. Njubo, a cooking type, supported significantly ($P = 0.05$) more *P. goodeyi* than Kikonjwa, Kiguruwe, Red sweet, Banana, Enshule, Jamaica sweet, Nkila, Kisubi and Nkonjwa Nshakara in test 1. Kimalindi, a cooking type, had significantly ($P = 0.05$) higher nematode numbers than those obtained from Ndibwabalungi, Nakawere, Mshare, Nkonjwa mafuni, Empindwi, Enyakumama, Kimula, Ndibwabalugi, Rumbugu, Nshansha II, Kisubi kanja, Pazi, Njurumuki and Rwondo in test 2. Namwezi, a cooking type, had a significantly ($P = 0.05$) higher number of *P. goodeyi* than Nyambo, Enkobe, Endibwabase, Entagola, Embululu, Kimpoma, Enyitabunyoni, Bagandebesa, Enyama and Endeisya. Entagolaza, a cooking type, supported significantly ($P = 0.05$) more *P. goodeyi* than Nyamaizi, Entemae, Nshashambile, Nshagya, Eushazi, Ngumba, Rwabugenda and Nkazi Mgumba in test 5.

The lesion nematode caused significantly ($P = 0.05$) more damage to the root systems of Namwezi, Nalugolima, Kalunge, Alingo, Enswella and Entama than to those of Nakabulu, Enyabwekonola,

Nandigombe, Entukuria, Nakitembe, Bandegeyo, Musakala, Nakabinyi and Goruguru, 600 days after planting.

The significant ($P = 0.05$) differences in *P. goodeyi* populations and root damages demonstrate that banana cultivars differ in their susceptibility to this nematode, a phenomenon that can be exploited in the management of the nematode in an IPM package.

1.29 HOST RANGE OF LESION NEMATODE, *PRATYLENCHUS GOODEYI* SHER AND ALLEN

A. A. S. Mbwana

The banana root lesion nematode, *Pratylenchus goodeyi* Sher and Allen was extracted from only four and five plant species out of 77 host plant species at 60 and 360 days after planting, respectively. *Musa* sp (cv Nyoya), *Tripsacum laxam, Commelina benghalensis, Hyperrnemia rufa* and *Plectranthus barbatus* were the plant species that supported the nematode. The lowest and highest numbers of nematodes/100 g wet root were extracted from *P. barbatus* and *C. benghalensis*, respectively, 60 days after planting. After 360 days after planting, *P. goodeyi* was extracted from *T. laxam*. The plant species *C. benghalensis* and *H. rufa* supported significantly ($P = 0.05$) more nematodes than other plant species including *Musa* sp, the known host, 60 days after planting. *Musa* sp (cv Nyoya) had the highest number of *P. goodeyi* 360 days after planting.

1.30 IMPACT OF INTERCROPPING AND MULCHING ON BANANA WEEVIL *COSMOPOLITES SORDIDUS* AND ON BANANA PERFORMANCE

B. E. M. A. Uronu

The impact of the three intercrops (banana and maize, banana and sweet potato, and banana and beans) and their respective mulches on the population of *C. sordidus* in the banana field was studied. There were no significant differences between the treatments on *C. sordidus* population changes when the four cropping seasons in 1990/91 and 1991/92 were investigated individually. However, a significant difference between the treatments on the impact to banana weevil population densities was shown when all the four cropping seasons were considered together.

Higher population indices of *C. sordidus* were recorded on mulches and on beans intercrop treatments which implied that they encouraged a conducive microhabitat for their increase. Low population indices of *C. sordidus* were shown by sweet potato intercrop treatment, and is likely due to a repellency effect.

Sweet potato and maize intercrops showed adverse effect on banana growth parameters and on yield due to mineral nutrient competition and shading, hence these are not recommended for intercropping with bananas.

Cultural practices, including banana intercropping and mulching for the control of *C. sordidus*, were found to take time to affect the population of the pest.

1.31 OBSERVATIONS ON NEMATODE AND WEEVIL DAMAGE ON SMALL BANANA SUCKERS

P. R. Speijer

Two banana nurseries were planted, one at Oyugis and the other at MPFS. The cultivars selected are shown in Table 1.6. Small suckers were collected at regular intervals and observed for nematode and weevil damage. The average incidence of nematode and weevil-affected suckers was 19% and 4%, respectively, in Oyugis and 17% and 9% at MPFS. The fraction of nematode and weevil-damaged suckers increased significantly with time at both sites. The incidence of nematode-damaged suckers was not significantly different in Oyugis or MPFS. However, at MPFS the fraction of weevil damaged-suckers was significantly higher than in Oyugis.

Table 1.6 Banana cultivars selected for resistance to weevil and nematode damage

Local cultivar name (genotype)		Use	Cultivar group
Giant Bogoya	(AAA)	dessert	Gross Michel
Gonja	(AAB)	roasting	French plantain
Kainja	(ABB)	multi-purp[1]	Pisang awak
Kivivuu	(ABB)	multi-purp[1]	Silver Bluggoe
Lusumba	(AAA)	cooking	East African Highland
Mbidde	(AAA)	beer	East African Highland
Nakyetengu	(AAA)	cooking	East African Highland
Sukali Ndizi	(AAB)	dessert	Ney poovan (AB), Silk (AAB)

[1] Multi-purpose cultivars can be used for brewing, cooking or eaten ripe. Beer and dessert cultivars can be cooked in case of famine.

PESTNET RESEARCH ACTIVITIES

1.32 PESTNET RESEARCH ACTIVITIES IN KENYA: STUDIES ON STALKBORER DAMAGE, YIELD AND ECONOMIC INJURY LEVELS

S. Kyamanywa

In 1991, PESTNET initiated studies to develop a simple method of determining economic injury level (EIL) based on natural infestation as well as to determine losses caused by stalkborers on maize and their EILs in different agro-ecological zones. At Mtwapa at the Kenya Coast, results indicated that the losses caused by stemborers depended on the time when maize plants were infested. The single plant analysis method was identified as an appropriate method of

determining EILs of stalkborers in the field under natural infestation. This research continued during 1992 in collaboration with the Kenya Agricultural Research Institute (KARI).

Results from Mtwapa show that maize intercropped with cowpea suffered less damage than the single crop. The number of plants showing leaf damage, mean holes per plant and mean leaf damage score were higher in the single crop than in the mixed cropping. However, there were no significant differences in damage between the two maize varieties, Coast Composite and Pwani Hybrid.

Stalkborer infestation was considerably higher in 1991 than in 1992. There were also more plants showing leaf damage symptoms during 1991 than in 1992.

The loss in yield (weight) caused by stemborers at the Coast depended on the time when maize plants were infested. Plants infested within four weeks after emergence (WAE) of maize suffered the greatest reduction in yield, followed by those infested between 4–8 WAE, and least or no loss at all in those plants infested late (more than 8 WAE) (Table 1.7). The relationships between leaf damage parameters and yield were significantly negatively correlated.

Table 1.7 Effect of time of infestation by stalkborers on yield of two commercial maize varieties at Mtwapa at the Kenya Coast

Cropping system	Time of infestation	Percent reduction in grain weight: Coast Composite	Pwani Hybrid
		1991	
Maize only	2 WAE	58.21	55.1
	4 "	51.90	33.8
	8 "	17.70	11.4
	Mean	52.5	33.4
Maize/cowpea	2 WAE	44.00	55.5
	4 "	26.36	33.8
	8 "	–0.13	28.76
	Mean	23.4	39.35
		1992	
Maize only	2 WAE	–0.4	–1.50
	3 "	55.8	22.90
	4 "	11.7	–0.90
	6 "	34.5	24.9
	8 "	30.0	–2.7
	Mean	26.5	–2.68
Maize/cowpea	2 WAE	–48.9	2.00
	3 "	33	7.40
	4 "		–60.10
	6 "	–6.80	–34.20
	8 "	15.1	35.90
	Mean	–1.92	–9.80

It is worth noting that in both years, there were significant interaction effects between intercropping and variety. Coast Composite suffered less yield reduction and also yielded more when it was intercropped with cowpea, while on the other hand, Pwani Hybrid suffered significantly more loss and also yielded less than when it was intercropped with cowpea.

Economic injury levels (EILs) calculated show that the early growth stages of maize are most susceptible to the maize stalkborer.

1.33 PESTNET RESEARCH ACTIVITIES IN ZAMBIA

C. Mugoya and K.C . Chinsembu

1.33.1 Screening of some maize cultivars for resistance to stemborers Chilo partellus *and* Busseola fusca *in Zambia*

The incorporation of stemborer resistance into existing maize cultivars is an essential component of maize improvement in Zambia. Screening of maize lines for resistance to the stemborers *C. partellus* and *B. fusca* on maize genotypes was carried out at the Golden Valley Research Centre. Open-pollinated and inbred lines from several sources, all of which have undergone improvement in the Zambian breeding programme, were artificially infested with 10 blackhead egg masses. Altogether, 14 maize cultivars were tested. These were: 660, 400, 857, Zuca, 574, 26, 289, 449, 363, 7316, MM400, 660 (N3-1752-1799), 544 (1474) and 512 (1413). Foliar damage and deadhearts were recorded at 3 and 6 weeks after inoculation, while number of larvae and tunnelling were recorded on 10 plants per plot at harvest.

In the *C. partellus* trial, cultivars 660, 400, 574, 26, 289, 449, 7316, MM400, 660N3, 544 and 512 presented low percent foliar damage. Foliar damage rating (scale 1–9) among seven of these cultivars was less than 2.7. Stem tunnelling, on the other hand, was significantly extensive in only one cultivar (574). Cultivars 26, 7316, 544 and 512 showed both low foliar damage as well as stem tunnelling, suggesting resistance to stemborer damage.

In the *B. fusca* trial, cultivar 857 showed the highest percent foliar damage as well as the highest foliar damage rating. Differences among other cultivars for all the parameters studied were not significant. This underscores the need to develop very sensitive methods of differentiating resistant, susceptible and tolerant maize genotypes. Owing to the persistent drought conditions that prevailed, most plants were attacked by termites which made the screening exercise rather difficult.

1.33.2 Role and preference of host plants maize, sorghum and wild hosts on stemborer complex in relation to the indigenous stemborer parasitoid Cotesia sesamiae

In order to establish the role and preference of host plants sorghum, maize and wild hosts *Hyparrhenia variabilis* (Stapf.) and *Sorghum verticiflorum* (Steud.) on the stemborer complex in relation to parasitism by

Cotesia sesamiae, ecological studies were carried out at Mt. Makulu and Golden Valley research sites on three stemborer species found in these areas: *C. partellus*, *B. fusca* and *Sesamia calamistis* Hampson.

Maize and sorghum were planted in opposite plots measuring 20 x 10 m. Plots were buffered from wild grasses and field edges by 4 rows of maize or sorghum. Popular maize and sorghum hybrids MM752 and WS287, respectively, were planted in 27 rows at the recommended spacing of 75 x 30 cm. Transects measuring 20 x 10 m of wild full-grown but green *H. variabilis* and *S. verticiflorum* verging on maize/sorghum fields were demarcated and by using a wooden frame, 27 quadrants measuring 0.25 m^2 were marked. 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 wild graminaceous hosts *H. variabilis* at Mt. Makulu and *S. verticiflorum* at Golden Valley. Weekly and fortnightly samples were taken throughout the season. On each sampling occasion two plants from each row of maize and sorghum and each quadrant of wild hosts (54 plants per population) were randomly selected and dissected. Number of stemborer larvae, species and stadia obtained were recorded. Live insects were maintained on their host plants for possible emergence of *C. sesamiae*.

Results obtained revealed that *C. sesamiae* did not parasitise first and second instar larvae. Secondly, *B. fusca* and *C. partellus* were the preferred hosts by *C. sesamiae* on maize and sorghum crops in both locations (Table 1.8). No *B. fusca* parasitised by *C. sesamiae* was recovered from the wild host *H. variabilis* at Mt. Makulu. On the other hand, *S. verticiflorum* sustained stemborers whose levels of parasitism were comparable to those of cultivated hosts. Stemborer infestation in wild hosts was generally lower than in cultivated hosts. Such low levels of infestation were, however, significant in that they sustained *C. sesamiae* parasitism as well as the stemborer itself during the long dry season when maize and sorghum crops were absent. All *S. calamistis* larvae recovered were parasitised in maize and in the wild host, while none were parasitised in sorghum.

1.33.3 *Studies on seasonal population patterns of stemborers* Chilo partellus *and* Busseola fusca *using pheromone traps*

For two consecutive years, we have monitored the flight phenology of *B. fusca* and *C. partellus* populations using pheromone traps. *Busseola* pheromone was obtained from ICIPE while the *Chilo* pheromone was obtained from ICRISAT/SADCC who also supplied us with the 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 in the ceiling of the trap. The number of moths caught each day was recorded and then added to give a total number of moths caught per week. Trends of trap catches and seasonal rainfall were then compared.

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

Table 1.8 Parasitism by *Cotesia sesamiae* at Mt. Makulu and Golden Valley, Zambia

Host plant species	Stemborer species	Mean larvae recovered/plant	Mean larvae parasitised	% parasitoid preference of different larval spp[1]
Mt. Makulu				
Maize	*B. fusca*	1.28	0.13	71.03
	C. partellus	0.31	0.04	20.03
	S. calamistis	0.02	0.02	8.19
Sorghum	*B. fusca*	0.75	0.05	60.00
	C. partellus	0.46	0.03	40.00
	S. calamistis	0.06	0.00	0.00
Hyparrhenia variabilis	*B. fusca*	0.03	0.00	0.00
	C. partellus	0.65	0.01	50.00
	S. calamistis	0.01	0.01	50.00
Golden Valley				
Maize	*B. fusca*	0.91	0.03	32.74
	C. partellus	0.36	0.04	38.05
	S. calamistis	0.21	0.03	29.20
Sorghum	*B. fusca*	0.60	0.67	47.61
	C. partellus	0.39	0.70	49.75
	S. calamistis	0.32	0.04	2.63
Sorghum verticiflorum	*B. fusca*	0.27	0.05	32.25
	C. partellus	0.01	0.10	64.51
	S. calamistis	0.02	0.01	3.22

Percent parasitoid preference of different larval hosts = $\frac{\text{mean no. parasitised larvae on a host spp}}{\text{sum of all parasitised larvae for each host plant spp}}$

between March and June. No moths were caught in the dry season starting in June. On the other hand, high mean trap catches of *C. partellus* moths were recorded from late December/early January rising gradually to October. An increased flight activity similar to that of the 1990/91 was recorded between mid-August and October.

These results are comparable to those recorded in 1990/91 season where *B. fusca* males were also caught in two distinct periods during the rainy season. Correspondingly, there were no rains between May to October and thus very few moths were caught. During that same period, *C. partellus* moths were also trapped from late April but shortly after the end of the rains in May a distinctly increased but brief flight activity was recorded. The presence of more rainfall in the 1990/91 season compared to 1991/92 seasonal totals appears to explain differences observed in the two seasons.

It is apparent that fluctuation of moths during the two years displayed a certain consistent pattern. Secondly, *C. partellus* peaks were usually preceded by periods of continuous and increased rainfall while *B. fusca* were first caught shortly after onset of the rains. This study showed that *B. fusca* was indeed the predominant borer species at the beginning of the cropping season. These results also infer that first generation *B. fusca* larvae pupate without diapausing. On the other hand, *C. partellus* is available almost throughout the year but its population is low at the beginning of the season.

1.33.4 Studies on the potential of Tephrosia vogelii *in the management of maize and sorghum stemborers*

Feeding biossays. Investigations on the role of *Tephrosia vogelii* Hook F in the management of stemborers were undertaken using extracts from flowers, pericarp and developing seed.

A standard procedure for extracting plant material was used. Plant material (50 g) was macerated in a blender for 5 min and extracted in 500 ml water. This yielded a crude extract containing 10% stock solution which was serially diluted into 5.000%, 1.250%, 0.625%, 0.313%, 0.156% and 0.0078% w/v concentrations and applied topically on maize leaf discs. Distilled water was used as a control. A feeding bioassay was carried out using maize leaf discs (cultivar MM 752) cut from 3 week-old plants. These were dipped into the extract for 30 seconds and placed in a Petri dish which was left open for 30 min. Newly emerged first instar larvae were then introduced into the Petri dish and the lid closed. The experiment comprised 3 replicates with 10 larvae per replicate and was arranged in a completely randomised design on a laboratory bench. Mortalities were observed after 12 and 24 hours.

Table 1.9 Percent mortality of 1st instar *C. partellus* larvae after treatment of maize leaf discs with crude extract of *Tephrosia vogelii* flowers and developing seed and pericarp

Concentration (% w/v)	Percent mortality recorded after 24 hours on different extracts		
	Flowers	Seed	Pericarp
0.0000	13	23	3
0.0078	23	36	3
0.156	23	80	10
0.313	10	73	33
0.625	23	90	3
1.250	60	100	26
2.500	76	100	40
5.000	60	100	33

Preliminary results obtained showed that aqueous extracts of flowers and developing seeds produced significant mortality rates as well as antifeedant action on the larvae, while the pericarp extract appeared to be ineffective (Table 1.9).

Oviposition bioassay. Manipulation of insect pest behaviour by repressing oviposition on its preferred host plant can effectively disrupt plant colonisation. Generally, insect feeding deterrents are also known to inhibit oviposition. This hypothesis was tested with regard to *T. vogelii* extracts. The aim was to investigate whether *T. vogelii* extracts inhibit *C. partellus* oviposition on maize. Two-week-old potted MM 752 maize plants were divided into three groups in a completely randomised design in the screenhouse. Leaves from the first group of plants acted as control and were sprayed with distilled water. Leaves of the second group of plants were sprayed with 10% w/v *T. vogelii* extracts. A choice oviposition test was carried out on the third group of plants. An equal number of randomly chosen leaves were carefully treated with the extract while the other were treated with distilled water. All potted plants were then covered with a netting material and a pair of newly emerged male and female moths were introduced and left for three days to oviposit.

Egg counts made after the experiment showed that most eggs were laid on plants in the control group sprayed with water. On the other hand, moths avoided laying eggs on plants sprayed with the extract, preferring to oviposit on the soil surface. In the choice test, the majority of eggs were laid on leaves sprayed with water while fewer eggs were laid on leaves sprayed with the extract (Fig. 1.2). This experiment demonstrated that *T. vogelii* leaf extracts also prevented oviposition in addition to being a phagodeterrent.

Field evaluation of an effective spray dose of T. vogelii. We carried out a field trial to evaluate the most effective spray dose of *T. vogelii* in suppressing stalk borer infestation. Stalk borer susceptible MM 752 hybrid maize was planted in plots measuring 6.9 x 5.25 m arranged in a randomised complete design with 3 replicates.

Tender *T. vogelii* leaves were pounded in a wooden mortar and six concentration levels ranging from 15% w/v concentration to 3% w/v were made. These were sprayed at weekly intervals in different plots from 5–9 weeks after emergence. Control plots were not sprayed. At 4 weeks after the commencement of spraying, counts were made of the number of plants showing foliar damage.

Results revealed that stemborer infestation was highest in unsprayed control plots. Percent plants

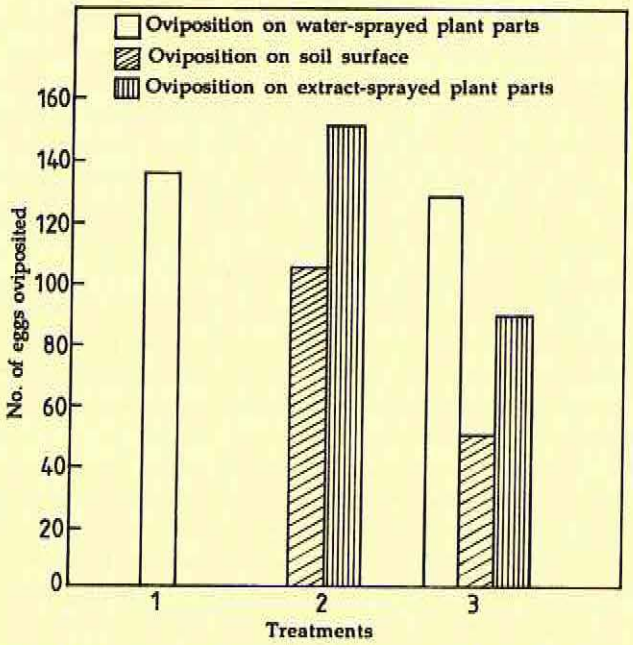


Fig.1.2 The effect of *T. vogelii* leaf extracts on the oviposition behaviour of *Chilo partellus.*

Treatment 1: leaves sprayed with water (control); 2, leaves sprayed with 10% extract; 3, choice test in which half number of leaves are sprayed with water and the other half with extract.

damaged by stemborers in control plots was almost 3 times higher from those sprayed with a 15% *T. vogelii* extract (Table 1.10). The results indicate that the extract was accountable for the foliar damage reduction observed.

Table 1.10 Percent maize plants showing stemborer folliar damage after application of various concentrations of aqueous *T. vogelii* extract

Extract concentration (w/v)	Percent plants attacked
0.0	61.5
3.0	20.1
6.0	18.9
9.0	33.7
12.0	34.9
15.0	19.7

1.33.5 Effect of early planting and use of resistant cultivars on incidence and severity of maize streak virus (MSV) on resistant and susceptible maize cultivars in farmers fields

The objective of this study was to use on-farm trials to demonstrate the advantages of early planting and use of a resistant cultivar in reducing incidence and severity of MSV on maize. The trial was set up in Mansa, Luapula Province on five small-scale farmers plots. Each farmer was requested to set aside 0.5 ha of land for this purpose. The land was divided into three plots. Two plots were planted with sole crop of maize cultivar MM 752 or ZUCA. In the third plot, both maize cultivars were alternately planted in different lines. All the maize were planted at the onset of the rains. Results showed that overall MSV incidence and severity on all farmers plots (except in the case of Mr. Chilufya's plot) were very low (damage rating on a scale of 1–5 was <3.0 in both cultivars) (Table 1.11). Planting of resistant and susceptible cultivars in the same plot did not appear to contribute to increased or decreased MSV occurrence.

Table 1.11. Maize streak virus (MSV) severity rating on farmer's fields on early planted MSV-resistant (ZUCA) and susceptible maize (MM 752) cultivars

Farmer	Cultivar	MSV severity rating on 1–5 scale
Mr. Siwale	MM 752	2.0
	Zuca	1.0
	MM 752 + Zuca	2.2
Mr. Nkandu	MM 752	1.8
	Zuca	1.0
	MM 752 + Zuca	1.0
Mr. Chilufya	MM 752	3.4
	Zuca	3.0
	MM 752 + Zuca	3.3
Ms Mwindula	MM 752	0.5
	Zuca	1.5
	MM 752 + Zuca	1.8
Ms Mwila	MM 752	2.8
	Zuca	2.8
	MM 752 + Zuca	2.6

**More information about PESTNET can be found under Section 11 Institutional Building, Interactive Research and Information (IBIRI)*

2
Locust Research

2.1 POPULATION DYNAMICS OF THE DESERT LOCUST *SCHISTOCERCA GREGARIA* IN A WINTER AND SUMMER BREEDING HABITAT

S. El Bashir and H. E. Abdel Rahman

Ecological conditions during the early part of 1992 (January–March) were conducive to successful locust breeding in the winter breeding zone along the Red Sea Coast of Sudan. Good rains which resulted in the outflow of many of the seasonal streams initiated the growth of various locust host plants and provided the required soil moisture for oviposition. Thus by mid-March, population density of solitaricolour locust was about 800 individuals per hectare. In April, vegetation in this zone dried out and no locusts were encountered; they had probably migrated to the mountain range where more favourable ecological conditions prevailed. Alternatively, they might have crossed the Red Sea to Saudi Arabia where spring breeding could take place. Regular monitoring of the coastal plain and the summer breeding zone during May, June and July showed no locust activity. However by July, some of the *Panicum turgidum* bushes started producing new shoots in the summer breeding area and some streams started to flow. Adult grasshoppers as well as 1st and 2nd nymphal instars of *Locusta migratoria migratorioides* were encountered in August.

Desert locust populations were recorded for the first time during early October in nine locations at the summer zone at a mean density of 220 adults/ha. By the end of October the mean density was 800 adults/ha and by December it was 2460 adults/ha; then the population moved to the winter breeding zone. A few swarms of gregaricolour locusts appeared in the Red Sea coastal plain in November and December; they laid eggs and scattered hopper bands were encountered almost everywhere south of Port Sudan. Judging by the colour, behaviour and number of eggs laid, there appeared to be two phases of the desert locust in the same location. However, morphometrically (F/C ratio) there was no difference between the two populations, indicating that the shift from the solitary to the gregarious phase was at its initial stages.

2.2 A METHOD FOR SAMPLING HOPPERS AND FLEDGLING ADULTS OF GREGARIOUS DESERT LOCUST POPULATIONS

S. El Bashir, C. Inayatullah, H. E. Abdel Rahman and A. O. Ahmed

Hopper bands (mainly 5th instars) and fledgling adults of *S. gregaria* were encountered together at Handoub (19° 13'N; 47° 14'E) in the Red Sea coastal plain of Sudan, during December, 1992. The habitat was uniformly covered with *Panicum turgidum* and *Salsola* sp, in addition to a wide variety of annual forbes and grasses. Plants of each of the two dominant species were classified as small, medium and large according to diameter, perimeter and height. Sufficient number of plants from each category were searched and all hoppers and young adults harboured in every plant were counted. *Salsola* sp was found to harbour three times as many locusts as *Panicum turgidum*.

Linear correlation analysis indicated that plant size had a strong positive correlation with the number of locusts harboured in it (r 0.07 – 0.85; t-test $P<0.01$). Simple linear regression models to predict numbers of locust individuals in different plant sizes were developed. Locust-infested and locust-free plants of the two dominant species were counted in 20 plots of 100 m^2 each. The percentage of infested plants in each size category was determined and the model was then used to calculate the hopper and adult locust population per unit area. According to the model, the estimated density was 157,000 individuals per hectare and the total population in the infested area of 4 km^2 was 62.8 x 10^6 locusts.

2.3 LOCUST MORPHOMETRICS

S. M. Ndugo, C. Inayatullah and S. El Bashir

Measurements of various body parts (length of body, compound eye, elytron, pronotum, forefemur, midfemur, hind femur, antenna, width of vertex, compound eye, head capsule and number of eye stripes) of a sample of solitary-reared and crowded locusts of every generation in the insectary were taken so as to monitor the occurrence of morphometrical changes. A total of 110 crowded and 215 solitary-reared individuals were studied. When these individuals were re-classified on the basis of E/F ratio, 5% of 'gregarious' and 47.7% of 'solitarious' individuals were mis-classified. Out of a total of 325 observed individuals, 175 (53.8%) were classified as 'transient'. When the re-classification was determined based on F/C ratio, only 1 (0.3%) individual was classified as 'gregarious', 178 (54.8%) were classified as 'solitarious' and 146 (54.8%) were classified as 'transient'. Most of the individuals of earlier generations of locusts reared in isolation were classified as transient. The solitary-reared locusts were true 'solitarious' after seven generations of isolated rearing.

Since the classification of individuals based on E/F and F/C ratios into true 'solitarious' or 'gregarious' groups is not consistent, a multivariate discriminant model is being developed to classify the individuals. MANOVA has indicated that the phases are distinct groups, and the group means are significantly different from each other.

2.4 DETERMINATION OF THE PHASE STATUS BASED ON MOLECULAR MARKERS

H. Mahamat, A. Hassanali, H. Odongo and E. O. Osir

2.4.1 *Chemometric markers*

Comparison of gas chromatographic patterns of cuticular components of the isolated and crowded desert locust *Schistocerca gregaria* from different sources at different physiological stages fed on different diets (millet, sorghum and wheat) showed varying differences which, however, were not consistently and significantly different so as to be useful in phase differentiation.

Volatiles from isolated and crowded locusts from one geographical source, when fed on the same diet, showed some interesting differences. However, to be sure that these can be used to characterise the two phases, we are studying volatiles from different insects of different geographical sources and developmental stages fed on different diets. Results of these studies will be reported next year.

2.4.2 *Protein markers*

Two-dimensional gels of haemolymph proteins of both isolated and crowded locusts have shown some differences. Similarly, differences in the protein patterns of the crowded and the isolated locust haemolymph were also found by polyacrylamide gel electrophoresis (PAGE). Some of these phase-specific proteins are now being isolated and purified for developing immunoassays.

2.5 PHEROMONE-MEDIATED MATURATION OF THE DESERT LOCUST

H. Mahamat, H. Odongo and A. Hassanali

Last year, we reported that extracts of the mature male desert locust accelerate maturation of the immature males. To determine if the factors involved are volatile, we designed a two-chamber bioassay with the upper chamber acting as the source of test volatiles (mature males, trapped volatiles or candidate compounds) and test immature insects placed in the lower chamber. No visual or tactile contacts were possible between insects placed in the two chambers. Based on this bioassay we observed that the presence of mature males accelerates maturation compared to immature males and mature females. Maturation of the males is associated with the appearance of several male-produced volatile compounds. These may be responsible for accelerated maturation. The compounds have been identified and are now being assayed. Maturation is being monitored by the appearance of yellow body colour in the males, specific haemolymph proteins and sexual activity in both males and females.

2.6 OVIPOSITION-AGGREGATING PHEROMONE OF *SCHISTOCERCA GREGARIA*

M. M. Rai, R. K. Saini, A. Hassanali, H. Odongo and J. R. Wawiye

Previous studies had confirmed that a chemical factor originating from egg pods caused aggregation of gravid females to common egg laying sites. Further experiments were conducted this year to determine the origin and chemical nature of the pheromone in choice experiments. Results indicated that the froth of egg pods and sand contaminated with it were more attractive (28% and 40%) than the control (17%). The eggs were not found to be attractive, indicating that the froth was the source of pheromone. Hexane and methanol extracts of froth contained the attractive materials. Results of these behavioural studies were also confirmed by electrophysiological investigations. Electroantennograms recorded with these extracts indicate that the receptors for these pheromones are present on the antennae.

Volatiles collected from froth were also found to be very effective in eliciting egg laying behaviour (79% compared to 21% control). Studies using GC-EAD and GC-MS are underway to determine the nature of active compounds.

2.7 ELECTROPHYSIOLOGICALLY ACTIVE COMPONENTS OF VOLATILES OF SOME HOST PLANTS OF *SCHISTOGERCA GREGARIA*

P. G. N. Njagi and B. Torto

Studies on the solvent-eluted airborne volatiles of several host plants of *S. gregaria* were carried out using GC-EAD technique to understand the mechanism of the learning behaviour of nymphs of *S. gregaria* in relation to their responsiveness to the host plant volatiles (*ICIPE Annual Report, 1991*) and to identify the chemical nature of the electrophysiologically active GC-peaks, some of which may also be active in modifying behaviour.

Gas chromatographic analysis of volatiles collected from sorghum (Graminae), *Schouvia* sp (Cruciferae), *Zygophyllum simplex* (Zygophyllaceae) and *Dipterygium glaucum* (Capparidaceae) showed qualitative and quantitative differences (Fig. 2.1).

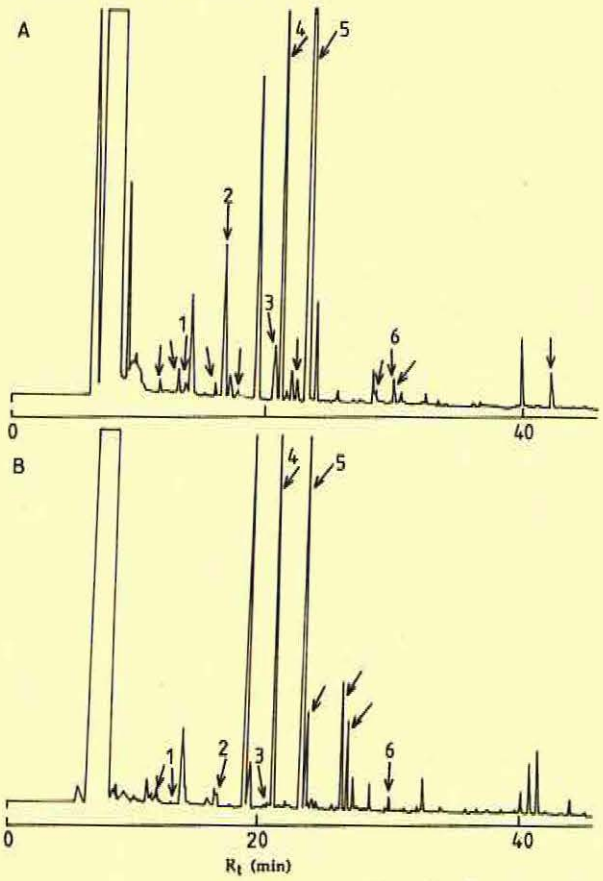


Fig. 2.1 Gas chromatograms of volatile collections from two host plants of the desert locust: A, sorghum (Serena) seedlings; B, *Schouvia thebaica*. Arrows indicate electrophysiologically active components of which 1–6 were common for both plants. RT, retention time.

Tests with volatiles on antennal preparations of adult mature males and females of *S. gregaria* showed that 10–16 GC peaks elicited EAGs and up to six of these peaks were common to all the plants (Fig. 2.1). The olfactory receptors on the antennae of 5th instar nymphae were less sensitive to the components of the plant volatiles and only 8 peaks elicited EAGs.

Preliminary Y-tube olfactometer bioassays with whole volatile collections from plants and some of the identified standards tested individually did not elicit significant responsiveness of 5th instar nymphae of *S. gregaria* when compared to the control, despite use of up to four different types of dispensers. Efforts have been made to design a wind-tunnel bioassay with improved stimulus delivery configuration. It is hoped that this will help in determining the usefulness of the individual EAG-active components of plant volatile collections and their blends in host location by the desert locust, especially the solitaria.

Identification of the electrophysiologically active components using GC-MS analysis is in progress.

2.8 STUDIES ON GREGARISATION/ COHESION PHEROMONE OF *SCHISTOCERCA GREGARIA*

D. Obeng-Ofori and B. Torto

Semiochemicals have been implicated in the gregarisation/cohesion of gregarious locusts. However, no detailed study has been carried out to elucidate the chemical bases for this behaviour. As a first step in isolating and characterising the semiochemicals involved in the gregarisation behaviour of *S. gregaria*, a more sensitive single chamber bioassay method and an efficient volatile-trapping technique have been developed. The bioassay system consists of a glass olfactometer fitted in the middle portion with a uniformly perforated aluminium metal plate and enclosed in an extraction hood (Fig. 2.2). Volatiles were collected on an adsorbent by drawing a charcoal-filtered clean air stream over locusts held in a sealed flask, using a suction pump.

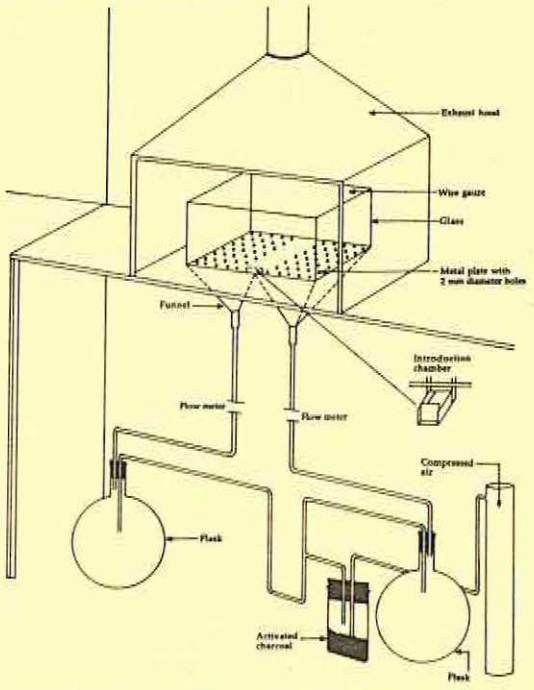


Fig. 2.2 Diagram of the bioassay system showing a glass olfactometer and a collection apparatus for the volatiles.

The response of crowded nymphs and adults to a choice of two columns of air, one permeated with airborne volatiles emanating from nymphs or adults and the other untreated, was investigated in the single-chamber bioassay arena.

In general, over 75% of the locusts tested showed preference for the volatile-treated column of the olfactometer compared to the untreated control. The nymphs, whether released individually or in groups, preferred to be within the precinct of the air column treated with airborne volatiles of the nymphs; however, the nymphs were indifferent to volatiles of the adults. Conversely, sexually mature adults responded only to their own volatiles but not to those of the nymphs or immature adults. The immature adults were responsive only to volatiles of the mature adults. Charcoal-trapped volatiles from the nymphs and the adults reproduced the effect of living locusts. These results indicate the mediation of two releaser pheromonal systems in the cohesive behaviour of *S. gregaria*: a juvenile pheromone produced by nymphs and an adult pheromone specific to adults.

Gas chromatographic analyses of the trapped volatiles from nymphs and adults indicate quantitative and qualitative differences in the profiles of immature and mature adults. Gas chromatography-electroantennogram (GC-EAG) responses were recorded from the antennae of adult male and female locusts when stimulated with the collected volatiles. Antennae of both male and female, crowded and solitary-reared locusts, responded to the same set of compounds in the volatiles. These compounds have been identified by GC-MS, and identical GC-EAG responses have been recorded for the standards. Behavioural bioassays on the identified compounds are currently in progress to elucidate their role in the gregarisation of *S. gregaria*.

2.9 SEX ATTRACTION IN THE DESERT LOCUST

C. Inayatullah, S. El Bashir and A. Hassanali

Experiments were continued to confirm the presence of a sex pheromone in the desert locust and to refine the wind tunnel used for this purpose.

Previously, the presence of a sex pheromone in solitary locusts was demonstrated. Further experiments were conducted to observe if a similar pheromone exists in the crowded locust. The treatments were male vs female (male released downwind while female held in a wire gauze cage covered with black muslin), male vs male, female vs male and female vs female. In control experiments, the male and females were released separately on the downwind side of the tunnel without keeping any individual in the wire gauze cage. In all treatments, the locusts on the downwind side of the tunnel travelled to the individual (whether male or female) held in the cage, indicating that the locusts were responding to a cohesion pheromone rather than to a sex pheromone. The cohesion pheromone in crowded locusts may be playing a role in bringing the sexes together.

It was observed that in the round tunnel (originally designed for tsetse fly), although the males showed sexual behavioural responses when exposed to female odour, they had a difficult time in locating the females. Since the tunnel was narrow (24 cm dia.), the males used to hit the walls when jumping (an important sexual behaviour) and slipped while trying to walk along the walls. After jumping several times they became over-excited, and became injured and exhausted. To overcome these difficulties, a flat-bed tunnel (150 x 60 x 40 cm) with an air-flow system of the pull-push type was designed and standardised. Previous experience also showed that the sexual behavioural events occur so fast that many important parameters cannot be recorded manually. To improve on recording of several simulataneously occurring behavioural events, the computer software OBSERVER was configured. The behavioural events were: time spent while resting, searching and walking in various locations of the wind tunnel, and frequency of behavioural acts such as peering, jumping, flying, movement, directional change, antennation, antenna cleaning, eye cleaning and rubbing of the forewing tips.

The treatments were male vs female (male released downwind, female in wire gauze cage covered with black muslin), male vs male, female vs female and female vs male. Separate controls were done by releasing males and females on the downwind side without an individual in the wire gauze cage. In the treatment male vs female, the males were able to reach the female; they spent most of their time in searching, peering and jumping frequently until they located the female. In all the other treatments and controls, the individuals (whether male or female) released on the downwind side simply remained inactive. These studies again confirm the presence of a sex pheromone in the solitary locust. Studies are in progress to determine the source of pheromone production and to determine the optimum age and time of release of the pheromone by the female.

The volatiles emitted by the mature solitary females have been trapped and studies using the EAG technique are in progress.

2.10 ORIENTATION OF THE DESERT LOCUST TO LIGHTS OF DIFFERENT WAVELENGTHS

A. O. Ahmed, C. Inayatullah and S. El Bashir

The orientation of the desert locust, *Schistocerca gregaria* to lights of different wavelengths was investigated with the aim of developing a trap for use in conjunction with semiochemicals, for monitoring solitarious and pre-gregarious populations in the field. The experimental arena consisted of a dark wooden tunnel, at one end of which a computer monitor was mounted. In single-choice tests, one side of the tunnel faced

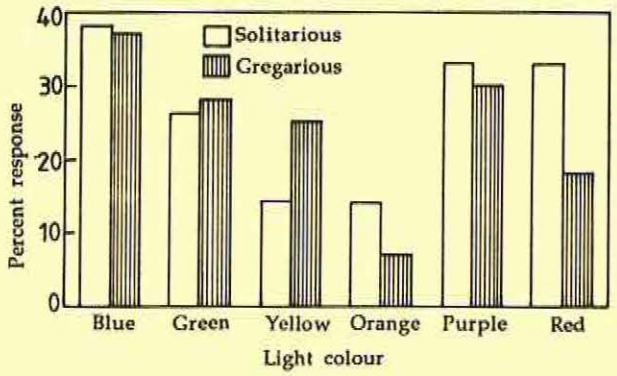


Fig. 2.3 Percent male *Schistocerca gregaria* locating targets of different colours.

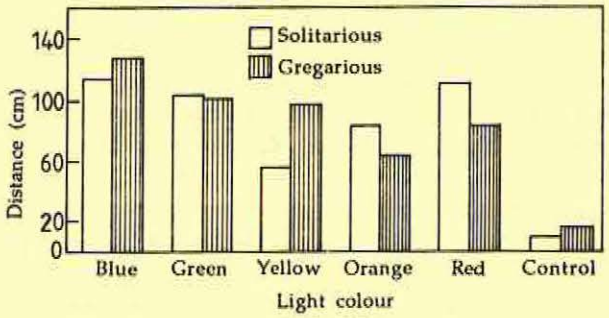


Fig. 2.4 Distance travelled by male desert locust towards light of different colours.

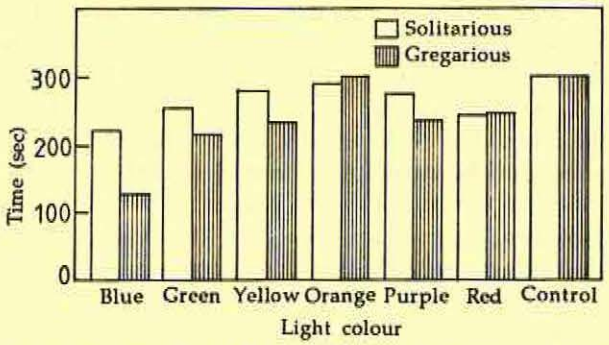


Fig. 2.5 Mean time taken by male desert locust to orient to targets of different colours.

towards the computer monitor having the test colour screen generated by using the computer software Dr. Halo. The spectral properties of the light emitted from the computer screen were determined by an Li-Cor Spectroradiometer. From the opposite side of the tunnel, adult males were released singly through a hole. Five minutes after release, the position of the test insect in the tunnel was marked, and the distance travelled by the male from the release point towards the computer screen was recorded. In two-choice tests, there were two computer screens with different combinations of colour screens placed at opposite sides of the tunnel, and the test insects were released through a hole in the middle of the tunnel.

The solitary-reared locusts responded maximally to blue wavelengths, followed by purple, red, green, orange and yellow, (Fig. 2.3). In controls (no radiation), all the test insects remained near the release point and showed no response. The distance travelled by the males from the release point towards the light source was maximum towards the preferred wavelengths, whereas it was minimum when least preferred wavelengths were tested (Fig. 2.4). On the other hand, the males reached the targets in minimum time when lights of preferred wavelengths were tested and *vice versa* (Fig. 2.5).

In two-choice tests (blue vs red), more males preferred blue to red and a few did not make any choice. The blue colour was more preferred than green or yellow. When the combination red vs green was tested, fewer insects responded to the former. The percent responding to each colour in the combinations red vs yellow and green vs yellow was equal and less than 50%. In these tests, most of the males did not make any choice and remained near the release point. When the mean response was pooled, it became evident that the response towards blue was more than three times higher compared to any other test colour, indicating that solitarious males prefer wavelengths in the blue region of the spectrum.

2.11 PATHOLOGICAL POTENTIAL OF THE FUNGUS *BEAUVERIA BASSIANA* AGAINST *SCHISTOCERCA GREGARIA*

K. Kambona, S. K. Raina and S. El Bashir

The study was conducted with the isolate BBA-NGI of *B. bassiana* to establish the pathogen-host range and virulence. The mechanisms of infectivity were initiated on the cuticle after 24 h with germ tube growth. Mycelia subsequently invaded the internal tissues of the host leading to its death. (See photo in Part I of this Report). Successive *in vivo* passage of the pathogen through host generations resulted in increased virulence. Peak mortality was achieved at a log dose of 5×10^7 conidia/ml following eight days of infection.

The principal abiotic factors affecting conidiospore activity were assessed. Formulations with different spray supplements were compared and the combined effects of the surfactant and the UV protectants were also evaluated. It has been observed that the conidiospore activity decreased with increased temperature, however the addition of surfactants was shown to sustain conidiospore viability at temperatures slightly above 35°C. The UV-protectants effectively improved the viability of conidiospores for a longer period than the controls.

Quantitative haemocytological tests were performed to demonstrate immune response of the host to conidiospore infection. Phenoloxidase and agglutination tests indicated that only limited immune response was induced.

Biological safety testing of the fungus was carried out against beneficial insects and mammals. The mass production of the fungus for field testing is underway.

2.12 ISOLATION AND CHARACTERISATION OF SOME HUMORAL FACTORS IN *SCHISTOCERCA GREGARIA* AGAINST INFECTION BY THE PROTOZOAN, *MALAMOEBA LOCUSTAE*

D. Dakouo, M. Brehelin, S. Essuman and S. K. Raina

Laboratory studies have established that *M. locustae* can cause only 80–85% mortality of the desert locust and that the survivors have lower fecundity than the controls. Understanding the nature of the defence mechanism of the survivors can help in developing methods for improving the pathogenicity of the protozoan and in making the desert locust more prone to infection. Our studies indicate that the responses to pathogenic infection are associated with activation and/or increased synthesis of humoral factors and cellular responses.

The highest phenoloxidase activity was found in the haemocytolysate fraction. Plasma might contain some inhibitors of the system. The highest agglutination titre was given by rabbit erythrocytes followed by suspensions of eland, buffalo and *M. locustae*. Negative agglutination reactions were observed only with red blood cells of sheep and goat. Out of 40 sugars tested, only three gave complete inhibition to agglutination reactions. Phagocytosis appeared to be a major factor in clearance of *M. locustae*. The highest level was reached 6 h after inoculation and clearance of cysts from live insects was completed after 48 h.

Lectin purification was done using an affinity column, methyl-α-D-galactoside-Sepharose 6B. The column was equilibrated with PBS Ca/Mg buffer. Plasma from 5th nymphal instars of *S. gregaria* was loaded into the column. Elution of the lectin was done using raffinose. Immunoblot analysis using antiserum raised against a lectin from *Locusta migratoria* indicated that lectins from the two species share common immunological characteristics. Moreover, the two lectins have the same relative mobility on SDS-PAGE. The lectin from *S. gregaria* which agglutinated rabbit blood cells and *M. locustae* cysts and the phenoloxidase system might be playing a role in the defence mechanisms in the surviving population of locusts against the protozoan infection.

2.13 DEVELOPMENT OF BROAD-RANGE PROTOZOAL BIOCIDES FOR LOCUSTS

S. K. Raina, F. Ondiek and S. El Bashir

The protozoa, *Malamoeba locustae* has been found to infect the desert locust, *Schistocerca gregaria* both in the field in the Red Sea coastal area of Sudan and in laboratory colonies at the ICIPE insectary, Duduville. In 1992 a field survey showed that migratory locust, *Locusta migratoria migratorioides* coexist with desert locust. Hence, it was felt necessary to develop a biocide that can infect both species with equal virulence. A colony of migratory locust was set up in the locust biocontrol laboratory at ICIPE and the F_1 third instars were inoculated with cysts of the protozoan, *M. locustae* isolated from infected *S. gregaria*. Pathogenicity after 20 days was only 18.5%. The infected migratory locust individuals were crushed and the isolated inoculum was given to third instar individuals of *S. gregaria*. The infection was found to be 92% on day 20. The biocide was isolated from infected *S. gregaria* and inoculated to F_2 survivals of *L. migratoria*. The pathogenicity increased further to 22% in F_2 adults in 20 days. The infected individuals were again used as an inoculum to a fresh batch of *S. gregaria* and more than 90% infection was recorded. Again the biocide was isolated and inoculated to F_3 third instars of the migratory locusts and the infection rate was increased. This criss-cross infection and selection procedure was repeated up to the F_4 generation when the infection rate in *L. migratoria* exceeded 80%. Thus a broad-range biocide of *M. locustae* has been developed. Safety tests are ongoing and the strain confirmation with ELISA is under investigation.

3

Livestock Pests Research

3.1 GENETIC VARIABILITY OF *GLOSSINA PALLIDIPES* AT NGURUMAN, SOUTH WESTERN KENYA

J. K. Stiles, L. H. Otieno, N. E. Darji and E. Mpanga

Monitoring of changes taking place in the gene profile of *Glossina pallidipes* population subjected to suppression by trapping was continued. Allele frequencies at the phosphoglucomutase (PGM) and phosphoglucose isomerase (PGI) in the fly samples from three localities in Nguruman, southwestern Kenya were compared using gel electrophoresis. Monthly fly samples were collected from a suppression area, non-suppression area (located 30 km away from the suppression area) and a site from the Nguruman escarpment. The three localities were typical of the Nguruman biotope. Genotype frequencies at the PGI and PGM loci were assessed at the different localities within a seasonal cycle of 12 months.

Certain alleles showed significant deviations from expected frequencies in some localities during certain months. Heterozygosity seemed to peak with the onset of the rains either in December or March (incidentally associated with optimised breeding conditions and increase in fly numbers). Rare PGI alleles disappeared during suboptimal conditions (hot/dry or cool/dry) and reappeared during periods of optimum temperature and humidity. It appeared as though certain individuals were susceptible to sub-optimal conditions. More than 80% of all alleles maintained their frequencies throughout a seasonal cycle with minimal variance and have similarly been maintained at these loci irrespective of the drastic decline in fly numbers (99% of population) by a 4-year tsetse suppression campaign. Comparisons of the results with previous data showed that an allele at the PGI locus which was hitherto rare or absent is currently present albeit at a low frequency ($\leq 10\%$). A consistent significant difference between representative parents and offspring emerging under laboratory conditions was observed among all flies.

3.2 DEVELOPMENT OF A TRAPPING TECHNOLOGY FOR *GLOSSINA FUSCIPES*

M. M. Mohamed-Ahmed, F. Oloo, L. H. Otieno, A. Hassanali, J. M. Muchiri and S. M. Mokaya*

The objectives of this project are to discover novel attractive odours and to improve existing trap designs for *G. f. fuscipes* and possibly other species of the palpalis group. It is expected that the effective odours will improve and render feasible control of this species with traps and targets, and will also provide better monitoring tools for residual tsetse populations following routine control operations.

A tsetse survey of the study area (*ca* 45 km of Lake Victoria shore, from Luanda to Ungoye, Mbita Division, Homa Bay District) was undertaken to define the limits of the distribution of *G. f. fuscipes*. The survey covered primary mangrove thicket habitats along the lake shore and secondary habitats further inland, comprised of thickets and woodland along water courses and hill gullies.

Experiments on diurnal activity of the flies were undertaken to determine the best time during which the flies would be available for a biconical trap in different biotopes. These experiments also provided samples of recently engorged flies (repletes) for blood meal identification to determine the host range of tsetse. Fly activity profiles were superimposed on those of the preferred host(s) to reflect correlations in diel activity patterns. Live preferred hosts, their waste products, and cured stuffed skins were investigated for their attractiveness for *G. f. fuscipes* occupying different habitats. In addition, conventional tsetse attractants derived from ox (e.g., phenols, ketones and octenol) and fresh hippopotamus dung were also investigated.

3.2.1 *Population ecology*

The preliminary results show that *G. f. fuscipes* exists mainly in mangrove forests along the lake shore and extends some 6 km further inland in thickets along

water courses and hill gullies. Biconical traps were found suitable in catching males and females approximately one metre from the edge of the mangrove biotope. Males predominated in catches from dense vegetation and dull days, while females from catches in open sites and bright days. Both sexes were available to traps primarily from 0900–1300 h. This activity pattern correlated well with that of the monitor lizard *(Varanus niloticus)* and temperature up to 29°C.

It was surprising that the blood meal identification showed that the monitor lizard constituted the only source of food for the flies (N = 33) although there was a high prevalence of other potential hosts in this area, including domestic animals (sheep, goat, cattle) hippopotamus, birds, rodents, small wild herbivores, green monkeys and man.

3.2.2 *Odour bait*

Phenols, ketones and octenol derived from ox waste products slightly increased the catch of *G. f. fuscipes* in biconical traps. Cow urine at high concentrations appeared repulsive, while a mixture of the phenols (*p*-cresol + 3-*n*-propylphenol) was significantly attractive for females, although not consistently. Monitor lizard aqueous wash was not an effective bait to *G. f. fuscipes*, whereas filtered monitor urine and fresh hippo dung significantly increased the catch of male and the total catch of *G. f. fuscipes*. There was no increase in the female catch. However, overall male and female catches increased with increasing doses of either waste product.

3.2.3 *Population dynamics*

Data on the population dynamics show that ground spraying (by the Ministry of Livestock of the Kenya Government) with cypermethrin had a very short-lived impact on tsetse. Flies were reduced by over 90% in the first month of spraying, but recovered to 50% of their pre-spray numbers 1–2 months later. Age grading showed that the majority of flies were young. This suggests that the spraying was effective against adult flies but not against those emerging from pupae a month after spraying. This indicates that the compound cypermethrin did not persist in the tsetse habitat for a month. The older flies caught in this area could have been either residual survivors of the spray or invaders from the neighbouring islands.

3.2.4 *Provisional inferences*

The tentative results described above show that the urine from monitor lizard and the dung from hippopotamus were attractive to male *G. f. fuscipes*. A mixture of phenols derived from ox urine (*p*-cresol + 3-*n*-propylphenol) was also attractive to females. There was evidence of repulsion of flies by high concentrations of cow urine.

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3.3 TSETSE BEHAVIOUR IN RELATION TO TRAP TECHNOLOGY: IMPROVEMENT AND ATTRACTION TO, OR REPULSION BY, ANIMALS

L. C. Madubunyi

Aspects of behaviour most liable to expose *G. pallidipes* to interception by static trapping devices and influence their trap entry response or choice of hosts in nature were the foci of investigations.

Probing responsiveness of both sexes during each of 8 stages of midgut evacuation (trophic categories, *ICIPE Annual Report* 1991) was explored as an indicator of foraging activity. It was found to increase exponentially during the first 4 midgut evacuation stages (MES), reaching a peak (100%) between MES 3 and 5, and to decrease steeply during the last 4 stages. Surgical assessment of *G. pallidipes* shortly after being caught in cow urine-acetone-baited NG2G traps at Nguruman revealed a total absence of flies at MES 1, a negligible percentage of those at MES 2 and a deficiency of those at MES 0 (tenerals), 3 and 4. The deficiency of the foregoing fly categories suggests that *G. pallidipes* at their peak of probing responsiveness (and presumably foraging activity) were weakly responsive to the trap odour-bait system used. The possibility that this reflects the low potency of cow urine/acetone as a tsetse attractant compared to animal (host) odour is being investigated further. The preponderance among odour-baited trap-caught *G. pallidipes* of individuals at MES 6, 7 and 8 suggests that the current generation of odour bait trap systems catch mostly *G. pallidipes* that were unsuccessful in locating a blood meal source readily. This hypothesis is strengthened by the observations that only 30–47% and 54–70% of trap-caught males and females, respectively ingested a blood meal from a calf shortly after entrapment; most of those which refused to feed were at MES 7 or 8.

A 4 x 4 Latin square experiment replicated 3 times was used to compare the *G. pallidipes* catch of two versions of a new trap design shaped like the NG2G but having 3 entrances, with that of the biconical (4 entrances) and NG2G (one entrance), respectively. Each trap was baited with cow urine and acetone. Both versions of the new trap design caught the same number of *G. pallidipes* but each caught significantly more flies than either the NG2G or the biconical trap ($P < 0.0001$). Thus, trap shape seems to be a major factor in the inferior catch of *G. pallidipes* by the biconical trap. However, among traps of comparable shape, the number of trap entrances seemed to have considerable effect on the size of tsetse catch.

The activities and behaviour of *G. pallidipes* around a cow urine/acetone-baited NG2G trap were observed from a distance of about 20 metres by means of binoculars (15 x 60) and a motorised telescope (30 x 60) during several sessions, each of 30 minutes duration, in the field. Attention was concentrated on the vertical black target and trap entrance.

On arriving in the immediate vicinity of the trap entrance, flies either flew straight upward into the cone or went off at a tangent away from the trap entrance or alighted on the black vertical target or horizontal shelf. Approximately 76% of the flies in the non-return cage entered the trap cone without alighting on any part of the trap. Most of the flies (approx. 87%) which alighted on the vertical target flew away from the trap while only about 13% entered the trap cone. Prior to either flying away or entering the trap cone, the flies spent an average of 20 seconds on the vertical target. No fly which entered the trap cone was seen exiting through the trap entrance. It seems that alighting on the black vertical target of the NG2G trap is not a prerequisite for trap entry. Most flies which ended up in the trap cone seem to get there as a result of trying to avoid collision rather than by recognising an entrance.

The NG2G traps baited with either a combination of acetone and the urine of established hosts (buffalo, cattle) or acetone plus the urine of a rare or non-host (waterbuck) of *G. pallidipes* were found to catch this tsetse in numbers that were not statistically different ($P > 0.05$). Chemical analysis of these urines revealed that they contained similar phenolic compounds. Implicit in these findings is a suggestion that, although animal urine may be a host habitat cue, it may not play an important role in the location, acceptance or rejection of animals as blood meal sources. It further suggests that the search for potent olfactory attractants or repellents of tsetse should target secretory, (e.g., body volatiles) rather than excretory products of animals.

3.4 ACTIVITY PATTERN OF THE TSETSE SPECIES *GLOSSINA AUSTENI* NEWSTEAD

M. L. A. Owaga and M. F. B. Chaudhury

Field sampling of *G. austeni* was carried out using two methods: continuous hand net catch in a stationary vehicle, and hourly trap catches using the biconical, the pyramidal and the NG2B traps. There were also separate day and night trapping periods. Laboratory observations were also made on fly activity in relation to feeding. Flies' take off/flight response to host odour was observed at different times of the day (from 0600 to 1700 hr).

The results showed that daytime catches were significantly greater than night time catch, but not significantly different from the 24-h continuous catch. The vehicle catch revealed that activity took place throughout daylight hours with two peaks, one occurring around 0900–1030 hr and the other between 1400–1700 hr.

The activity of starving *G. austeni* responding to host odour without any visual stimulus in a flight chamber in the laboratory, showed a similar bimodal pattern of activity. There was no significant difference between the (old) non-tenerals and the tenerals (young unfed). There was, however, some relationship between activity and temperature in the morning hours. Temperatures above 30°C coupled with bright sunlight resulted in reduced activity or no activity at the open vegetation on the edge of the forest. The fact that the pattern of activity persisted even under a 12 : 12 light : dark cycle under controlled temperature and humidity conditions suggests that the activity is controlled by an endogenous programme.

3.5 TRYPANOSOME INFECTIONS IN THREE CO-EXISTING TSETSE SPECIES AT THE KENYA COAST

M. L. A. Owaga

A study was undertaken in Muhaka-Shimba Hills area, Kenya coast, to determine the rate of trypanosome infections in three co-existing *Glossina* species, *G. brevipalpis* Newst., *G. austeni* Newst., and *G. pallidipes* Aust. The main objective was to assess the relative role of each species in harbouring, and possibly in transmitting, animal trypanosomiasis in the area. Sampling was carried out using four trap-types: the biconical, the NG2B, the pyramidal and the 4t-traps. Altogether, 1152 *G. pallidipes*, 1210 *G. austeni* and 755 *G. brevipalpis* were dissected and examined. The *Trypanosoma* species encountered included the *T. congolense*, *T. vivax* and *T. brucei* groups of trypanosomes.

The highest infection was observed in *G. austeni* and the lowest in *G. brevipalpis*, with *G. pallidipes* infection falling in between. The difference in infection rates between *G. austeni* and *G. brevipalpis* was highly significant ($P < 0.01$). *T. congolense* was significantly the most prevalent parasite in all the three *Glossina* species in Muhaka forest ($P < 0.01$), where the main hosts are suids. On the other hand, in the Shimba Hills game reserve, where the main hosts are bovids, the prevalent parasite species was *T. vivax*. The incidence of infection generally fluctuated with the seasons and apparent density of the fly populations. Higher infection rates were recorded during high levels of apparent density in all the three species, which coincided with two rainy seasons, April–June and October–November. No *T. brucei* was encountered in *G. austeni* either in Muhaka or Shimba Hills. Most of the *T. brucei* were detected in *G. pallidipes*, although some *G. brevipalpis* in Muhaka were found to be infected with *T. brucei*.

3.6 TSETSE VECTORIAL CAPACITY

S. Mihok, R. O. Olubayo, E. Munyoki, J. Stiles and E. Mpanga

Tsetse flies are not passive vectors of trypanosomes; they possess many 'immune' factors that can prevent infection (lectins, lysins, agglutinins, etc.). These factors are poorly characterised for most tsetse species, but show great promise for practical applications in manipulating infection rates in flies.

Preliminary transmission experiments on various tsetse and trypanosome species described in the 1991 Annual Report were continued. These studies were based on early dynamics of infection in *G. m. morsitans* and *G. m. centralis* infected with *T. congolense* or *T. brucei* mixed with goat, buffalo or eland blood. This work confirmed previous findings on the superior ability of goat blood in maintaining trypanosome infections in the fly. Goat blood appears to facilitate infection by protecting trypanosomes from natural clearance by the fly gut between days 3 and 6, after ingestion of a second blood meal. The processes responsible for this time-lag effect are currently under investigation with manipulations of host bloods.

To differentiate between lectin-mediated and protease-mediated clearance of infections, we conducted a survey of protease activity in flies fed on different host bloods and parasites, with or without the presence of a lectin inhibitor (glucosamine). This survey failed to detect any relationship between infection rates and protease activity under a variety of normal conditions. However, we found a synergistic effect on protease activity when both parasites and glucosamine were included in blood meals. Together, these factors substantially reduced protease activity, even though alone neither had an effect. These results suggest that glucosamine may not act as a simple lectin inhibitor *in vivo*. The biochemical basis for these observations is still under investigation.

3.6.1 Epizootiology of trypanosomiasis

The development of DNA probes for the characterisation of trypanosomes has revealed that *T. congolense*, an important parasite causing disease in livestock, is actually a complex of different genotypes, possibly even different 'species'. The role of these different parasites in disease in livestock has yet to be elucidated. Hence, we are developing techniques for the isolation of parasites so that we can assess the distribution of trypanosomes in vectors and in wildlife. These studies will lead to more specific targeting of control programmes, as well as strategies for wildlife management in areas of conflict between wildlife and livestock.

Collaborative studies with the Kenya Wildlife Service on the trypanosomes found in wildlife areas continued. These studies focused on the use of xenodiagnosis with *G. m. centralis* as a tool for isolating trypanosomes. Through this method, *T. simiae* was identified as the cause of an outbreak of disease in camels in Tsavo East National Park, Kenya. We also isolated *T. simiae* from a new host, the white rhinoceros, in an area without tsetse, but with numerous warthogs.

The new 'Tsavo' type *Nannomonas* reported in the 1991 *ICIPE Annual Report* was characterised in collaboration with ILRAD and KETRI. A DNA probe was developed; so far application of the probe has revealed the presence of the parasite in a few tsetse flies from other areas of Kenya. The parasite may be restricted to suids, as it causes a mild disease in pigs, but does not appear to infect bovids. Surprisingly, it is closely related to Savannah-type *T. congolense* rather than *T. simiae*, and has therefore been named as a subtype of *T. congolense*.

Field and laboratory experiments were started on the direct isolation of trypanosomes from the gut of tsetse flies through expansion in *G. m. centralis*. Through various manipulations of membrane feeding using goat blood, we have been able to transfer procyclic forms from all the major groups of tsetse (savannah, *fusca*, *palpalis*) to *G. m. centralis*. The technique has proved useful in identifying infections in wild tsetse and has provided us with a number of unusual isolates for characterisation. We are now using the method for three tsetse species about which we know very little in terms of disease transmisison: *G. brevipalpis*, *G. longipennis*, *G. swynnertoni*.

3.7 VECTORIAL CAPACITY OF *GLOSSINA MORSITANS CENTRALIS* AND *GLOSSINA MORSITANS MORSITANS* FOR DIFFERENT TYPES OF TRYPANOSOMES IN DIFFERENT MAMMALIAN HOSTS

R. O. Olubayo

A study was carried out to determine the infection rates in *Glossina morsitans* sspp experimentally infected with either *Trypanosoma congolense* or *T. brucei* and maintained on different mammalian host bloods. The main objective of this study is to explore factors within mammalian hosts which inhibit or promote parasite development, in an effort to disrupt the parasite cycle in the fly.

The pattern of infection in *G. m. centralis* and *G. m. morsitans* membrane-fed on goat, eland, and buffalo blood mixed with *T. congolense* or *T. brucei* was studied from day 1 to day 10. Tsetse were initially permissive vectors, with most flies harboring infection of 104 to 105 parasites on day 3. However, after a second blood meal on day 3, flies cleared many infections, with *G. m. morsitans* clearing more infection 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.

This effect was reproduced by feeding flies on erythrocytes, but not on serum. These results suggest that compounds from some mammalian erythrocytes act in a similar manner to midgut lectins, and hence have a protective effect on trypanosome establishment in the fly.

3.8 ODOUR BAITS FOR TSETSE FROM WILDLIFE

S. Mihok, E. Munyoki, J. Kiilu, C. Kyorku and A. Hassanali

Odour baits and traps for fusca group tsetse are at present relatively ineffective. In control programmes, these species often remain as residual components of

the tsetse community after the savannah species have been controlled. Hence, we have been exploring the use of waste products from wildlife as novel odour baits for tsetse trapping programmes. The initial work is concentrating on rhinoceros, elephant, and hippopotamus — three species often utilised by fusca group tsetse.

Experiments with rhinoceros waste products were completed with tests of both urine and dung under a wide variety of conditions in different areas of Kenya. Rhino waste products were as attractive to *G. pallidipes* as was cow urine. Chemical analysis revealed the presence of phenols similar to those found in cow urine that are known to be tsetse attractants. Unfortunately, we found no evidence for novel attractive properties in rhino waste products for two target species, *G. longipennis* and *G. brevipalpis*.

3.9 REPRODUCTIVE PERFORMANCE OF *GLOSSINA PALLIDIPES* FED ON VARIOUS HOSTBLOODS

J. O. A. Davies-Cole, R. Olubayo and P. Mwamisi

Except for the palpalis group, tsetse flies (*Glossina* spp) are generally regarded as being selective in the choice of hosts from which their bloodmeals are obtained. We wanted to know whether various host bloods could sustain *G. pallidipes* equally well. *G. pallidipes* was trapped at the Masaai Mara game reserve in Kenya. Non-teneral females were fed on laboratory mice soon after being removed from the traps, and were later brought to the laboratory in Nairobi.

Groups of 90 females were then maintained on rabbit, buffalo, goat, eland and waterbuck blood. Feeding was done through silicon membranes. The flies were maintained in the laboratory at a temperature of 25 ± 1°C, L:D 12:12 and 70–80% relative humidity. The following parameters were measured: daily puparial production, abortions, mortality and puparial weight. The experiment was terminated after 41 days.

Mean puparial weights were above 30 mg in any one group. However, mean puparial weight for flies fed on rabbit blood was higher (37.2 mg) than those fed on buffalo, waterbuck, eland or goat. The lowest mean was obtained for waterbuck-fed flies (30.8 mg). Mean puparial weight for rabbit-fed flies was significantly higher than those fed on goat and waterbuck ($P < 0.05$) but there was no significant difference between rabbit, eland and buffalo-fed flies ($P > 0.05$). There was also no significant difference between goat and waterbuck-fed flies ($P > 0.05$).

Abortions were very few, with not more than 10 in any group. The number of pupae produced by rabbit-fed flies was higher than those fed on any other host blood. Mortality was very high (84–99%) irrespective of the group. The number of puparia per initial number of females was highest (0.92) for rabbit-fed flies and the lowest was for goat-fed flies (0.67). These results indicate that the failure to maintain *G. pallidipes* successfully in the laboratory is not due to a deficiency in the quality of rabbit blood.

3.10 IMMUNISATION OF CATTLE WITH CHELICERAL DIGIT-DERIVED GLYCOPROTEINS FROM THE TICK *RHIPICEPHALUS APPENDICULATUS*

A. O. Mongi, T. R. Odhiambo, I. G. Onyango, J. G. Kabii, R. Chesang, G. K. Ochung and D. M. Munyinyi

To date, a number of protein components which show promise as protective immunogens have been detected from tick tissue extracts. Glycoprotein extracts from cheliceral digits were examined in detail this year.

Affinity-purified glycoproteins from *R. appendiculatus* cheliceral digits were prepared for cattle immunisation in two adjuvant systems. Humoral and cellular immune responses were produced by the glycoproteins incorporated in either adjuvant system. The immune responses were similar to those produced in laboratory animals immunised with solubilised extracts of fully fed female ticks of *R. appendiculatus*. Partial resistance to tick infestation was demonstrated by the significant reduction in adult and nymphal engorgement weights. Further reduction in infestation was shown by disruption of larvae and nymphs in their feeding positions as revealed by detachment and/or attachment to new sites. This led to a significant reduction in the number of tick instars able to feed successfully. The immune response also produced severe skin reactions characterised by the formation of oedema, serous exudation and large feeding lesions in the experimental (but not in the control) cattle. Some ticks were encrusted in the serous exudate while others appeared to be engorged with host fluids other than heme-containing erythrocytes, thus accounting for increased number of dead larvae and nymphs in these animals compared to controls. Both adjuvant systems produced adverse anti-tick effects compared to the controls. However, one of the adjuvants augmented the effects more than the other.

Antibody levels were detected in the experimental but not in the control cattle (using ELISA), thus confirming immunogenicity of the purified cheliceral digit glycoproteins. Subsequent identification of antigens that were possibly involved in eliciting the partial protection against the feeding ticks was carried out. Immunoblot analysis showed detection of four antigens with experimental (pre-tick challenge) sera while control (pre-tick challenge) sera showed no presence of these antigens. The detected antigens were estimated to have molecular weights ranging from 20,000–200,000 daltons. They corresponded to those detected earlier from whole tick extract (*1991 ICIPE Annual Report*) and suggested the possibility of being involved in triggering partial protection against the engorging ticks observed in this study.

The present study shows that cheliceral digits of the tick *R. appendiculatus* contain glycoprotein components that are capable of inducing partial

protective immunity against feeding ticks.

3.11 TICK-GUT ANTIGENS: PARTIAL PURIFICATION AND IMMUNOLOGICAL CHARACTERISATION

S. Essuman and P. Muteria

3.11.1 Immune protection potential of a glycoprotein

Through a lectin affinity column (Pharmacia) a relatively low molecular weight glycoprotein from the gut of *R. appendiculatus* was partially characterised. The glycoprotein, with some minor contamination, was eluted using 0.2 M methyl-α-D-mannopyranoside in TX-114-Tris-HCl buffer, pH 8.2. Protective effects of the fraction were studied in rabbits. The immune response induced reduced the mean engorgement weight by about 25%, the egg batch weight by about 20%, and hatchability by about 15% compared to the controls. There was no significant effects on the larvae and the nymphs. The relatively low level of protection induced by this glycoprotein might be due to application of inappropriate dose of the antigen. The experiment is being repeated using a higher dose.

3.11.2 The peripheral and integral proteins of the gut

We have recently initiated a study on the immune protective effects of the peripheral and integral proteins of the gut of *R. appendiculatus*. Triton X-114 is being used for this purpose. The homogenate is phase-partitioned into detergent and aqueous phases. Both phases, when used as immunogens, showed that the detergent phase (integral proteins) induced a higher protection against subsequent tick infestations.

On immunoblots, higher molecular weight polypeptides of the detergent phase reacted more prominently with the specific antisera (anti-integral proteins). Moreover, in immunisation studies, the high molecular weight polypeptides (> 60 kDs) induced a much higher immune protection than intermediate molecular weight (30 kDs – 60 kDs) and the low molecular weight (< 30 kDs) polypeptides. High molecular weight polypeptides will be electro-eluted from SDS-Gels and subjected to further purification procedures.

3.12 HUMORAL IMMUNE RESPONSES OF THE TICKS *RHIPICEPHALUS APPENDICULATUS* AND *AMBLYOMMA VARIEGATUM*

G. P. Kaaya, A. W. Muia and E. Ouna

Studies on the immune responses of economically-important livestock ticks, e.g., *Rhipicephalus appendiculatus* and *Amblyomma variegatum* to microbial and parasitic infections were undertaken in order to identify some of the humoral immune factors produced by ticks in response to bacterial infections.

Adult ticks were immunised by injection of *Enterobacter cloacae* 2 x 10^4 (lectins) per tick and haemolymph collected in micropipettes from amputated legs at various times after immunisation. Lysozyme assays were conducted in agar plates seeded with killed *Micrococcus luteus*. Known concentrations of egg white lysozyme were placed in agar wells to prepare a standard curve.

Lysozyme was found to be present in the haemolymph of both immunised and non-immunised *R. appendiculatus* and *A. variegatum*. In *A. variegatum*, it increased after immunisation, reaching a peak after 4 h and then declined gradually. In *R. appendiculatus*, the increase in lysozyme reached a peak 3 h post-immunisation. In both tick species, however, the increase in lysozyme concentration following immunisation was not very remarkable. This might be due to the species of the immunising bacterium or to the dosage.

3.12.1 Antibacterial activity

The antibacterial activity assays were prepared by seeding live *M. luteus* (a bacterium found to be most sensitive to tick haemolymph factors) in agar. Test haemolymph placed in wells created inhibition zones proportional to concentrations of antibacterial activity. As in the case of lysozyme, high levels of antibacterial activity were found in the haemolymph of both non-immunised and immunised ticks of both species. The concentrations increased after immunisation, reaching a peak between days 4 and 5 in *A. variegatum* and days 3 and 4 in *R. appendiculatus*. The increase in levels of antibacterial activity in both species of ticks following immunisation was just about a third of pre-immune levels and was therefore not remarkable. Unlike the response in other arthropods, e.g., the cecropis moth, *Hyalophora cecropia* and *Glossina morsitans*, normal tick haemolymph, and the immune haemolymph contain high levels of antibacterial activity, and the immune haemolymph does not seem to be active against *Escherichia coli*, *Bacillus subtilis* and even the *E. cloacae* used to induce the immunity.

3.12.2 Humoral lectins

The lectin assays were conducted in v-shaped microtitre plates in serial dilutions of 5 µl haemolymph in buffer to which 5 µl of erythrocytes (in buffer) were added and incubated overnight at 4°C. Initially, agglutination activity of tick haemolymph was tested with erythrocytes from rabbit, horse, sheep, cow, goat, dog, eland, buffalo and waterbuck. Rabbit erythrocytes gave the best agglutination results and were therefore used in all subsequent experiments. A total of 24 sugars and glycoproteins were tested for inhibition of lectin activity in tick haemolymph.

Lectin(s) were found to be present in the haemolymph of both the tick species, but titres were higher in *A. variegatum* (256) than in *R. appendiculatus* (32). The sugars that blocked lectin activity in the haemolymph of both tick species were *N*-acetyl-α-D-glucosamine, D-mannose and D(+)-fucose. On the other hand, Fetuin blocked lectin activity in the haemolymph of *R. appendiculatus* only, whereas D(+)-glucosamine blocked activity only in the haemolymph of *A.*

variegatum. Immunisation of both species of ticks with bacteria resulted in slight increases in lectin titres.

The blocking of lectin activity by different sugars suggests that either the active sites of these sugars have architectural similarities or there may be more than one lectin in the haemolymph. The differences in the reactions of *A. variegatum* and *R. appendiculatus* haemolymphs with respect to Fetuin and D(+)-glucosamine also suggests the presence of different lectins in the two tick species.

In general, both *A. variegatum* and *R. appendiculatus* have high levels of lysozyme and antibacterial activity in their haemolymph and their levels increase slightly following immunisation with *E. cloacae*. Lectins which tend to increase with immunisation are also present in both species. At least three sugars inhibit lectin activity in the haemolymph of both tick species. Further research is required to study the immune system in ticks with respect to induction, duration, dose response, individual immune proteins involved, characterisation of immune lectins and the role played by cellular immunity.

3.13 BIOCONTROL AGENTS OF TICKS

E. Mwangi and M. Kimondo

Studies were initiated to look for natural enemies of ticks, which could eventually be used in tick management. Engorged nymphs of *Amblyomma variegatum* and *Rhipicephalus appendiculatus* were collected from cattle from four areas in Kenya: Kuja River, Rusinga Island (both in South Nyanza District), and Muhaka and Kaloleni from the Kenya Coast Province. Collections from each area were made monthly from a group of farms, to investigate the occurrence and level of parasitisation of ticks with parasitoids, and to establish whether there were seasonal variations.

No parasitoids were found in ticks of both genera collected from Rusinga Island, Muhaka and Kaloleni areas. Out of 484 engorged nymphs of *A. variegatum* collected from the Kuja River area, 63% of them were parasitised with *Ixodiphagus hookeri*, a hymenopteran.

Attempts to rear the parasitoid in the laboratory were made using two methods. Ticks were exposed directly to parasitoids in glass tubes. This method only gave 40% parasitisation. A second and more efficient method was to expose ticks to parasitoids while on the host rabbits. Unfed nymphs of *A. variegatum* were placed on rabbit ears using ear bags. Parasitoids were introduced using a tick at a parasitoid ratio of 1:1. This method resulted in 90% parasitisation. By using about 30 rabbits a week, it has been possible to produce 180,000–300,000 parasitoids a week.

3.14 DOMESTIC CHICKENS AS BIOCONTROL AGENTS OF LIVESTOCK TICKS

S. M. Hassan and P. O. Ngoko

Our previous investigations have shown that domestic chickens are natural predators of livestock ticks. We extended our investigations to study chicken management and to determine the number of chickens required to effectively reduce tick infestation levels on cattle.

The study was started in March 1992 on two farms on Rusinga Island, Kenya. Cattle were tethered within an enclosed structure of 7 m long, 6 m wide and 2 m high, constructed of wire mesh and strengthened by wooden poles. Each enclosure was divided with a partition of mesh and poles into two smaller units (7 x 3 x 2 m). A corrugated iron sheet of 30 cm high was fixed at the bottom of the partition to prevent cross-movement of ticks. Five head of adult cattle were confined in one of the small enclosures with 10 chickens released among them. Another group of 5 adult cattle was confined in the other small enclosure without chickens to serve as control. The chickens were released among the animals on a daily basis from 0700 hr to the time when cattle were released for grazing at 1100 hr.

Ticks were collected on a monthly basis from the ten head of cattle. Tick collection started 6 months before the release of the chickens so as to establish the level of tick infestation of the two groups.

Chickens drastically reduced the number of ticks on the experimental cattle. The investigation is still in progress.

4

Medical Vectors

4.1 MBU CLOTH TECHNOLOGY DEVELOPMENT

M. J. Mutinga, C. M. Mutero, M. Basimike, A. Mnzava, D. M. Renapurkar, C. C. Kamau, F. A. Amimo, D. W. Wachira, R. Kimokoti, M. Nyamori, D. M. Omogo, F. M. Kyai and B. Muia

The Mbu Cloth is an appropriate technology developed for rural resource-limited communities as well as for use in urban areas. It is a permethrin-impregnated cloth made of cotton or polyester material which is hung along the walls in bedrooms, and thus provides an insecticidal effect for the entire room.

The Mbu Cloth technology development was continued in 1992. It included the monitoring of the efficacy of the wall cloth to suppress mosquito and sandfly populations in Perkerra Irrigation Scheme, Marigat, Baringo District, Kenya, and a few other selected areas with different climatic features. Prior to the introduction of the cloth, parasitological and clinical investigations were carried out in the Marigat area to assess malaria prevalence. These continued during and after the application of the technology. Socio-economic and anthropological studies were undertaken in order to assess the acceptability and sustainability of the Cloth. Furthermore, the monitoring of possible insecticide resistance in mosquitoes and sandflies was carried out.

4.1.1 Improvement of the Mbu Cloth

Research and development back-stopping on the Mbu Cloth technology continued in the area of looking at whether various coloured cloths attract or repel mosquito and sandfly vectors inside houses. Investigations on the possibility of incorporating natural plant extracts as insecticides impregnated on the Mbu Cloth continued.

The results of the above studies show a definite attraction of both sandflies and mosquitoes to specific coloured fabrics. Sandflies preferred colours that were different from those preferred by mosquitoes. Both vectors demonstrated species-specific colour preferences.

Different species of mosquitoes and sandflies differed also in their choice of landing position on the cloth when experimentally tested. Position preference by mosquitoes was different for *C. quinquefaciatus* as compared to *Aedes aegypti* and *Anopheles gambiae*.

4.2.2 Assessment of Mbu Cloth efficiency

In order to assess the efficacy of the Mbu Cloth, various trapping methods were employed to evaluate the quantity of the trapped population. Studies were continued using various vector trapping techniques including exit traps, updraft traps, CDC light traps and suction traps. For the outdoor resting populations, mosquito larval population was sampled from breeding places using dips, while resting adults were sampled from artificial pits. The indoor adult vector populations were assessed and recorded as unfed, fed, semi-gravid and gravid in order to determine the population age, and hence, the vector potential.

4.2 EVALUATION OF THE RESIDUAL EFFICACY OF PERMETHRIN-IMPREGNATED SCREENS USED AGAINST MOSQUITOES IN MARIGAT

M. J. Mutinga, D. M. Renapurkar, D. W. Wachira, C. M. Mutero and M. Basimike

The use of insecticide-impregnated fabrics is gradually finding wider use in malaria and other disease control programmes. The efficacy of these devices is dependent on how they are applied, the acceptability by the users and the effectiveness of the chemicals applied. This study was aimed at determining the duration of the effectiveness of permethrin-impregnated (Mbu Cloth) wall cloth applied inside houses at Marigat, Baringo District against mosquitoes and sandflies.

Table 4.1 shows the knock-down and mortality in *An. gambiae* s.l. after their exposure for 3 min to

Table 4.1 Knock-down time (mean ± S.E.) and percentage mortality (in parentheses) of *Anopheles gambiae* s.l. after exposure to the Mbu Cloth for 3 minutes

Months after treatment	Total no. of mosquitoes used	Knock-down time (min) 10	30	60	No. dead after 24 hours	Corrected % mortality
1	168	22.2 ± 5.3 (79)	28 (100)	28 (100)	28 (100)	100
2	186	22.8 ± 5.7 (73)	31 (100)	31 (100)	31 (100)	100
3	165	11.6 ± 4.4 (48.3)	18.6 ± 4.4 (78)	22.4 ± 3.5 (93)	24 (100)	100
6	190	1.0 ± 1.0 (4)	13.5 ± 3.7 (66)	17.3 ± 2.0 (72)	18.3 ± 5.0 (76)	73
7	140	0	8.7 ± 1.4 (43)	11.0 ± 2.1 (55)	13.4 ± 2.0 (67)	63
10	140	0	3.14 ± 1.0 (16)	10.0 ± 1.2 (50)	10.3 ± 2.2 (52)	44

permethrin-impregnated screens. For the first three months after insecticide application, the knock-down effect in *An. gambiae* s.l. was 100%. This was followed by a gradual decline in the knock-down effect with time. For *Aedes aegypti*, the knock-down rate observed was 100% after 30 min exposure on a 10-month-old cloth and 100% after 60 min exposure on a 12-month-old cloth. However, not all the *Ae. aegypti* knocked down after 60 min exposure on a 6-month-old cloth died. There was a recovery of 6% in some mosquitoes exposed on a 6-month-old cloth which increased to 45% by the 13th month. Mortality rates of 100% were maintained for 2, 3 and 6-month-old cloths for *Culex quinquefasciatus*, *An. gambiae* s.l. and *Ae. aegypti*, respectively, after a 24 hour post-exposure observation period. The three mosquito species also took different lengths of time to reach a mortality rate of 70%, the point at which re-impregnation of the experimental screens were considered necessary. *C. quinquefasciatus* required the shortest period (four months) for its overall mortality rate to fall below 70%; it was followed by *An. gambiae* s.l. (six months) and *Ae. aegypti* (ten months).

The overall population of both sandflies and mosquitoes remained suppressed to over 70% for sandflies and 90% for mosquitoes. The malaria parasites rate was reduced by over 70%. No leishmaniases cases have been reported in the experimental area from the time of the introduction of the Mbu Cloth technology.

These observations demonstrate that screens impregnated with permethrin at the dosage of 0.5 g/m^2 can be relied on for about 6 months to control *An. gambiae* s.l., the vector of malaria in the Marigat area. *Culex quinquefasciatus* and *Aedes* species are of great biting nuisance to the local people. Because of the varied susceptibility of *An. gambiae* s.l. and *C. quinquefasciatus* in Marigat, impregnated screens against the two species would be most effective if re-treated after four months, particularly during the dry season when the population of *C. quinquefasciatus* is predominant. By so doing, the overall mosquito population would be kept in constant check, thus controlling malaria transmission as well as reducing nuisance biting.

4.3 BIOLOGICAL CONTROL OF MOSQUITOES

E. J. Asimeng, M. J. Mutinga and M. M. Miti

Although a wide variety of mosquito-invading bacteria have been isolated in several geographical areas, isolation of additional local entomopathogens is required due to economic cost and restrictions imposed on the use of foreign micro-organisms. Thus the present study was aimed at finding local pathogens as an alternative to the use of imported agents. Additionally, there is potential for isolating new pathogens or serotypes of previously known pathogens possessing characteristics that make them more suitable for development and field application.

The search for entomopathogenic bacteria as potential mosquito biocontrol agents from Mwea Rice Irrigation Scheme Kirinyaga District, Kenya, which was started in 1990, continued in 1992. Forty-two soil samples produced several types of bacteria, five of which were mosquito-toxic. The five were identified as variants of *Bacillus thuringiensis* based on their structural and growth characteristics, coupled with larvicidal activity. These were highly pathogenic to *Anopheles*, *Aedes* and *Culex* mosquito larvae. When the isolates were sent to the WHO reference centre in France, they were typed as *Bacillus thuringiensis israeliensis* (*Bti*).

4.3.1 *Larvivorous fish*

Among vertebrate and invertebrate predators, larvivorous fish play a positive and significant role in reducing mosquito breeding. Recently there has been

a renewed interest in their use for mosquito control. The rationale for choosing fish as biological control agents are two-fold. They can ingest larvae or they can alter habitats and make them unfit for mosquito larvae. An important criterion is the suitability of the habits of both larvae and the fish species in question for co-existence.

Laboratory experiments on several species of fish showed that predatory fish collected from the Rice Irrigation Scheme at Mwea Tabere in Kirinyaga District, Kenya could be used as biological control agents against mosquito larvae. The larvivorous *Tilapia zilli* was evaluated in the field in 1992 to assess its potential using experimental ponds. This species was found to be extremely effective in controlling mosquito breeding throughout the year. Reductions of larvae by 90–100% occurred in clear-water ponds within 2–3 weeks of introduction of the fish. However, the presence of vegetation and water turbidity, especially as aggravated by catfish, a substrate feeder, significantly reduced its efficiency in predation.

4.4 SANDFLY ECOLOGY

M. Basimike, M. J. Mutinga and R. Kumar

Studies on the ecology and behaviour of phlebotomine sandflies form an integral part of the epidemiology of leishmaniasis. Although studies have been carried out on sandflies of Marigat area, information on their seasonal fluctuations remain scarce. The objective of this work was to identify more sandfly breeding/resting sites in the Marigat area, a focus of both visceral and cutaneous leishmaniases, in order to determine species composition, relative abundance and seasonal fluctuations of their population.

A number of natural and man-made habitats were surveyed for sandflies in 1985/86 in Marigat area of Kenya (Table 4.2). Of the 98,573 adult sandflies collected, 2.7% belonged to genus *Phlebotomus* and 97.3% to *Sergentomyia*. Sandflies of the genus *Phlebotomus* were four times more common in burrows than in termite hills, while twice as many sandflies of the genus *Sergentomyia* were collected from termite hills as from burrows. Termite hills had the highest sandfly population compared to other sites, followed by tree holes and animal burrows. Using a standard key, 15 species were identified, of which five belonged to *Phlebotomus* and 10 to *Sergentomyia*. The most abundant and widespread species were *Sergentomyia antennatus, S. bedfordi, S. africanus* and *P. dubosca*. Sandflies of both genera were present for the greater part of the year. Most species of sandflies decreased in numbers during the dry season. High population densities of sandflies were recorded during the wet period. Correlations between relative abundance of sandfly vectors of leishmaniasis and rainfall were positive. However, none of the correlation coefficients was statistically significant.

4.5 ALTERNATE VECTOR STUDIES: DEFECATION BY *ANOPHELES ARABIENSIS* MOSQUITOES OF HOST BLOOD INFECTED WITH LIVE *TRYPANOSOMA CONGOLENSE*

C. M. Mutero and M. J. Mutinga

The potential of mosquitoes to mechanically transmit African trypanosomiasis has not been previously assessed. This is probably due to a general assumption by many scientists that mechanical transmission of blood-borne parasites by insects is mainly through contaminated mouthparts, which in mosquitoes are too small to be of significance.

Defecation of a host's blood by mosquitoes of *Anopheles* species has been observed on a number of occasions by previous investigators. However, information is lacking on whether such blood contains live infective parasites. In view of the high degree of contact that exists between man, domestic animals and certain *Anopheles* spp, an assessment of the latter's potential to mechanically transmit diseases through defecated blood is necessary. The present study was undertaken with the main objective of determining whether or not live and infective *Trypanosoma congolense* picked up by *An. arabiensis* during feeding on an infected animal are present in defecated blood. In addition, the proportion of *An. arabiensis* mosquitoes defecating live trypanosomes was assessed, and an attempt was made to estimate the amount of blood that is defecated by a single mosquito.

Female *An. arabiensis* mosquitoes collected from houses in Mwea Irrigation Scheme, Kirinyaga District,

Table 4.2 Prevalence of *Phlebotomus* and *Sergentomyia* sandflies in the trapping sites

Site	Distribution of *Phlebotomus* spp	Distribution of *Sergentomyia* spp	Percentage of sandflies	No. species collected
Termite hill	16.3	31.9	31.4	11
Animal burrows	71.5	18.0	19.4	13
Tree hole	1.7	25.9	25.2	12
Human habitation	4.3	8.5	9.2	12
Animal enclosure	5.9	10.3	11.3	12
Open field	0.3	5.4	3.5	12
Total sandflies	2663	95910		
Percentage of total	2.7	97.3		

Table 4.3 Number of *Anopheles arabiensis* fed on balb/c mice infected with *Trypanosoma congolense* and percentage ejecting live trypanosomes in defecated blood

Donor mouse no.	No. mosquitoes defecating blood	Mosquitoes ejecting *T. congolense* No.	%
1	53	50	94.3
2	51	47	92.2
3	55	55	100.0
4	43	42	97.7
5	66	61	92.4
Total	268	255	95.1

Kenya were used in the experiment. Four or five starved mosquitoes were placed in a cage with sides made of transparent perspex except the top, which consisted of fine mosquito netting. The mosquitoes were offered a blood meal by placing a clean hamster on top of the net. As soon as partial repletion was noticed, a plastic Petri dish lined with filter paper was held about 4 cm below the feeding mosquitoes and the blood defecated by a replete individual mosquito was made to fall on the filter paper. The Petri dish and blood-stained filter paper were removed when defecation stopped and the experiment repeated with another batch of starved mosquitoes. The procedure was repeated with mice infected with *T. congolense*.

The mosquitoes readily fed on either animal. A blood repletion rate of 82.7% was recorded for mosquitoes feeding on hamsters. Seventy-seven per cent of the replete mosquitoes continued to feed while at the same time defecating the host blood in droplets, ejected in quick succession from the anus. Ninety-five percent of mosquitoes defecating blood while feeding on mice infected with *T. congolense* ejected live parasites (Table 4.3) along with the blood. Clean mice inoculated intraperitoneally with *T. congolense* or via the tail developed parasitaemia between the third and seventh day. This phenomenon of defecating live parasites could imply the possibility of these parasites being mechanically transmitted on by the mosquitoes.

4.6 CHARACTERISATION OF PHLEBOTOMINE SANDFLIES USING ISOENZYME ANALYSIS

H. Mahamat, J. Mutinga, A. Hassanali and N. N. Massamba

Isoenzyme analysis of Diptera such as mosquitoes, blackflies and sandflies, has been used widely for population genetic studies and for the identification of different species. A list of possible diagnostic isoenzymes for use in sandfly taxonomy has been proposed. The study reported here was designed (a) to select a set of enzymes for development of a key for distinguishing between a group of eight sandfly species in Kenya, and (b) to determine the phenetic relationships between these species.

Eighteen isoenzymes were screened to distinguish eight sandfly species collected from the field and reared in the laboratory: *Phlebotomus duboscqi, P. martini, P. aculeatus, P. pedifer, Sergentomyia bedfordi, S. garnhami, S. ingrami* and *S. schwetzi*. Of these, nine isoenzymes were found to give banding patterns potentially useful for taxonomic purposes. Three of these (GPI, MDH and PGM) were selected as diagnostic enzymes to develop a dendrogram for sandfly identification in Kenya.

4.7 DIFFERENTIATION OF VECTOR SPECIES OF PHLEBOTOMINAE (DIPTERA: PSYCHODIDAE) IN KENYA BY CHORIONIC SCULPTURING OF THEIR EGGS

L. M. Rogo, E. D. Kokwaro*, M. J. Mutinga and C. P. M. Khamala**

In Kenya, *Leishmania* parasites are transmitted by sandflies of three subgenera of *Phlebotomus: Phlebotomus* (*Phlebotomus duboscqi* Neveu-Lemaire transmits *Leishmania major*); *Larrossius* (*Phlebotomus pedifer* Lewis, Mutinga and Ashford and *Phlebotomus aculeatus* Lewis, Minter and Ashford all transmit *Leishmania aethiopica*; *Phlebotomus guggisbergi* Kirk and Lewis transmits *Leishmania tropica*), and *Synphlebotomus: (Phlebotomus martini* Parrot transmits *Leishmania donovani*). In the subgenus *Larroussius*, females of the 'Pedifer' species group, namely *P. pedifer, P. aculeatus* (*P. elgonensis* Ngoka, Madel, and Mutinga), and *P. longipes* Parrot and Martin, are morphologically indistinguishable. In the subgenus *Synphlebotomus*, females of the 'Synphlebotomus' species group (*P. martini, P. celiae* Minter, and *P. vansomeranae* Heish, Guggisberg and Teesdale) are also morphologically indistinguishable. In both species groups, the taxa have been defined on the basis of male features, particularly the genitalia. Consequently, the identity of the females can be verified only by rearing single egg batches or by collecting them *in copula*, which is a rare occurrence. The aim of this study was to examine eggs of the two phlebotomine sandfly species groups by scanning electron microscopy and compare their chorionic patterns for biosystematic purposes.

Wild collected *P. pedifer, P. aculeatus* and *P. martini* were fed and allowed to oviposit. The eggs were simply air-dried, mounted on metal stubs, and double-coated with carbon and gold-palladium in a vacuum evaporator. They were examined and photographed using a scanning electron microscope (Joel JSM-15).

P. pedifer: Based on examination of 50 eggs from 10 females, *P. pedifer* eggs had a general pattern of parallel ridges respectively on the same egg. However, it was noted that no two females had identical parallel ridges.

P. aculeatus: Variations in sculpturing were observed in this species. Most eggs from a sample of 48 had a general pattern of long polygons, but at the apices, the polygons were reduced in size to form a pattern like a 'beehive cell'. Five eggs from a single female had parallel ridge patterns but the nature of the

ridges is unlike those of *P. pedifer*.

P. martini: Examination of 28 eggs from three females revealed three basic patterns: a hexagonal pattern, tiny mountainlike patterns with an interconnecting wall; and an irregular pattern. It was observed that eggs laid by an individual female were exactly alike. The observed differences were between eggs of different females of the same species. Hence in differentiating these species, chorionic sculpturing was not a reliable criterion.

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4.8 CHARACTERISATION OF *LEISHMANIA*

N. N. Massamba, M. J. Mutinga and B. N. Odero

4.8.1 Leishmania *parasites and their kinetoplast DNA (kDNA)*

Parasites of the genus *Leishmania* cause a spectrum of human diseases, including cutaneous, mucocutaneous and visceral leishmaniasis. Each disease tends to be associated with a particular species of *Leishmania*. Where the presence of more than one species of *Leishmania* is suspected, it is crucial that characterisation studies are carried out to supplement epidemiological work. The purpose of such studies is to establish the geographical distribution of the different organisms, to identify suspect vector species of sandflies and reservoir hosts, and to provide accurate information to clinicians on the presence of pathogenic organisms in the lesions of their patients.

At least three species of human *Leishmania* parasites exist in Kenya: *Leishmania donovani*, *L. aethiopica* and *L. major*. *Leishmania donovani* and *L. major* are endemic at low altitudes in Baringo, Kitui, Machakos and West Pokot Districts while *L. aethiopica* occurs at high altitudes in Bungoma District on the slopes of Mount Elgon. In addition, there have been recent reports of human cutaneous leishmaniasis in Kenya from *L. tropica*.

Several methods for the identification and characterisation of *Leishmania* have been developed. These include: (1) isoenzyme analysis, by starch gel electrophoresis (SGE) or cellulose acetate electrophoresis (CAE), (2) the use of highly specific monoclonal antibodies in a radioimmunoassay and in indirect immunofluorescence, and (3) the use of morphological and behavioural characteristics and clinical manifestations.

All these methods have limitations in their usefulness. Isoenzyme analysis requires at least 10^7 cells grown in experimental animals or culture media, which is sometimes difficult to achieve. A few species-specific monoclonals are available, but the problem of cross-reaction in the case of double or multiple infection complicates their use for the identification of *Leishmania* species in biological samples. One of these approaches uses kinetoplast DNA (kDNA), a distinguishing feature of the Order Kinetoplastida, which includes trypanosomes, *Leishmania* and crithidia. This kDNA is a complex network of two groups of catenated circles: a minor fraction of large circular transcribed DNA (the maxi-circles) and a major fraction of small molecules (the mini-circles) whose function is known. The mini-circles are heterogeneous in sequence and because they have evolved rapidly, should be useful for grouping together closely-related *Leishmania* isolates.

The kDNA has been used by MVRP for grouping related *Leishmania* reference-strains and *Leishmania* isolates from different regions of Kenya. In addition, the application of clones derived from recombinant DNA libraries of reference-strain kDNA in hybridisation experiments, for the characterisation of the new isolates has been done.

Restriction enzyme DNA analysis was applied to determine the genetic differences between *Leishmania* reference strains. In addition, Southern blot hybridisation using cloned kDNA sequences from reference strains was used to discriminate different *Leishmania* species.

4.8.2 Leishmania *isolates, reference strains and* in vitro *cultivation*

The *Leishmania* isolates used for this study were isolated from rodents, canids, bovids and phlebotomine sandflies. They were stored as stabilates in vapour phase liquid nitrogen(-160°C) with glycerol (10%) as cryoprotectant. The *Leishmania* reference materials used in this study were obtained from the collection of the World Health Organization's Reference Centre for Leishmaniasis.

The stocks were initially cultivated *in vitro* as promastigotes on rabbit blood-based biphasic (NNN) medium. Samples of overlay were examined at regular intervals to monitor growth and checked for the presence of contaminants. Contaminated cultures were cleaned before use according to available methods or discarded.

5

Behavioural and Chemical Ecology Research

5.1 A REAPPRAISAL OF THE ROLE OF THE FEMALE SEX PHEROMONE COMPONENTS OF *CHILO PARTELLUS*

S. A. Lux, W. Lwande, N. Gikonyo and A. Hassanali

Research on the pheromonal biology of *C. partellus* was initiated at the ICIPE some years ago to develop effective tools and tactics for utilising the female sex pheromone in IPM. The two major components of *C. partellus* female pheromone, (Z)-11-hexadecenal and (Z)-11-hexadecenol, were tested extensively in previous years. One report (from outside ICIPE) claimed high catches with traps baited with the aldehyde alone (*J. Chem. Ecol.* 1979, 5, 153–167). However, neither of the two components has been found to be effective when dispensed alone, and previous deployment of blends of the two compounds has never given catches higher than 30–40% of those obtained from virgin females. Moreover, although over 10 minor components have been identified in extracts of the female sex glands, none of these, when blended with the major components alone or in combinations, has shown a significant improvement in attractancy.

Analysis of information already available by November 1991, led us to the conclusion that there was little chance that important pheromone components still remained unknown. Accordingly, we hypothesised that the low attractiveness of traps baited with the synthetic pheromone could be due to the use of an erroneous dispensing technique which failed to take into account critical elements of *C. partellus* behaviour. We therefore decided in 1992 to verify the biological importance of the two major components of the pheromone and to determine the basic conditions for its effective dispensing.

Working on the hypothesis that failure to achieve high catches in previous studies was due to the male insect's receiving a distorted signal near the trap, dispensers were placed at varying proximities with respect to each other. Observations showed the need for the emission of the two components to simulate the point-release which occurs from the female insect. Our initial studies showed that the high emission rates for the main component (the aldehyde) which were used in earlier studies could have affected male response. Using an experimental paper dispenser imbibed with the active compounds which allows separate but close release of the two components at moderate rates, we have demonstrated that

- the components act synergistically (contrary to the previous report) and both components are important for optimal attractiveness of the pheromone;
- on-field effectiveness of the traps baited with the synthetic blend is high, with catches averaging 85% relative to that using virgin females as bait;
- field monitoring of the pest with traps baited with the synthetic blend is feasible.

Further optimisation of the pheromone bait by manipulating release parameters (rate and ratio) is now underway.

5.2 BEHAVIOUR-CONTROLLING CHEMICALS FROM BANANA AND THE BANANA WEEVIL

I. O. Ndiege, W. J. Budenberg, D. O. Otieno and F. W. Karago

In last year's Annual Report, we reported the identity of the major chemical components of three banana cultivars, including that of a susceptible cultivar (Githumo). A blend of the major components of this cultivar failed to elicit any behavioural or electrophysiological activity, unlike the natural blend. Electrophysiological examination of the host-plant

volatiles showed the presence of several active minor components, of which four gave prominent EAG peaks. One component, an oxygenated monoterpene, has been identified by GC-MS and shown to be active in behavioural assays. The natural blend has now been fractionated into EAG-active and non-active fractions. Most of the components of the blend are non-active, and this should now facilitate the identification of the EAG-active compounds.

We have also screened volatiles from eight banana cultivars by GC-EAG. The oxygenated monoterpene, although present in all susceptible and tolerant cultivars, was absent in a resistant cultivar. On the other hand, another active peak was observed in this cultivar and could possibly be an allomone. Identification of this compound (also an oxygenated monoterpene) is in progress.

5.3 OLFACTION AND ORIENTATION RESPONSE OF *MARUCA TESTULALIS* MOTHS TO HOST PLANT SEMIOCHEMICALS

*S. I. Kamara**

The success of *M. testulalis* in finding and colonising the cowpea crop depends on the interaction of the sensory system of the insect and the chemical/physical characteristics of the host plant. Knowledge of how the host plant semiochemicals affect the sensory biology of the pest can provide a basis for the development of ecologically sound and more practical strategies for the control of *M. testulalis*. This study investigates the role of cowpea airborne volatiles on the orientation behaviour of *M. testulalis*.

5.3.1 *Antennal morphology of* M. testulalis

An indispensable starting point for the study of insect olfaction is a reasonable knowledge of the olfactory sensilla. This provides a basis for electroantennogram (EAG) and single sensilla response investigations as well as for interpreting behavioural responses when insects are subjected to the same chemical stimuli.

Antennae of male and female *M. testulalis* moths were examined under a scanning electron microscope to obtain knowledge about the types, population and spatial distribution of the antennal olfactory sensilla.

This study reveals that antennae of both sexes of *M. testulalis* are morphologically identical. The ventral surfaces of the antennae are covered with a dense mat of sensilla while the dorsal surfaces are completely covered with scales. Four olfactory sensilla types were identified on both sexes. These are sensilla trichodea, basiconica, coeloconica and auricularia. Sensilla basiconica, coeloconica and auricularia are known to be involved in plant odour perception. The presence of these odour-receptive sensilla in both male and female *M. testulalis* moths suggests that plant odour may play a significant role in the orientation of the moths to their host plants.

5.3.2 *Electroantennogram (EAG) studies*

The electroantennogram technique was used to examine the sensitivity of *M. testulalis* antennal sensilla to odours of the host plant, cowpea. Antennae of male and female moths were stimulated with odour emanations from cowpea leaves, flowers and green pods of a susceptible cultivar, Vita 1.

Results of this study show that olfactory receptors of both male and female *M. testulalis* moths are responsive to odours of the cowpea host plant. This suggests that both sexes of the moth share common receptors for host plant odours. Inputs into these cells may be responsible for releasing the in-flight behaviour of the moths.

5.3.3 *Orientation response of* M. testulalis *moths to airborne odours of cowpea: A wind tunnel bioassay*

The orientation response of *M. testulalis* moths to cowpea odours was investigated in a wind tunnel. Odours from undamaged potted cowpea plants at the flowering, flowering/podding and non-flowering growth stages were assayed on 3–5 days old male, virgin and mated female moths.

Results of this bioassay reveal that all three phenological stages of cowpea are attractive to male, virgin and mated *M. testulalis* moths. The moths exhibited positive odour-modulated anemotaxis and zigzag flights to locate plants 2 m upwind. Plants at the flowering and flowering/podding stages evoked higher percent flights and landing on the host than non-flowering plants. Virgin and mated female moths were more attracted to odours of cowpea than were the males. Knowledge of the chemical components of the cowpea plant mediating this host-finding behaviour may be of importance in controlling *M. testulalis* by manipulating the behaviour of the pest in the agroecosystem.

*ARPPIS Graduate Scholar

5.4 TSETSE BEHAVIOUR AND CHEMICAL ECOLOGICAL STUDIES

R. K. Saini, D. Nyarango, A. Hassanali, J. Andoke, P. Ahuya and W. Ouma

Work is in progress to identify tsetse semiochemicals with broader versatility with respect to different tsetse species and in different physiological states. With this objective in mind research has focused on:

(i) evaluating new and long/medium/close range attractants and analogues for *G. m. morsitans* and *G. pallidipes*;
(ii) molecular optimisation of phenolic analogues with the objective of identifying better attractants;
(iii) larviposition behaviour; the role if any, of semiochemicals and the receptor sensitivity of gravid females.

Isolation and purification of active components which at close range induce arrestment, alightment and probing have been hampered by the presence of large amounts of non-active compounds in the body washings. A new technique based on selective trapping of body volatiles has been developed and the collected volatiles (Fig. 5.1) shown to be active in wind tunnel bioassays. Identification of components of these volatiles is now in progress.

The olfactory sensitivity of *G. pallidipes* to 13 phenolic analogues (9 of which were synthesised at ICIPE) was investigated using electrophysiological (EAG) techniques. Results indicate that integrating the structural features of 4-cresol and 3-*n*-propylphenol into one molecule (4-methyl-3-*n*-propylphenol) led to reduced activity (Fig. 5.2) suggesting the existence of two different phenolic receptors, one for 4-cresol and the other for 3-*n*-propylphenol. A three-carbon chain at the 3-position was found to be optimal for *G. pallidipes* (Fig. 5.3). Introduction of alkyl branches or oxygen in the side chain at the 3-position led to reduced activity (Fig. 5.4). On the other hand, the presence of terminal unsaturation in the 3-alkyl chain or removal of the phenolic OH group does not appear to significantly affect the EAG responses (Fig. 5.5). Additional analogues are also being synthesised for testing. The

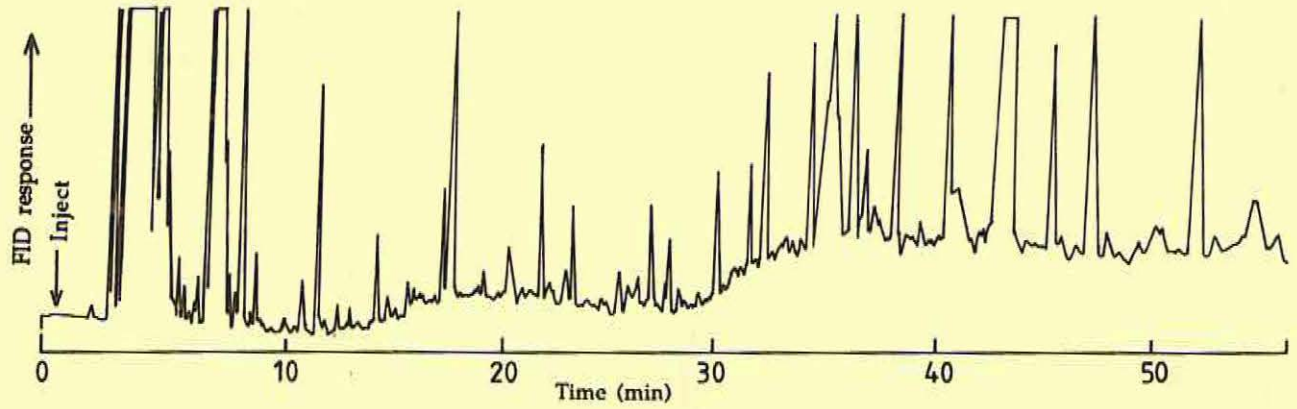

Fig. 5.1 Gas chromatographic profile of cattle body volatiles trapped on reverse-phase adsorbent. (Hewlett Packard GC; 5 cm carbowax capillary column; 60° (5 min) to 220° at 5°/min).

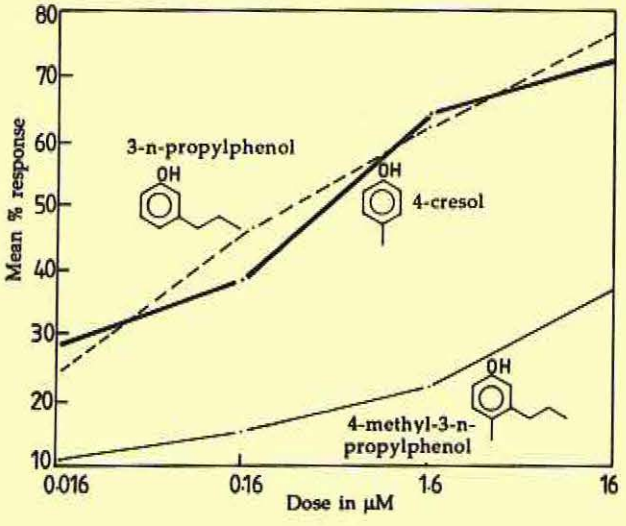

Fig. 5.2 EAG response of *Glossina pallidipes* to phenolic analogues.

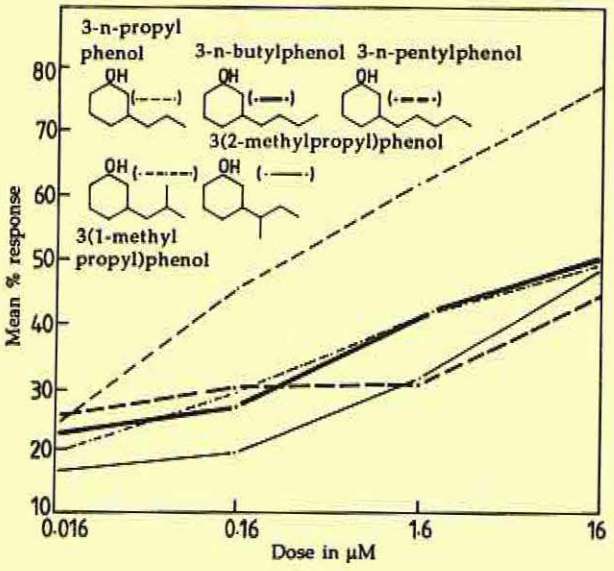

Fig. 5.3 EAG response of *Glossina pallidipes* to phenolic analogues.

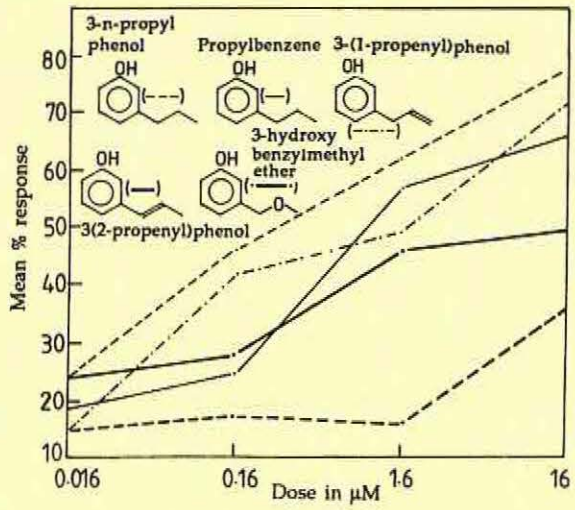

Fig. 5.4 EAG response of *Glossina pallidipes* to phenolic analogues.

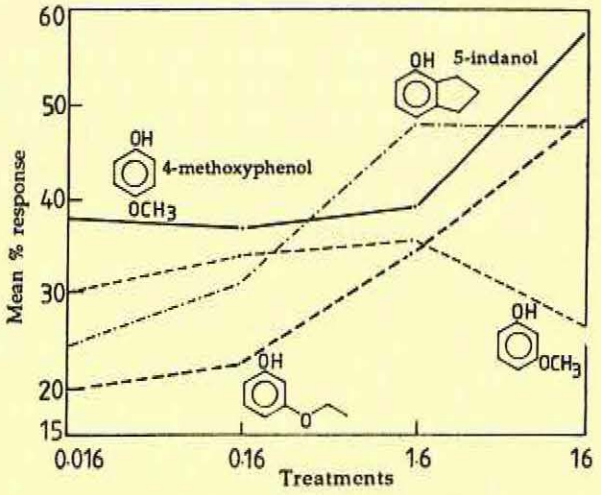

Fig. 5.5 EAG response of *Glossina pallidipes* to phenolic analogues.

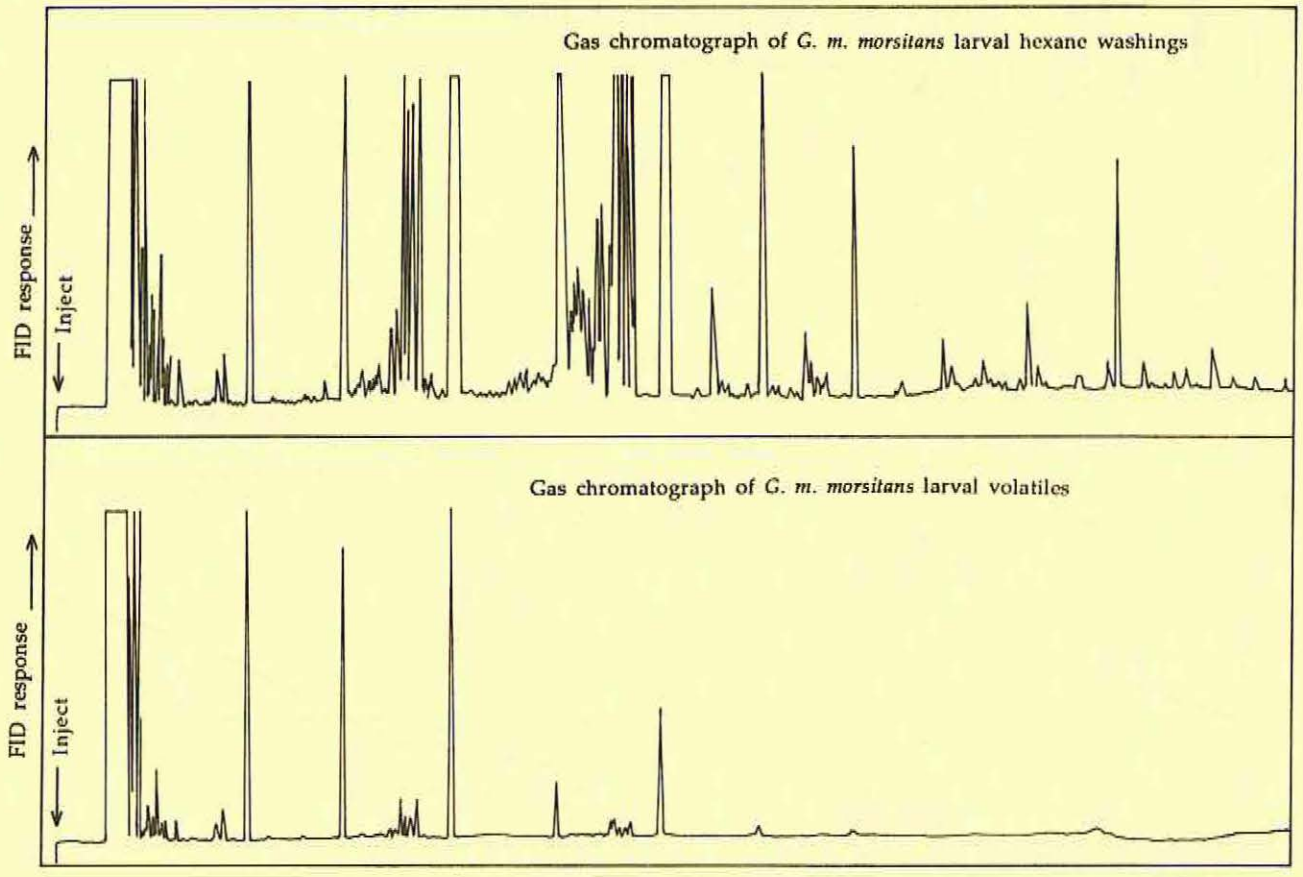

Fig. 5.6 Gas chromatograms of *Glossina morsitans morsitans* larval hexane washings (A) and larval volatiles (B).

whole set of compounds are being tested for *G. m. morsitans* to elucidate the structural requirements for attractancy of this class of compounds for this species.

Isolation and purification of the active compounds involved in the attraction of gravid female *G. m. morsitans* and *G. m. centralis* to larviposition sites was hampered by the large number of non-active compounds present in hexane washings of larvae (Fig. 5.6). Hence volatiles were collected from larvae prior to pupariation and were also shown to be active in attracting gravid females. GC profiles of larval volatiles indicate few peaks and these are currently being identified (Fig. 5.6).

5.5 RESPONSES OF TICKS *RHIPICEPHALUS APPENDICULATUS* AND *R. EVERTSI* TO OLFACTORY STIMULI

*Sika Fra Kutua**

Behavioural studies were initiated to investigate orientation responses of two ticks, *Rhipicephalus appendiculatus* (RA) and *R. evertsi* (RE), using odours from various cattle body regions as kairomonal cues. Preliminary results show that tick species are sensitive to host odours emanating from either ear or anal regions.

The odours were obtained by washing various parts of the body of a steer with *n*-hexane, followed by rotary evaporation of the solvent and concentration of the odour under a gentle stream of nitrogen. T- and Y-shaped glass tube olfactometers, as well as a glass columns pairs were used to observe the orientation responses of 2–3 month old ticks towards the test odours. Parameters assessed were repellency, attraction, scanning time, time spent in the olfactometer arm, and dose-responses to the extracts. The available data from T- and Y-shaped olfactometer bioassays indicate that RA adults respond to the ear better than any other instars. As for the attractiveness of odours from various body parts, ear washings evoked the best attraction responses among RA adults tested ($P < 0.001$) when compared with odours from belly and axillae, dewlap and neck and legs. The anal washing was found to be repellent to RA species. On the other hand, adults RE were attracted to the anal washings and repelled by the ear washings. Dose-relationships towards the stimuli of these predilection sites were demonstrated for both tick species in a climbing column pair. When RA and RE were exposed to the ear and anal odours (single adult used in Y-olfactometer), it was found that the two species differ in their scanning activity and the time spent in the olfactometer arm in response to host odour. The two extracts tested elicited a different response pattern within a species ($P < 0.01$). Results also indicate that the duration of the responses, *viz* scanning time and time spent in the treated olfactometer arm, were negatively correlated.

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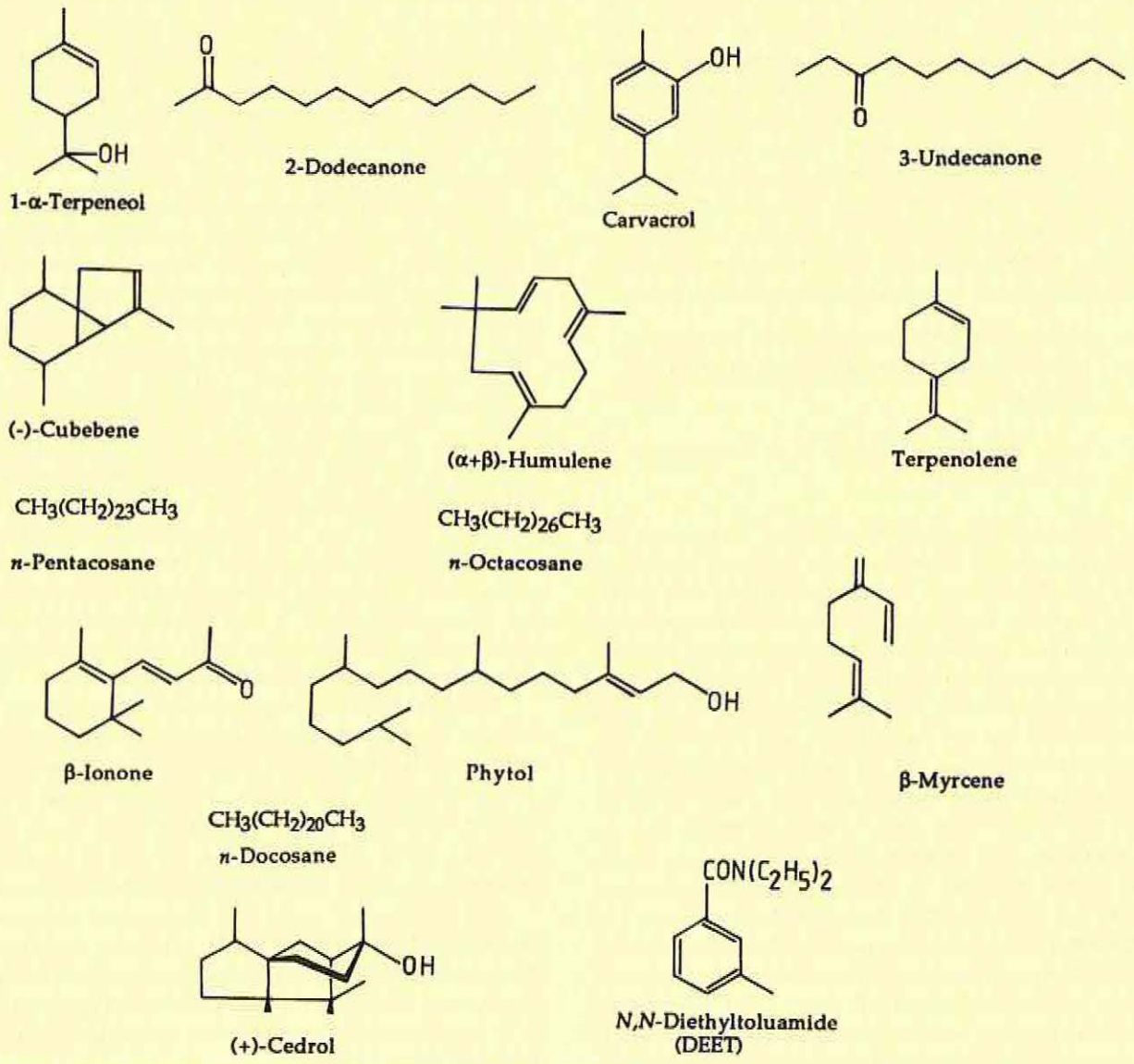

Fig. 5.7 Compounds identified from *Cleome monophylla* essential oil.

5.6 CONSTITUENTS OF *CLEOME MONOPHYLLA* AS LIVESTOCK TICK *(RHIPICEPHALUS APPENDICULATUS)* REPELLENTS

W. Lwande, M. Ndungu, A. Hassanali, L. Moreka, H. Amiani and G. Achieng

Control of ticks using anti-tick plants which repel, immobilise or cause mortality to the non-parasitic stages, thereby preventing them from seeking or attaching to animal hosts, has been proposed by several workers. Such plants could be grown in livestock pasture where they could reduce the tick population. Recently, the shrub *Gynandropsis gynandra* (Family: Capparidaceae), has been reported to repel ticks and has been proposed as a possible anti-tick pasture plant (see 1990 and 1991 *ICIPE Annual Reports*). We have examined a closely related plant species, the shrub *Cleome monophylla*, which belongs to the same family as *G. gynandra*. The essential oil of *C. monophylla* was found to be repellent to *R. appendiculatus* adult ticks, as was that of *G. gynandra* in the tick climbing repellency bioassay. Fourteen constituents of *C. monophylla* essential oil were identified (Fig. 5.7). Samples of all the compounds identified showed significant repellency to *R. appendiculatus* at all the doses tested.

Of the 14 compounds, the most repellent were 1-α-terpeneol, 2-dodecanone, carvacrol, 3-undecanone and (-)-cubebene. The first three showed higher repellencies than the essential oil of *C. monophylla*. Like *G. gynandra* (1991 *ICIPE Annual Report*), *C. monophylla* is also eaten as a vegetable in a number of regions in Africa, a factor which will render it more acceptable for growing as an anti-tick pasture plant by farmers.

5.7 PRODUCTION OF INFECTED TICKS AND IMPROVEMENT IN ARTIFICIAL FEEDING METHOD

S. M. Waladde, A. Young, S. A. Ochieng and S. Mwaura**

The anticoagulant method required to prepare the most appropriate blood meal for artificial feeding of ticks was determined. Heparinised blood was found to be superior to the defibrinated blood which was used earlier in these investigations. Acid citrate dextrose- and EDTA-treated blood was unsuitable for tick feeding. For the first time, nymphal ticks were successfully fed on membranes and their size was comparable to those fed on cattle. Heparinised and defibrinated blood obtained from *Theileria parva*-infected cattle was infective to nymphs fed on membranes, and these nymphs moulted into adults that could transmit *T. parva* to cattle. Heparinised blood was more infective than defibrinated blood. The infection levels on membrane-fed ticks were generally lower when compared with those of ticks fed on blood donor cattle infected with *T. parva*. With the present artificial feeding method, it is possible to feed to repletion 4000–5000 nymphal ticks in one experiment. The mode of presenting blood to the tick is under review. The initial approach was to feed ticks on a membrane placed over the blood meal. However, when the situation was reversed, the initial data indicated that the resultant engorged ticks were generally heavier than those obtained when the blood meal was beneath the ticks.

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5.8 EFFECTS OF *OCIMUM* PLANT SPECIES AND THEIR ESSENTIAL OILS ON SOME STORED-PRODUCT INSECT PESTS

*Bekele Jembere Adgeh**

The effects of three *Ocimum* plant species (*O. suave, O. basilicum* and *O. kenyense*) on three storage insect pests (*Sitophilus zeamais, Sitotroga cerealella* and *Rhizopertha dominica*) have been evaluated.

Maize and sorghum seeds, disinfected in an oven at 40°C for 4 h, were treated with (i) the essential oil, (ii) fresh leaves, (iii) dried whole leaves and (iv) ground dry leaves. Three levels of concentration were used, equivalent to 0.012, 0.06 and 0.3% mg. The seeds were treated with the plant materials in 1 litre-glass jars. Insects (10 pairs) were introduced into the jars and the effects of the *Ocimum* on their survival, feeding and reproduction periodically recorded. Seed viability was also noted. Control jars were set up as described, but without the addition of any plant material.

The essential oil of *O. basilicum* was found to be the most toxic, producing 100%, 93% and 90% mortalities in *S. cerealella, R. dominica* and *S. zeamais*, respectively, at 24 h post-treatment at the 0.3% mg level of application. In the case of the essential oil treatments with *O. suave* and *O. kenyense*, the mortality rates of *S. zeamais* were 88% and 30%, and that of *R. dominica* were 88% and 85%, respectively, 96 h post-treatment at 0.3% mg. *S. cerealella* has been the most susceptible insect, showing 100% mortality at 24 h post-treatment with 0.3% mg and 48 h with 0.06% mg of the essential oils. Other plant materials did not cause mortality to any treated group of *S. zeamais*. Ground leaves of *O. suave* at 0.3% mg caused 100% mortality to *R. dominica* and *S. cerealella* at 72 h and 48 h post-treatment, respectively. All treatments with the three *Ocimum* spp affected the survival of *S. cerealella*.

The numbers of F_1 progeny produced by the insects and the damage they produced were significantly reduced by treatments with the essential oil or dried ground leaves of the plants. However, these were found to increase under treatment with fresh leaf material, most likely because of the favourable conditions provided by the moisture in the fresh leaves.

Dry leaves of *O. suave* and *O. kenyense* enhanced the germination of maize seeds, while no significant effects were observed for all three plants on the viability of sorghum seeds. At the highest level of application (0.3% mg), all three plants showed toxic effects against the three insects tested.

*ARPPIS Graduate Scholar

6

Molecular Biology Research

6.1 DEVELOPMENT OF DNA PROBES FOR IDENTIFYING *LEISHMANIA* PARASITES: CUTANEOUS LEISHMANIASIS IN KITUI DISTRICT, KENYA

N. N. Massamba and R. K. Rotich

While gene cloning is fashionable, it can also contribute to real and specific rewards, such as the selection of probes for identification and taxonomy, the production of specific diagnostic reagents and the development of vaccines.

To determine the vectors and animal reservoirs of leishmaniasis in Tseikuru, Kitui District, Kenya, *Leishmania* parasites were isolated from various hosts including rodents, canids, and lizards. The promastigotes were cultured in diphasic NNN medium at room temperature and examined after 7–10 days. The positive cultures were subsequently mass-cultured in RPMI-1640 medium supplemented with 25 mM HEPES, pH 6.5 buffer, heat-inactivated foetal calf serum (15–20% v/v) and antibiotics (penicillin 100 U/ml and streptomycin 100 µg/ml). The cultures were grown at 26°C.

The stationary phase cells were harvested by centrifugation for 15 min at 3000 rpm at 4°C and washed three times in cold normal saline solution. Cells were used immediately for DNA preparation or stored at –70°C for later use. Genomic DNA was prepared using standard procedures. Restriction endonuclease digestion of genomic DNA from various *Leishmania* reference strains and isolates was carried out to completion. The resulting DNA fragments were separated by electrophoresis in 0.6–0.8% (w/v) agarose gels. After electrophoresis, the gels were processed for transfer to nitrocellulose filter paper.

A kinetoplast DNA (kDNA) probe was selected from a small kDNA library constructed in plasmid pUC-19 with kDNA sequences isolated from *Leishmania* reference strain of *L. major* IC-236. When this probe was hybridised with Southern blots from genomic DNA fragments of various *Leishmania* parasites,

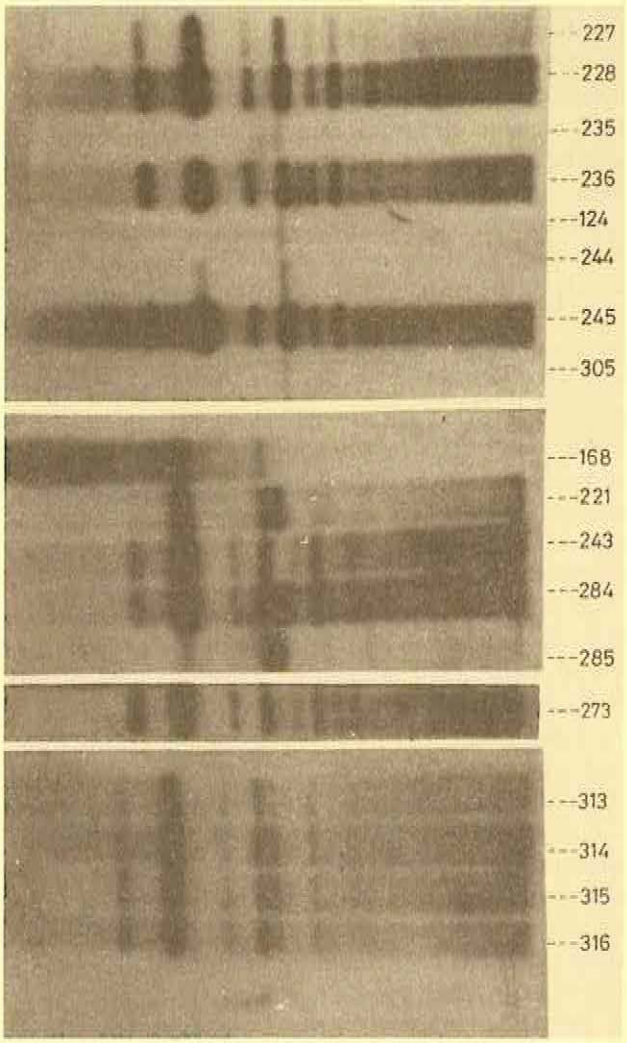

Fig. 6.1 Autoradiograph of Southern blot of EcoRI-restricted DNA fragments from *Leishmania* reference strains: *L. infantum* IC-227, *L. aethiopica* IC-228, *L. major* IC-235, *L. major* IC-236, *L. adleri* IC-124, *L. adleri* IC-244, *L. donovani* IC-245, *L. tropica* IC-305 and isolates, from sandflies: *Sergentomyia garnhami* (IC-168, IC-284; IC-285, IC-313, IC-314, IC-315 and IC-316) and from gerbil (IC-273) of Kitui District, Kenya, hybridised to radiolabelled pL 236-30. IC-221 and IC-243 were *L. major* isolates from *S. ingrami* of Baringo District. Each lane contained approximately 2 µg of DNA.

positive signals were obtained with DNA samples from *Sergentomyia garnhami*, indicating that these sandflies were infected with *L. major* (Fig. 6.1). The result suggests that *S. garnhami* is a possible vector of *L. major*, the parasite reponsible for cutaneous leishmaniasis, in Tseikuru, Kitui District, Kenya.

6.2 STUDIES ON *BACILLUS THURINGIENSIS* δ-ENDOTOXINS

E. O. Osir, M. W. Vundla and E. Kenya

Studies on the δ-endotoxins from three *Bt* isolates, the *Chilo partellus/Spodoptera exempta*-active (MF4B/2), the *Aedes aegypti*-active and the *Glossina morsitans morsitans*-active (*TIKKI*) isolates (*ICIPE Annual Report*, 1991) have continued. This report presents data obtained on the enzymatic activation, chemical and immunological properties, as well as bioassay of the δ-endotoxins of the three *Bt* isolates.

Activation of the 63 kD MF4B/2 protoxin gave interesting results: while treatment of *G. m. morsitans* or *S. exempta* midgut homogenates with commercial bovine trypsin resulted in no apparent change in molecular weight, when the protoxin was treated with either commercial chymotrypsin or *C. partellus* midgut homogenate, a toxin of Mr ~60 KD was formed. For the Tikki protoxin (Mr ~64 KD), activation with commercial bovine trypsin gave a toxin of Mr ~62 KD, while treatment with commercial chymotrypsin resulted in a toxin of Mr ~60 KD. Similarly, a mixture of trypsin and chymotrypsin or *G. m. morsitans* midgut homogenate gave a toxin of Mr ~60 KD. The *Ae. aegypti*-active protoxin was similarly activated. There was no apparent change in the molecular weight of either the Mr ~66 KD or the Mr ~21 KD subunit, when the two were treated with commercial trypsin or chymotrypsin, or with midgut homogenates from *Ae. aegypti*, *G. m. morsitans*, *C. partellus* or *Musca domestica*. These results raise interesting questions with regard to the selective toxicity of *Bt* δ-endotoxins.

The presence of carbohydrate moieties on all three endotoxins was determined using the periodate-Schiff (PAS) stain and fluorescein isothiocyanate-conjugated concanavalin A (FITC-Con A). All three protoxins gave positive results, indicating the presence of N-linked glycosyl moieties of the high mannose type. The exact role of the glycosylation sites is still unknown although it has been suggested that they may play a role in insect toxicity.

Antibodies were raised against the three endotoxins. Double radial immunodiffusion showed that antibodies to the MF4B/2 protoxin cross-reacted with the Tikki protoxin but not with the *Ae. aegypti*-active protoxin. Similarly, antibodies against the Tikki protoxin cross-reacted with the MF4B/2 protoxin but showed no cross-reactivity with the *Ae. aegypti*-active protoxin. For the *Ae. aegypti*-active protoxin, the antiserum raised against the Mr ~21 KD protein subunit did not cross-react with the Mr ~66 KD protein and *vice versa*. Similarly, the two antisera did not cross-react with the protoxins active against *G. m. morsitans* or *C. partellus/S. exempta*. Further investigations using the more sensitive immunoblotting method are currently underway.

The bioassay results obtained for the three protoxins were interesting, since some correlation between these and the immunological data was apparent. The MF4B/2 protoxin caused mortalities in *C. partellus*, *S. exempta* and *G. m. morsitans*. Similarly, the Tikki protoxin was active against both *G. m. morsitans* and *C. partellus*. In contrast to this, all three species were unaffected by the mosquito-active protoxin. Likewise, mosquitoes were unaffected by both MF4B/2 and Tikki.

Finally, preliminary investigations on the midgut endotoxin receptors of *C. partellus* and *G. morsitans* have been initiated using the ligand blotting technique, and are currently in progress. For the MF4B/2, two bands of Mr ~68 KD and ~64 KD have been identified in *C. partellus*, while for the Tikki protoxin, a band of Mr ~64 KD has been identified in *G. m. morsitans*. It would be interesting to see if any similarities exist between the MF4B/2 and Tikki midgut receptors, in view of the apparent similarities in their immunological properties and toxicity.

6.3 DEVELOPMENT OF DNA MARKERS TO STUDY THE BASIS OF BEHAVIOURAL (AND INSECTICIDAL) RESISTANCE TO TRAPS/TARGETS OF *GLOSSINA* SPP

M. Limo, E. Osir, C. Savakis and L. H. Otieno

Insects have received little attention with regard to the molecular and genetic basis of olfaction, despite its importance. The efficacy of using kairomone-baited and insecticide-impregnated targets for tsetse population suppression has been tested against *Glossina* spp in Nguruman and Lambwe Valley in Kenya. Such field trials have reduced the fly population by over 90%. However, little is known of the characteristics of those flies refractory to traps/targets and which subsequently cause population resurgence. Recent molecular genetic studies of insecticide resistance have shown that point mutations in genes, DNA amplification and alterations in regulatory genes are involved physiologically. At present it is not known whether there is any genetic basis for behavioural resistance to traps/targets developed by flies in the field. If shown to be under genetic control, then this vector control strategy has great potential for development.

DNA markers can be used to study genotypic diversity in the olfactory behaviour of different tsetse populations. Electrophoretically detectable variation was observed when phosphoglucomutase and glucose phosphate isomerase were used to define polymorphism in flies from Nguruman. In contrast with RFLP surveys and isozyme profiles, microsatellites which are common and polymorphic reveal a lot about genetic diversity. They can therefore be used to define vector species complexes that show

behavioural differences.

The other important aspect of the work that we wanted to explore was to isolate antennal-specific odorant receptors. At present receptor molecules that are localised in antennae and interact with chemical stimuli have not been identified in insects. Although there are no known tsetse mutants defective in some olfactory behaviour, it may be possible to clone the genes using a PCR-based strategy. If shown to be directly involved in host choice behaviour, such receptors could help in the design of improved traps/targets.

The objectives of our work were therefore to (i) develop microsatellites to be used in population analysis, and (ii) isolate and characterise the olfactory genes.

6.3.1 Construction of genomic library of Glossina morsitans morsitans

A plasmid genomic library of *Glossina morsitans* was constructed. Tsetse DNA was cut to completion with Sau3A1 and separated on agarose gel electrophoresis. Fragments in the size range 200–500 bp from gel were extracted and cloned in Bluescript digested with BamHI. Colonies with simple repeats were determined by colony hybridisation with a (dG-dT)15 oligonucleotide probe. Filters were processed by incubation for 5 min on 3 mm Whatman paper presoaked with 10% SDS, followed by denaturation and renaturation, dried and baked. Hybridisation was carried out in lx ssc, 0.05% sodium pyrophosphate, 10x denhardts, 0.2% SDS with labelled (GT)15 at 55° overnight. The filters were washed twice in the same hybridisation buffer. Several strong positive colonies were picked for sequencing.

The DNA sequences with (GT)n repeats will be used to select primers that will be employed to genetically type the fly populations for polymorphism. Future work will involve characterisation of microsatellite markers. This will involve sequencing the clones and designing primers that yield very high levels of polymorphism. The markers will initially be used to characterise *Glossina pallidipes* that exhibit unique behavioural traits in Nguruman. Subsequent studies will concentrate on the adaptive nature of such polymorphism.

6.3.2 Isolation of receptors involved in insect olfaction

An attempt was made to isolate receptors involved in insect olfaction using a PCR-based approach. Total nucleic acid was prepared from antennae preparation in Holmes Bonner Lysis buffer. First strand cDNA was synthesised from total RNA and subjected to PCR with different primer oligonucleotides. The primer sequences used were derived from seven transmembrane domain conserved regions of putative olfactory receptors. The 5 ■ primers used had the following sequences - TTAAGGATGCTAATA-GAAGGAGTT - and TTAAGGCATGCTAATAGA-ATGGAGTT - and the 3 ■ primers were CTTTC AACTCTTTCCTTGCGA - and - CTGTCAACTCT-TCCTTGCGA -. PCR was performed according to the following conditions: 96°C for 45 s, 55°C for 2 min, and 72°C for 3 min. Aliquots of PCR reactions were analysed by agarose gel electrophoresis.

In future, we hope to clone tsetse olfactory genes. Although the degenerate primers tested did not give the expected size band in PCR, the reason may be that rats and insects are distant relatives with a large phylogenetic gap. Some consensus primers from 24 seven transmembrane receptors could be tested, including some sense primers and antisense primers. Many bands of cDNA PCR products were visible on agarose gels that require further analysis to see if they are candidates for odour receptor gene(s).

6.4 DETECTION OF INTRA- AND INTERPOPULATION GENETIC DIVERSITY: APPLICATION OF THE POLYMERASE CHAIN REACTION TO STUDIES OF TSETSE FLIES

M. Limo and A. Robinson

Studies on the definition of vector species from the field and inbred colonies require quick, sensitive and reliable methods for distinguishing genetic variation within and among different populations. Current methods employ allozymes that often show little or no electrophoretically detectable genetic variation. Restriction fragment length polymorphism (RFLP) that require unique DNA restriction sites and other molecular probes that require cloning prior to sequencing are also used.

Random amplified polymorphic DNA polymerase chain reaction (RAPD-PCR) that uses short primers and amplifies arbitrary regions of the genome is sensitive although it has some limitations, and has potential application in detailed studies of genetic polymorphisms. With specific primers directed towards rapidly evolving portions of the genome, it is now possible to directly measure genetic heterogeneity between and within insect populations.

6.4.1 Measurement of DNA sequence variation in the mitochondrial cytochrome b gene of wild tsetse

Genomic DNA was prepared from individual flies. Primers were designed based on the highly conserved regions of the cytochrome b published sequences. The sequences of the light chain primer was - ACC/AGC/TCC/AAT/TAA/TAT/TTC/AAG/ATG/ATG/A and of the heavy chain primer was - TAC/AGT/TGC/TCC/TCA/AAA/TGA/TAT/TTG/TCC/TCA-.

The DNA was amplified in a PCR using 30 cycles (92°C denaturation for 45 s, 50°C annealing for 45 s, 72°C extension for 3 min) followed by a final 10 min step at 72°C. Electrophoresis of the amplification products was done. Direct PCR sequencing using Taq polymerase and ^{32}P-ATP labelled primers was carried out. Unmodified PCR fragments were cloned in home-made T vectors.

The primers amplify a 372 bp region of cytochrome b gene of individual tsetse flies. However, reamplification of the purified band resulted in false priming (forms a ladder). Different PCR conditions were used but preliminary attempts to sequence directly with ^{32}P end-labelled primer were not successful. This may be due to the nature of the A+T rich region (= 0.8 kb) of mt DNA. This was surprising because a 1:10 diluted sample gave a single band; further work could be done to optimise the PCR conditions. The 372 bp fragments were cloned in bluescript for sequencing.

Future plans include sequencing the 372 bp inserts that were cloned in bluescript and checking for genotypic diversity of tsetse flies. If the different populations reveal significant DNA sequence polymorphism, conditions for direct sequencing will be standardised. The same work could be extended to primers that amplify ribosomal RNA genes (rDNA).

6.4.2 *Detection of DNA polymorphism in tsetse populations using RAPD-PCR*

Total nucleic acid was extracted from individual flies for DNA fingerprints of tsetse populations obtained from ICIPE. 10 mer primers (Operon Technologies, Inc.) were individually used for the amplification of random DNA. Using RAPD-PCR technique we were able to see many amplified fragments from the individual flies that could be used for generating RAPD profiles.

Although the technique shows extensive polymorphism, it is rapid and requires small amounts of DNA; the utility of the technique would be substantially improved if the experiments were done under well standardised conditions. Thus, RAPD fingerprints may be useful for detecting genetic variability, but reproducibility is sometimes a problem. In future, we plan to explore further the utility of RAPD-PCR to generate genetic markers for use in definition of tsetse vector species complexes.

6.5 DEVELOPMENT OF EFFICIENT, PRACTICAL METHODS FOR MASS-INFECTING TSETSE, *GLOSSINA* SPP WITH A DNA VIRUS

W. G. Z. O. Jura

The DNA virus causes sterility in tsetse males. A number of studies we have carried out previously have focused on evaluating the potential of the virus as an alternative sterilant to radiation, for use in the sterile insect control technique (SIT). In the past year, we demonstrated that the virus-infected tsetse males, despite sterility, retain their normal sexual vigour, behaviour and mating competitiveness. Such males will exert a greater influence in regulating populations than can be achieved by destroying or removing the same number of individuals from the population.

In 1992 investigations aimed at developing the more practical approaches for use of the virus to control field populations of tsetse were initiated. Various techniques for mass-infecting tsetse with the virus were investigated. These include (a) membrane feeding of teneral tsetse on blood contaminated with the virus; (b) intra-haemocoelic inoculation of third-instar larvae with a tissue homogenate containing the virus, (c) topical application of the virus suspension onto the cuticle of third-instar larvae.

Both the intra-haemocoelic inoculation and topical application methods were found to be extremely promising. Further investigations are continuing.

6.6 FACTORS AFFECTING TRYPANOSOME ESTABLISHMENT IN THE TSETSE MIDGUT

M. O. Imbuga, E. O. Osir, L. Abubakar and V. Labongo

The differentiation of bloodstream trypanosomes into procyclic forms is vital for the survival of the parasites within the tsetse midgut. The harsh tsetse midgut environment consists of proteolytic enzymes, lectins and agglutinins to which the bloodstream trypanosome has to adopt physically and biochemically, as well as morphologically, by transforming into procyclic forms. We reported in the 1991 *ICIPE Annual Report*, factors within the tsetse midgut which are essential for this transformation to occur. These include the presence of optimal concentrations of midgut trypsin and whole blood, among others.

In addition to these factors, lectins (carbohydrate-binding proteins) have also been implicated by other research groups, and it appears that lectins and tsetse midgut trypsin play similar roles. Firstly, they are both involved in the lysis of the parasites and secondly, they have been implicated in the differentiation of parasites. Lectins lyse the parasites through agglutination.

We have shown that tsetse midgut lectins are specific for D(+)-glucosamine. At the same time, other research groups have shown that a blood meal containing 60 mM of this sugar significantly increased infection rates in flies. It was therefore of major importance to investigate the effect of this sugar on the lectin and trypsin activities of the tsetse midgut. Increasing concentrations of glucosamine progressively reduced trypsin activity down to 10% of the original activity. Other hexose sugars including glucose, mannose and *N*-acetyl-glucosamine were ineffective (Fig. 6.4). This inhibition was partial competitive and specific for trypsin and not other midgut proteases.

Glucosamine also specifically inhibited the agglutination of trypanosomes by tsetse midgut lectin, whereas other closely related sugars had no effect (Table 6.1). It has also been noted that the tsetse midgut lectin agglutinates procyclics better than bloodstream parasites, but pre-incubation of bloodstream forms with trypsin improved the agglutination of these parasites by tsetse midgut lectins. Presumably, trypsin function precedes the lectin one, i.e., trypsin removes the variable surface glycoprotein (VSG) and thus exposes the lectin binding sites on the

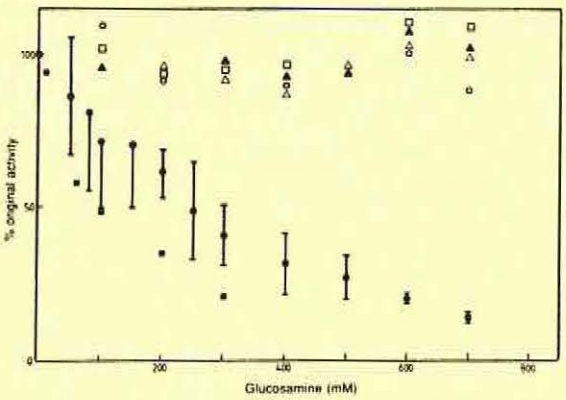

Fig. 6.2 Inhibition of tsetse midgut trypsin by D-glucosamine *in vitro* . Crude *Glossina m. morsitans* midgut homogenates (100 µg/ml) were pre-incubated for 5 min with 0-700 mM of D-glucosamine (●), D-galactosamine(▲), β-D-fructose (○) D-glucose (△) and D-mannose (□) and trypsin activity assayed using the standard assay system. Data represents averages of three determinations.

procyclin for the agglutination process to occur. Since trypsin and lectins eliminate parasites from tsetse midgut, the inhibitory effect of glucosamine on the two activities could be important in the susceptibility of the tsetse to trypanosome infection.

In addition to the factors mentioned above, this study has revealed other striking similarities between trypsin-like enzymes and lectins. These include:(i) the occurrence of the two activities in the tsetse midgut, (ii) the stimulation of their release by blood meal, (iii) peak activity at the same time (at 48 h in teneral flies and 24 h in non-teneral flies), and (iv) their co-elution on the FPLC anion exchange column.

The biochemical similarities between these two proteins are presently under investigation, including the purification and biochemical characterisation of the tsetse midgut lectin.

Table 6.1 Effect of glucosamine on lectin activity of *Glossina morsitans* midgut

Type of sugar	Agglutination titre at 50mM	100mM
Control	2048	2048
D-glucose	2048	2048
D-galactose	2048	2048
D-mannose	2048	2048
Sucrose	2048	1024
Lactose	2048	2048
Maltose	2048	2048
D-glucosamine	64	2
N-acetyl D-glucosamine	2048	1024

Sugar solutions at 50mM and 1200 mM concentrations were added to the midgut homogenate and incubatefd with *Trypanosoma brucei* procyclics (5 x 10^6 parasites/ml). Agglutination titre was scored as a reciprocal of end point dilution.

7

Biomathematics Research

7.1 CONVERSION OF CROP YIELD DATA FROM EXPERIMENTAL PLOTS TO LARGER PLOT UNITS

A. Odulaja and S. Nokoe

Agricultural research workers have usually converted the yield obtained from their experimental plots to larger plot units (usually in hectares) by linear extrapolation. However, yields obtained by farmers using the treatments recommended have been found to usually fall, sometimes by a very wide margin, below the expected yields as predicted by researchers.

The relationship between crop yield and plot size has been found to be best described by the power function

$$Y_x = uX^v \quad \ldots\ldots (1)$$

where Y_x is the yield obtained from plot size X, and u and v are constants. Hence, for any two given plot sizes, X_1 and X_2, in which $X_2 > X_1$, and which are uniformly cropped, Y_{X2} can be expressed, using (1), as

$$Y_{X2} = (X_2 / X_1)^v Y_{X1} \quad \ldots\ldots (2)$$

The conventional conversion by research workers gives Y_{X2} as

$$Y'_{X2} = (X_2 / X_1) Y_{X1} \quad \ldots\ldots (3)$$

Estimates obtained using equation (2) will be equal to that obtained using (3) only when $v = 1$. However, v cannot always be equal to unity in all circumstances, since this will imply the ideal situation of perfect soil homogeneity, non-environmental variability and perfect uniform maintenance of field and crops. When $v < 1$, then $Y'_{X2} > Y_{X2}$, which is the situation usually reported. Since v cannot be less than zero, as this will imply a negative correlation between the yield and size of plots uniformly cropped, it is reasonable to assume that

$$0 < v < 1 \quad \ldots\ldots (4)$$

The widely used quantitative measure of soil heterogeneity due to Smith (1938)* relates plot variance to size by

$$V_x = V_1 / X^b \quad \ldots\ldots (5)$$

where $V_x = V_x / X^2$, with V_x being the variance between yield of plots of size X, and b is a constant called the index of soil heterogeneity. Re-writing equation (5) and relating it to equation (2) gives

$$v = 1 - b/2 \quad \ldots\ldots (6)$$

Since it is assumed that $0 < b < 1$, then $0.5 < v < 1$.

A knowledge of b, the index of soil heterogeneity, which is now widely determined for many crops and environments, can therefore be used to determine v which may be used for yield conversion to give more realistic estimates.

*Smith, H. F. (1938) An empirical law describing heterogeneity in yields of agricultural crops. *J. Agric. Sci. (Camb.)* 28, 1–23.

7.2 CONVERSION OF CROP YIELD DATA FROM EXPERIMENTAL TO LARGER PLOT UNITS: MANAGEMENT LEVEL-BASED APPROACH

S. Nokoe and A. Odulaja

Using the yield-plot size relationship

$$Y = uX^d, \quad 0 < d < 1, \quad \ldots\ldots (1)$$

where Y is the yield obtained from a plot of size X and both u and d are constants, d has been found to be related to the index of soil heterogeneity, b, by

$$d = 1 - b/2 \quad \ldots\ldots (2)$$

Conceptualising d to be made up of components relating to soil heterogeneity and management level, we now attempt to develop methods of partitioning d into these two components.

Quantifying soil heterogeneity by b, the value of b can be regarded as constant for a particular crop and field or environment. Hence, variation in yield in this particular crop and environment can be said to be due to management levels. Two possible models considered on the structure of d are as follows:

(i) Additive Model

Supposing the effect of soil heterogeneity, b, and management level, m, hereafter referred to as the management index, are additive. Then,

$$d_i = m_i + b_i + e_i \quad \text{..... (3)}$$

where e_i is the error term assumed to be normally distributed with zero mean and constant variance. Then

$$m_i = 1 - 3b_i/2 \quad \text{..... (4)}$$

Since $0 < bi < 1$, then $-0.5 < mi < 1$

Hence, assuming three management levels — low, medium and high — the management index interval may be partitioned, on the basis of equal intervals, into these levels as

$-0.5 < m_i < 0$ (Low)
$0 \leq m_i < 0.5$ (Medium)
$0.5 \leq m_i < 1$ (High)

Thus, predictions can be made on a management level basis once the value of b for the particular crop and environment is known.

(ii) Multiplicative Model

If the effects of b and m are multiplicative, then

$$d_i = m_i b_i + e_i \quad \text{..... (5)}$$

where e_i is as formerly defined. This gives

$$m_i = (2 - b_i)/2b_i \quad \text{..... (6)}$$

where $0.5 < m_i < \infty$.

No obvious partitioning of this interval into the three management levels is apparent. However, a parallel partitioning may be obtained by estimating the b values corresponding to the class divisions of the additive model intervals. Applying this method gives the partitioning of the multiplicative model interval as

$0.5 < m_i < 1$ (Low)
$1 \leq m_i < 2.5$ (Medium)
$m_i \geq 2.5$ (High)

Since farmers rarely attain the high level of management of fields and crops as in on-station or researcher-managed trials, it is essential to take cognisance of this fact to accommodate the different levels of farmers' management skills and the expected output from their farms. A knowledge of the b value for a particular crop and environment sufficiently enables such management level-based predictions using our method. The choice between the additive and multiplicative models needs to be further investigated. Both models, however, seem to give similar results for the set of data examined.

7.3 A MAXIMIN-MINIMAX APPROACH FOR CLASSIFYING CROP VARIETIES INTO RESISTANCE GROUPS BASED ON YIELD POTENTIAL AND LOSS

A. *Odulaja and S. Nokoe*

A variety is usually judged resistant or non-resistant relative to known resistant and susceptible checks; the variables used for classifying the varieties into resistance groups are usually the percent yield losses and, very rarely, the yield potentials of the varieties under consideration.

A variety may have a relatively high percent yield loss but still produce a moderately high yield under this condition. On the other hand, a relatively low percent yield loss variety may yield below average. It is therefore important for selection purposes to simultaneously give attention to both yield potential under pest or disease attack and percent yield loss due to this attack.

The main purpose of selection for resistance is to maximise yield while minimising yield loss. Hence, the problem can be conceptualised as maximisation of minimum expected yield (maximin) and minimisation of maximum expected percent yield loss (minimax). Since a variety is, in most cases, judged resistant relative to the resistant check, and susceptible relative to the susceptible check, the maximin approach is to obtain the yield potential of each variety relative to the resistant check, while the minimax approach is to obtain the percent yield loss relative to the susceptible check.

Given V varieties to be tested together with one each of resistant and susceptible checks, let Y_R and Z_R be the yields of the resistant check when unprotected and protected from the pest or disease attack, respectively, Y_S and Z_S the corresponding yields of the susceptible check, while the corresponding values for variety i, $i = 1, .., V$, are Y_i and Z_i. Furthermore, let P_R, P_S and P_i be the percent yield loss due to the pest or disease attack for the resistant, susceptible and with variety respectively, obtained as

$$P_R = 100\ (Z_R - Y_R)/Z_R \quad \text{..... (1)}$$
$$P_S = 100\ (Z_S - Y_S)/Z_S \quad \text{..... (2)}$$
$$P_i = 100\ (Z_i - Y_i)/Z_i \quad \text{..... (3)}$$

The relative yield of each variety i may be obtained as:

$$RY_i = 100Y_i/Y_R \quad \text{..... (4)}$$

with the relative percent yield loss given as

$$RP_i = 100P_i/P_S. \quad \text{..... (5)}$$

When checks are not included in the experiment, the highest yielding variety under exposure to the pest or disease in question may be used as the resistant check while the variety with the highest percent yield loss may be used as the susceptible check. The higher the value of RY and the lower RP for any variety, the more

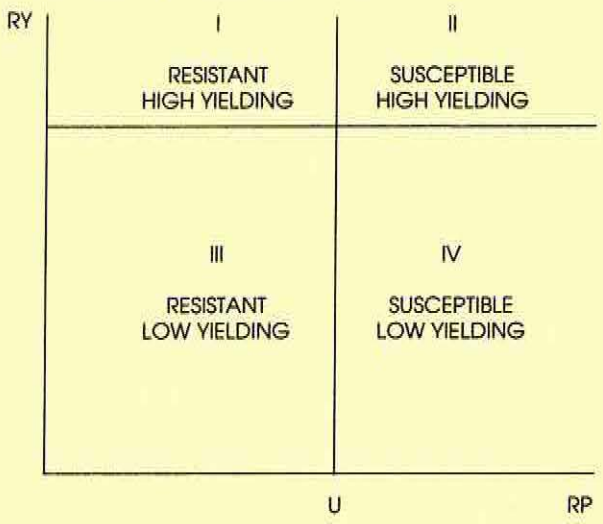

Fig. 7.1 A maximin-minimax plot for classifying crop varieties into resistance groups.

acceptable the variety is for selection. Setting *a priori* an acceptable lower limit, L, for RY and upper limit, U, for RP, a scatter plot of RY against RP, maximin-minimax plot, can be divided into quadrants as in Fig. 7.1. Varieties in the first and third quadrants can be classified resistant but high- and low-yielding, respectively, while those in the second and fourth quadrants are susceptible but high- and low-yielding, respectively.

When the lower limit for RY and upper limit for RP cannot be fixed, the quadrant dividing lines may be determined in such a way that very few or no varieties are left in quadrant III, thus maximising the computed chi-square for the null hypothesis that the overall distribution of varieties into the quadrants is random.

More than one each of the resistant and susceptible checks are at times included in this type of experiment. In such a situation, the mean or lowest yield of the resistant checks may be used in computing RY while the mean or the highest percent yield loss of the susceptible checks may be used in computing RP.

7.4 A SERIAL CORRELATION ANALYSIS OF EXPERIMENTAL FIELD SCORES

A. Odulaja and S. Nokoe

Experimental plots are often scored for the incidence or severity of pest or disease infestation. Such assessments are made visually using different predetermined ranges of scores (e.g., 0 = none to 9 = aggressive; 1 = short to 5 = very tall). Scoring is usually done serially, one plot after the other, in the order of field plan, regardless of treatment differences.

One fundamental problem in the analysis of such scores is that the score of any plot, except the first, is usually dependent on the score of the immediate previous plot. A scorer will naturally look back to the previous plots in order to determine the score of the present plot. This gives rise to a sequence of serially correlated observations.

Conventional analysis of variance (ANOVA) tests are usually carried out, either on the original or transformed data, with no provision for the obvious serial correlation.

7.4.1 *General model*

Let $Y = \{ y_{i(jk)} \}$ be a vector of unit plot observations (scores) on a measure of plant performance. The subscript i denotes the position of the plot on the field in order of observation, j denotes the treatment or treatment combinations applied to the plot and k denotes the replication. Consider the general model

$$Y = \mu + \gamma_j + \varepsilon_{i(jk)} \quad \text{.....(1)}$$

with γ_j representing all the factor effects, including blocking (where applicable) and interaction effects, and

$$E(\varepsilon_i^2) = \sigma^2 \quad \text{.....(2)}$$

The error term, ε_i must allow for serial correlation. When serial correlation is neglected, the danger is that of declaring a significant effect where there is actually none. The magnitude of this underestimation will depend on the nature and magnitude of the serial correlation.

7.4.2 *Correlation between successive plots only*

Assuming only successive plots' scores are correlated, that is,

$$E(\varepsilon_i \varepsilon_{i+z}) = \delta, \text{ when } z = 1,$$
$$= 0, \text{ otherwise,} \quad \text{.....(3)}$$

Thus,

$$g = 1 + 2\delta (N - 1)/N. \quad \text{.....(4)}$$

If serial correlation is positive as expected, g will exceed unity. As $\delta \rightarrow 1$ and N is large, $g \rightarrow 3$. The change in g value, θg, for a given change, $\theta\delta$, in δ, is given by

$$\theta g = 2\theta\delta (N - 1)/N. \quad \text{.....(5)}$$

θg is symmetrically distributed about $\theta\delta = 0$ and increases in magnitude as N increases.

The estimate of δ is computed as lag one autocorrelation of the residuals.

7.4.3 *Serial correlation with autoregressive structure*

Assuming all possible pairs of the ordered observations are correlated, that is

$$E(\varepsilon_i \varepsilon_{i+z}) \neq 10 \text{ for all } z,$$

a serial correlation analysis can be developed as follows:

With allowance for a correlation coefficient δ_z between plots z intervals apart,

$$g = 1 + (2/N) \sum_{i=1}^{N-1} (N - i)\, \delta_i, \quad \text{.....(6)}$$

When $\delta_i \neq 0$ for all $i \neq 0$, $g = 1$. As $\delta_i \rightarrow 1$ for all $i \neq 0$, then $g \rightarrow N$.

When the autoregressive structure is assumed and N is large, it may be very tedious and cumbersome computing autocorrelation of all possible lags. It seems therefore appropriate to assume that correlation between two plots, i and j, scores is a monotonic decreasing function of the interval between the plots; that is,

$$\delta_z = f(z), \quad \text{.....(7)}$$

where f is some known function and z is the interval. Thus, it may be possible to choose an interval, m, such that for all pairs of plots greater than m units apart, δ_z is effectively zero.

A second possible approach is to allow for a correlation coefficient δ^z between plots z intervals apart, computing δ as the autocorrelation of lag one. Putting $\delta_z = \delta^z$ then gives

$$g = 1 + (2/N) \sum_{i=1}^{N-1} (N - i)\delta_i \quad \text{.....(8)}$$

As $\delta \rightarrow 1$, then $g \rightarrow N$.

It may also be assumed that the values of the correlation coefficients are similarly serially related. That is to say,

$$\delta_{z+1} = h(\delta_z), \quad \text{.....(9)}$$

where h is some function which can be determined

from previous studies or assumed. If

$$\delta_{z+1} = u\delta_z, \quad \text{.....(10)}$$

where u is a constant, then

$$g = 1 + (2\delta/N) \sum_{i=1}^{N-1} u^{i-1} (N - i) \quad \text{.....(11)}$$

δ being the δ_1. The value of u will necessarily be less than unity for δ_z to be a monotonic decreasing function of z. As both u and δ approach unity, $g \rightarrow N$.

When

$$\delta_{z+1} = \delta_z^v, \quad \text{.....(12)}$$

where $v > 1$ is a constant, then

$$g = 1 + (2/N) \sum_{i=1}^{N-1} (N - i)\delta^t, \quad \text{.....(13)}$$

where $t = v^{i-1}$. As $\delta \rightarrow 1$, $g \rightarrow N$ for all v. The value of g is unity when $\delta = 0$.

Any analysis that ignores the possibility of serial correlation in such data risks underestimation of the relevant error variance. The effect and magnitude of this underestimation depend on the nature and magnitude of the serial correlation.

7.5 CHOICE OF TRANSFORMATION IN ANALYSING INSECT COUNT DATA

A. Odulaja and S. Nokoe

It is widely established in literature that the distributional pattern of insect count data is non-random with heterogeneous sample variance. The distribution of such data have been confirmed in the literature to be that of an aggregated dispersion pattern which fits best to the negative binomial distribution. The consequence is that the variance varies with the mean in a particular pattern. High coefficient of determination, R^2, values have been reported when the log variance is plotted against the log mean. Such data is also characterised with high variance, usually larger than the mean.

Before the analysis of variance (ANOVA) can be carried out on such data, the variance should be stabilised and made independent of the mean. The usual method of achieving these is by transforming the original count data to another scale. The transformation to be employed should, however, depend on the nature of the variance-mean relationship of the data. The reported form of this relationship is usually given as

$$\sigma^2 = a\mu^b \quad \text{.....(1)}$$

However, in most recent literature, this established functional relationship between the variance and the mean of such data is usually not taken into consideration before deciding on what transformation to use. Most often, the logarithm or square root transformation is arbitrarily employed.

Twenty-seven (27) sets of data collected over a period spanning many years at the Crop Pests Research Programme (CPRP) of ICIPE was used in this study. These data cover three crops — cowpea, maize and sorghum. Pests involved include thrips, pod borers and stemborers in their various developmental stages. The counts were either on per plant or per plot of given sizes for the crop involved.

Equation (1) was fitted to each of the data sets and the b values obtained. ANOVA, depending on the structure of the experimental treatments, was carried out on each data set for the following transformations of the count data, y :

I. $y' = y^1$ (no transformation)
II. $y' = \text{Log}_e(y+1)$
III. $y' = \sqrt{y}$
IV. $y' = y^{1-b/2}$

To compare the relative efficiencies of these four transformations in the stabilisation of the variation within each data set, the coefficient of variation (CV) was computed for each ANOVA. The statistical significance of the b values were determined to indicate how good the relationship (1) was for each data set.

Judging by the CVs, 13 of the 27 data sets were best transformed using method IV, 12 by method II, 2 by method III and none by method I. This indicates that one type of transformation or the other is necessary to stabilise the variance and remove the mean-variance dependency of these types of data whether the b value is significant or not.

Eleven (11) out of the 27 b values were not statistically significant at the 5% level. While this may indicate the independence of the variance and mean in the respective data sets, it does not necessarily establish homogeneity of variances. Hence, transformation is still appropriate in these cases.

Out of the 16 data sets with statistically significant b values, 11 were best transformed using method IV while the remaining 5 are best transformed using method II. Seven (7) of the statistically non-significant b values data sets are best transformed using method II while two each are best transformed using methods III and IV. The percentage reduction in the CV when the best transformation is compared with no transformation (method I) is between 22 and 92.

Even when $b = 0$ (an almost impossible situation), suggesting that no transformation may be required for the de-dependency of the mean and variance, some transformation may still be necessary to stabilise the variance. The percentage reduction in the CV when the best transformation is compared with no transformation further stresses the need for some transformation of insect count data.

If any CV greater than 25% is considered too high, none of the transformations discussed in this paper is good enough for 17 out of the 27 data sets. This suggests that some other transformations may be needed apart from the family discussed here. Such other transformations have been suggested by some authors.

From the results of this study, it is clear that no particular blanket transformation may be recommended for any of these crops pests or pests growth stages count. This is likely to be true also for other crops pests and environments. It is therefore important to investigate, firstly, the functional

relationship between the mean and variance of any insect count data before the choice of transformation procedure. From this study, however, there seems to be a general pattern in the relationship between the b values and the best transformation to adopt. When b is small (near zero), method III seems to be best followed by method II. For b values lying between 1 and 2, method IV is best, followed by method II when the b value approaches 2 and by method III when the b value approaches 1. When b is negative, and for other values of b, method II is best, followed by method III. One rule that could therefore be adopted is to use method IV when the b value is significant or lie between 1 and 2, and method II otherwise. This, however, needs further empirical evidence or confirmation.

7.6 A NON-LINEAR MODEL DESCRIBING YIELD LOSS IN COWPEA (*VIGNA UNGUICULATA*) DUE TO THE LEGUME POD BORER, *MARUCA TESTULALIS*

A. Odulaja and S. Oghiakhe

Previous studies on yield loss due to this pest have not seriously considered the use of mathematical models in relating yield loss to the pest infestation level. By developing models that give adequate fit and account for substantial variability in yield loss based on the relevant parameters, yield loss can be estimated for given levels of the infestation variables. This will also assist in timing control measures and determining economic injury levels.

A plot of % yield loss against pest infestation levels is usually characterised by considerable scatter and indicates substantial non-linearity in form. Linear models have been shown to be unsuitable for such plots. Non-linear models are, therefore, considered in this study.

Several non-linear models were examined for their ability to describe the relationship between yield loss in cowpea and three infestation parameters of *Maruca testulalis*. The best model for all the three parameters was of the form

$$y = ab^x ,$$

where y is the yield loss and x is either percent flower infestation, larval count or pod damage. A validation of the model using data collected from an independent experiment confirmed its suitability.

When infestation is nil, it is reasonable to still expect some yield loss due to extraneous uncontrollable factors. For the two sets of data used in this study, percent yield loss at zero infestation level was put between 13 and 16 in the model. Comparing the parameter estimates of model 3 using a simple t-test, no significant differences were found between values at both locations for each of the infestation parameters. This was also true for the b values. This seems to suggest that the model may be generalised for the different environments.

A unit increase in infestation level will increase the % yield loss by a multiple of the b value which lies between unity and 1.08. That is, if % yield loss at infestation level x is y_x, then, y_{x+1} is given by by_x. This represents an increase of $(b-1)y_x$, and a percentage increase of $100(b-1)$. This increase is highest for larval count with up to 7.8% yield loss. The increase for both % flower infestation and % pod damage were up to 1.5%.

Total yield loss is expected when the infestation level, x, is given by

$$x = \log(100/a) \,/\, \log(b) .$$

This value of x was given as 111–169, 23–39 and 133–324, respectively, for % flower infestation, larval count and % pod damage. This reveals further the militating effect of larval count. At 100% level % flower infestation and % pod damage, some 16–46% and 39–68% yield, respectively, could still be recovered because of compensatory growth or recovery from injury by the plant.

The model identified in this study serves as a useful tool in relating yield loss to the various infestation parameters of *M. testulalis*. It also meets the desired objective of predicting yield loss given the levels of the infestation parameters. Given a tolerable % yield loss, this model can be used to predict the appropriate time for taking necessary measures to control *M. testulalis* in cowpea fields, provided other factors are kept controlled. Hence, the model can serve as a useful tool for determining economic injury levels. Larval count seems to be the most sensitive parameter to use for such predictions.

7.7 AN AGE-STRUCTURED STOCHASTIC MODEL FOR THE PROJECTION AND CONTROL OF TICK POPULATIONS

J. O. Owino

A simple age-structured life cycle model for *Rhipicephalus appendiculatus* has been developed. It incorporates development, survival, pick-up/drop-out, mating probabilities and fecundity rates. Starting with an initial distribution of eggs, larvae, nymphs and adults, and assuming that new entrants into the system were only *via* the egg stage, the population distribution changes under certain homogeneous conditions are generated over discrete time periods. A hypothesised life cycle is presented in Fig. 7.2.

Population projections are based on the basic matrix model $n(t+1) = P(t)\ n(t)$, where $n(t)$ is a partitioned age structured vector of individuals in the various instars at time t and $P(t)$ is a partitioned projection matrix consisting of the above age specific probabilities and fecundity rates.

To illustrate the functioning of the model we assume that:

i. The partitioned matrix is time homogeneous, i.e., $P(t) = P$.
ii. There is a uniform age distribution of individuals per instar.
iii. The number of age classifications per instar are equal.

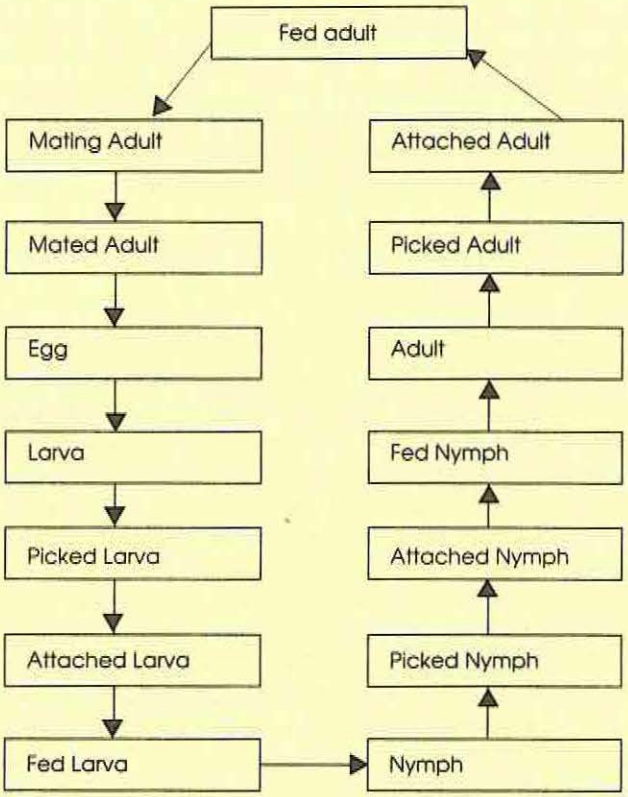

Fig. 7.2 The hypothesised life cycle for *Rhipicephalus appendiculatus*.

iv. The sex ratio is 1:1 and the fecundity rate per age group is 2000 eggs.
v. The survival probabilities are fixed at 50%.
vi. The developmental probabilities are fixed at 5%.

The model can then be used recursively for illustration purposes to project off-host and on-host populations of different life-cycle stages of ticks at different times.

We are now preparing to collect data to validate the model under the real conditions which are generally non-homogeneous.

7.8 GEOGRAPHIC INFORMATION SYSTEMS ACTIVITIES

H. H. Meena

The objective of the GIS section is to build geographic databases covering ICIPE research sites. The primary source of data is the 1 : 50,000 topographic maps produced by the Kenya Government (Survey of Kenya), from which physical features are extracted, and climatic data from satellites such as NOAA. In addition, climatic data from ICIPE's weather stations in the various sites is incorporated. Other data built into the databases are related to the relevant research activities, such as position of participating farms, crop yield, borer numbers, species, position of tsetse traps, trap catches by species, etc.

The first site selected for building the database is on the Kenyan Coast covering Kwale and Kilifi Districts. Here, three projects have been selected:

(i) *ICIPE/WAU Biological Control of Crop Pest Project*: In addition to the provision of physical and climatic features, 14 participating farms were geo-located using a Global Positioning System (GPS).

(ii) *Illinois/ICIPE Collaborative Project*: Use of ARC/INFO GIS, Spatial Analysis and Expert Systems for Tsetse Management. This project started in Lambwe Valley and was later extended to Kwale District. Databases for the Lambwe and Kwale area have been developed and were finalised during a visit to Illinois in April by BMRU staff. The databases include locations for tsetse traps, enclosing physical features (thickets size, direction of open area), etc.

(iii) *Integrated Socio-Economic and Bio-Agriculture Pest Management Technology Trial and Development*: In addition to providing the physical and climatic databases, GIS will be used in selecting study sites (at the macro-level) for the project and to locate at the micro-level participating farms (using GPS). These farms will provide data on pest and yield levels that will be extrapolated to cover uniform areas of the study.

8

Biotechnology Research

8.1 PRELIMINARY FIELD EVALUATION OF *BACILLUS THURINGIENSIS* (*BT*) AGAINST *MUSCA DOMESTICA* AND ASSESSMENT OF PILOT SCALE PRODUCTION

M. Makayoto

Application and assessment of *Bt* serotype 1 (*Bt* H-1) effectiveness against the housefly, *Musca domestica* in the field were studied. The *Bt* product was produced at the Technical University of Finland. Major field work was done in Kenya. It has been established that most toilets need re-treatment about 5–6 months after initial treatment. Preliminary technical assessment and cost estimates of *Bt* pilot scale production have also been made. The pilot scale plant would consist of the main fermenter of size 2–3 m^3. Annual production capacity of such a plant would be about 100 tonnes per year of *Bt* liquid product. The major raw materials required would be cowpea and molasses. In addition, phosphate, antifoam and pH control agents would be needed.

Preliminary product formulation would include 1% propionic acid or 10% sodium chloride. The study came up with three recommendations: the use of local nitrogen sources is feasible; the establishment of a pilot plant for *Bt* production is feasible; other local nitrogen sources should be investigated.

8.1.1 Application and assessment of Bt *effectiveness in the field*

The *Bt* serotype 1 (*Bt* H-1) product was used in this work. Three preparations were used, the broth, the paste and the powder. The broth consists of bacteria, spores and thuringiensin. Both paste and powder consist of bacteria and spores. Major treatment work was done in the Kibera area in Nairobi where 15 pit latrines of different shapes and structures were used. Other study areas were Kakamega, Bungoma, Busia, South Nyanza and Nguruman. Apart from pit toilets, garbage heaps and condemned meat pits were also treated. The initial dosage per toilet was 2 litres of the *Bt* formulation. The assessment of the *Bt* effectiveness went on for a year. During this period, re-isolation of *Bt* was also carried out to ascertain the presence of the bacteria.

Table 8.1 shows the initial response of the housefly larvae in different types of pit latrines. It can be observed that for the shallow and open pit latrine, treatment had to be done three times for any effect to be observed. This was because it was raining during the time. In other toilets, the effect on larval population reduction was noticed after 4–5 days. After 3–4 weeks most of the toilets had no larvae at all and this continued for six

Table 8.1 Effects of various formulations of *Bacillus thuringiensis* on *Musca domestica* larvae breeding in toilets in Kibera, Nairobi

Toilet type	Formulation	May 18	May 22	May 28	June 4	June 18	July 2	July 23	Aug 2
Shallow Open	Broth-A	+++	+++[2]	+++	++	++	+++[3]	+	+
Shallow Roofed	Broth-A	+++	–	–	–	–	–	–	–
Two-Holed	Broth-A	+++	++	++	++	++	–	–	–
Pit Latrine	Broth-A	+++	++	++	++	+	–	–	–
VIP Type[1]	Paste-B	+++	+	–	–	–	–	–	–
Pit, Roofed	Powder-C	+++	–	–	–	–	–	–	–

[1]VIP, Ventilated improved pit latrine.
[2]+++, many live larvae; ++, some effect seen; +, almost no larvae; –, no live larvae present.
[3]Re-treatment.

months. Results indicated that six months after treatment, *Bt* could still be re-isolated from different toilets.

It was established that most toilets need two treatments per year. It was also established that it does not matter which preparation is used. The broth, paste and powder gave the same results.

8.1.2 *Assessment of* Bt *Pilot scale production: Preliminary and economic evaluation*

A study on the installation of a pilot plant of fermentation size of 2 m^3 has been carried out. The annual production capacity is 100,000 kg of liquid product (or 10,000 kg of paste). The preliminary production cost is estimated at Ksh 30/kg of liquid product. From field evaluations, the estimated dosage per year is 3 kg/year/toilet. The total annual cost of treating one toilet is Ksh 90/year.

The major raw materials required are cowpea and molasses. In addition, phosphate, antifoam and pH control agents are needed.

8.1.3 *Preliminary product* (Bt) *formulation*

When formulating a product such as *Bt*, consideration must be given that the product meets qualitative and quantitative standards. It should be handled easily and must maintain its activity for a given specified period. Most of the information on commercial products is confidential and one has to formulate one's products to suit the specific local conditions. Good formulation is prerequisite for cost-effectiveness, shelf-life, easy handling and application. The additives in the formulation should include diluents, preservatives and other inert ingredients.

In fermentation of *Bt* bioinsecticide, formulation is based on either the broth or paste (centrifuged broth) or powder (spray-dried). In this study, a number of additives which include inerts such as bagasse, sisal waste and pig faeces, and preservatives such as propionic acid, ethanol, sodium chloride and molasses, were tested. Other materials which have been tried before such as xylenes and sorbitol also do preserve the product but the dosage levels required are quite high. As shown in Table 8.2, 1% propionic acid or 10% sodium chloride show some potential in preserving *Bt* based products. Spore count after a year's storage shows that both sodium chloride and propionic acid do not affect spore viability (Table 8.3). The shelf-life studies are still in progress.

Table 8.2 Odour elimination and spore viability count of *Bt*-based insecticides

Additives	Observations	
	Odour[1]	Spore count viability (spores/ml)
1% Propionic acid	++++	$1.5.10^8$
0.5% Propionic acid	++	$2.2.10^8$
0.5% Ethanol	+	–
10% Sodium chloride	+++	$2.7.10^8$
5% Sodium chloride	+++	$3.5.10^8$
1% Sodium chloride	+	–
Control	+	

[1]No odour at all, ++++; Acceptable odour, +++; unsatisfactory odour, ++; bad odour, +.

8.2 COMPARISION OF GROWTH, SPORULATION, AND PRODUCTION OF THURINGIENSIN BY *BACILLUS THURINGIENSIS* ON SOYBEAN, COWPEA AND LOCAL WASTE RAW MATERIALS

M. A. Okech

Soybean has been used in the production of *Bacillus thuringiensis* serotype 1 for the control of filth flies. However, as soybean is such a good source of protein and food for humans, it is wasteful to use it for this purpose. We are now screening locally available protein-rich waste materials as alternatives to soybean.

Studies were carried out to find the best conditions for growth and production of spores and thuringiensin (exotoxin) by *Bacillus thuringiensis* serotype 1 (*Bt* H-1) on soybean, cowpea, blood meal, meat, bone meal, horn, and hoof meal as sources of nitrogen.

Shake-flask cultures were set up in 250 ml Erlenmeyer flasks with 100 ml of culture media. Media in the different flasks were made up of the different nitrogen sources listed above, all set in triplicates. These were autoclaved before inoculating with 10–12

Table 8.3 Observation of growth and sporulation of *Bt* cultured on local raw materials

Time[1]	Soybean	Blood Meal	Meat/Bone Meal	Horn/Hoof Meal
24 h	few cells sporulated	most cells sporulated	no spores in cells	no spores in cells
48 h	all cells sporulated	free spores and crystals	most cells sporulated	cells starting sporulation

[1]Hours after inoculation.

h-old culture grown in Typtone-Yeast extract-Glucose (TYG) broth media. The inoculated flasks were incubated at 30°C on a rotary shaker and driven at a speed of 200 rpm.

The toxin concentration was determined from autoclaved culture broth. Different concentrations (10, 15, 20, 40 and 80 µl) of the autoclaved product were made up in cups and set up in triplicates. Six control cups were also set up. Pieces of tissue paper were placed in the test cups before 20 three-day-old larvae of houseflies were introduced. The cups were then covered with plastic film and small holes made to allow aeration. The cups were incubated at 25°C until the flies emerged. From the results the lethal dose (LD_{50}) was calculated.

At 48 h the average cell count was carried out in all the flasks. The spore count was carried out after 96 h when all the cultures had completed sporulation.

Recently we received a new strain of *Bt* H-1 from the University of Helsinki. It grows very fast and sporulates in less than 24 h. We have tried it on the different protein sources mentioned above and preliminarily observations show good cell growth and sporulation (Table 8.3).

8.2.1 Scaling up on the 15 litre fermenter

Scaling-up fermentation trials were carried out using soybean as a standard protein source. The fermenter used was the Biostat*E (B. Braun). The cultures were started from lyophilised *Bt*, inoculated in 250 ml Erlenmeyer flasks containing TYG broth medium. This was incubated on a rotary shaker at 30°C for 18 h. This culture was used to seed four flasks containing soybean medium, which after incubation for about 15–18 h were used to seed the fermenter.

The fermenter was set up with the following parameters controlled on line:

pH	7.0
Temperature	32°C
Aeration	1 vol/vol/min
Stirrer speed	200 rpm

Growth in the fermenter was followed hourly and at the end of the fermentation, total cell count, spore count and toxin value were noted. The product was tested in pit toilets and the results show that *Bt* H-1 product is effective in controlling filth flies.

8.2.2 Detection of thuringiensin (β-exotoxin) in the fermentation product

The fermentation product was tested using HPLC to confirm the presence of thuringiensin. The results were compared with those of standard thuringiensin obtained from the de Barjac Institut Pasteur, Paris.

The chromatography was carried out on a Waters 715 model HPLC equipped with a UV-detector (Waters Associate model 440). The thuringiensin was analysed on a Nova-Pak C_{18} column (8 mm x 10 mm, 4 µm particles). For gradient elution, degassed sodium phosphate buffer at pH 4 was used, among other solvents. The samples were read at different wavelengths for thuringiensin. The results show that the best detection is given at wavelengths between 250–270 nm.

9

Insect and Animal Breeding

9.1 EXPRESSING PRODUCTION AND SUPPLY OF CROP BORERS IN TERMS OF EGG-EQUIVALENCE

F. O. Onyango

In previous years, production and supply of *Chilo partellus*, *Busseola fusca* and *Maruca testulalis* have been expressed in terms of total quantities of insects produced and supplied, regardless of the stage of development. Users usually request for specific stage(s) of development of an insect species. Based on the variable production costs of the various insect stages, the production and supply of adults, pupae or larvae were this year expressed in terms of respective egg-equivalence for standardisation yearly projections, budgeting and costing. This was done as follows:

1 *Chilo* adult/pupa = 2 L_4/L_5 = 12 L_3/L_4 = 160 eggs/L_1

1 *Busseola* adult/pupa = 1 $L_2 - L_6$ =150 eggs/L_1

1 *Maruca* adult/pupa = 1 $L_2 = L_5$ = 100 eggs/L_1

1 *Busseola* egg = 3.2 *Chilo* eggs = 5.3 *Maruca* eggs.

The above equivalencies were worked out on the basis of the total costs of rearing each stage of the insect, including the cost of 1 litre of the artificial diet, casual labour in preparation of the diet, and laboratory maintenance costs. One pair of adult *B. fusca* produce on average 300 viable eggs which hatch to give rise to 300 1st instars. About 50% of larvae survive to pupate, so one pair of adult moths produce 150 pupae. The 1992 cost of 1 litre of diet is Ksh 176.40, and this is sufficient to raise 35 pupae (or 34 adults). The cost of 1 adult is therefore Ksh 5.25.

9.2 PRODUCTION AND SUPPLY OF *CHILO PARTELLUS* AT MPFS

M. D. O. Bungu, J. O. Osuri, J. O. Maoro, M. O. Chacha, W. I. Odhiambo, J. N. Kunyu, P. A. Nyakwamba, F. O. Onyango and J. P. R. Ochieng'-Odero

The colony of *C. partellus* was maintained on a semi-synthetic diet throughout the year. The peak demand occurred in the months of April and October for the long and short rainy seasons, respectively. All insects demanded were supplied. The quantities of *C. partellus* produced and supplied totalled 60.3 and 19.2 million egg-equivalents, respectively during the year.

9.3 REARING OF *CHILO* SPP AT DUDUVILLE

P. E. Njoroge, M. Gitau and A. Majanje

The production of *Chilo partellus* at Duduville was stepped up during the year to cater for the requirements of the ICIPE/WAU and Kwale/Kilifi projects. Between 8–9 million egg-equivalents of this species were supplied to ICIPE/WAU (10.6%), Kwale/Kilifi project (85.0%), BCERU (1.7%), CPRP (2.3%) and other users (0.4%).

In the course of the year efforts were directed towards developing a cheap artificial diet for rearing *C. partellus* as well as rearing a coastal species, *C. orichalcociliellus*, using artificial diet.

An artificial diet composed of sawdust, wheat bran and reduced quantity of agar was found to be promising in rearing *C. partellus*. Detailed evaluation of this diet is in progress.

Initial attempts to rear *C. orichalcociliellus* on the standard *C. partellus* diet was not very successful. However, with the reduction of agar, the development of the species on the artificial medium improved. Improvement of the artificial diet for suitability of *C. orichalcociliellus* rearing continues.

9.4 PRODUCTION AND SUPPLY OF *MARUCA TESTULALIS*

P. O. Wangara, F. O. Onyango and J. P. R. Ochieng'-Odero

The quantity of *M. testulalis* supplied for research declined drastically this year due to the reduced number of users with a relatively low demand compared to the previous two years. The irregular

means of transporting the insects from Mbita Point Field Station where the insect is produced to Duduville, where regular users are stationed, was also a factor affecting supply. Major users were ARPPIS Scholars and Behavioural and Chemical Ecology Research Unit (BCERU). Relatively fewer insects were used by the Plant Resistance to Insect Pests (PRIP) section of the Crop Pests Research Programme (CPRP). The quantity produced was deliberately kept just above the quantity demanded for cost considerations. The quantities of *M. testulalis* supplied in 1992 was 2.8 million egg-equivalents compared to 7.3 and 7.2 million in 1991 and 1990, respectively.

9.5 PRODUCTION AND SUPPLY OF *BUSSEOLA FUSCA*

A. G. Nyangwara, B. O. Owiyo, D. J. Okode, J. M. Okomo, F. O. Onyango and J. P. R. Ochieng'-Odero

The production of *B. fusca* in 1992 increased ten-fold since 1990 and nearly 4 times as in 1991. The quantity supplied in 1992 was 1.2 million egg-equivalents, 6 times and 2.5 times more than the quantity supplied in 1990 and 1991, respectively. Major users this year were ARPPIS (67.7%), CPRP (13.2%), and CBRU (10.6%). The colony was continuous and sustained throughout the year.

A colony of *B. fusca* was initiated at Duduville in March, 1992 using ex-Mbita insects. The colony is steadily building up and in time should be able to cater for Duduville users, particularly BCERU and ARPPIS.

9.6 PROCEDURES FOR ARTIFICIAL REARING OF *MARUCA TESTULALIS*

F. O. Onyango, P. O. Wagara, A. G. Nyangwara and J. P. R. Ochieng'-Odero

The ingredients used in preparing *M. testulalis* diet used in ICIPE since 1989 are listed in Table 9.1. About 10 ml of the diet per vial is dispensed while warm into heat-sterilised flat-bottomed glass vials (7.5 x 2.5 cm dia.) by means of a ketchup dispenser. The vials are then covered with paper towels and allowed to stand overnight at room temperature to gel and to remove any condensate before use.

Five neonate larvae are introduced into each vial which are then covered with tight-fitting sterilised cotton wool plugs. The cotton wool plugs are removed 16 days after inoculation and the vials placed in clean adult emergence perspex cages (40 x 40 x 25 cm). Most pupae emerge 18–20 days after inoculation of the larvae.

Adult oviposition units are made of rectangular metal framed cages (30 x 30 x 45 cm) covered with wire mesh (5 squares cm^{-1}) on the sides and top and a metal base. Distilled water soaked in cotton wool is placed inside the cage in a Petri dish for the adult diet. Clean potted young cowpea plants (a *Maruca* susceptible variety) approximately 2 weeks-old are provided inside the cage for oviposition. Fifty adult pairs are introduced per cage.

Eggs are checked beginning 2 days after setting up the oviposition cage. Potted plants are removed each morning and checked for eggs on both surfaces of the leaf. The leaves with eggs are excised and incubated at ambient laboratory conditions (optimum 28 ± 2°C; 70–80% r.h.) in a sandwich box lined with moist filter paper and covered with a perforated lid.

The semi-synthetic diet and rearing procedure is capable of producing 70–90% normal adults from neonate larvae. It produces uniform insects of predictable performance without loss of vigour or reproductive capacity over successive generations of laboratory rearing. The procedure minimises handling of insect stages, thus saving time and labour (one person working 8 hours/day can produce over 1000 healthy pupae or adults/day), and over 400 healthy pupae or adults can be produced per litre of diet.

Table 9.1 Components of the artificial diet NMD/89 for rearing *Maruca testulalis* at the ICIPE

	Quantity per 3.2 L diet
Distilled water for blending	1200 ml
Brewer's yeast	40.0 g
Ascorbic acid	11.0 g
Sorbic acid	2.5 g
Methyl *p*-hydroxybenzoate	5.0 g
Vitamin E (300 i.u.) capsules	1.5 g
Soybean flour	350.0 g
Cowpea flower powder*	50.0 g
Agar (technical No. 3) powder	50.0 g
Distilled water for agar	200.0 ml
Formaldehyde 40%	1.0 ml

*Dried in the oven at 60°C for 12 h.

Adults reared on the diet are able to recognise the host plant for oviposition of viable eggs, while hatching larvae are able to feed and develop normally on fresh cowpea flowers.

Thus, this method of rearing *M. testulalis* was found to be very suitable for high-volume host plant screening at marginal costs per production unit in terms of labour requirements and diet ingredients.

9.7 PROCEDURE FOR SUSTAINED REARING OF *BUSSEOLA FUSCA* ON A SEMI-SYNTHETIC DIET

F. O. Onyango, A. G. Nyangwara, B. O. Owiyo, D. J. Okode and J. P. R. Ochieng'-Odero

The ingredients for the artificial diet for rearing *B. fusca* are listed in Table 9.2. Approximately 15 ml of diet is dispensed while warm per heat-sterilised glass vial (7.5 x 2.5 cm dia.) using a ketchup dispenser. The vials are covered with clean paper towels and left overnight on the bench in the laboratory to gel and remove condensate before use.

Table 9. 2 Ingredients of the semi-synthetic diet D2/88 for continuous rearing of *Busseola fusca* at the ICIPE

	Quantity per 2 litre diet	
Fraction A		
Distilled water for blending	800	ml
Bean (*Phaseolus vulgaris*) powder	175	g
Brewer's yeast	45	g
Sorbic acid	1.3	g
Methyl *p*-hydroxybenzoate	2	g
Ascorbic acid	5	g
Vitamin E capsules (300 i.u.)	4.2	g
Sorghum leaf powder*	50	g
Sucrose	70	g
Fraction B		
Agar (tech. No. 3) powder	25	g
Distilled water for agar	800	ml
Fraction C		
Formaldehyde 40%	2	ml

*4–8 weeks old leaves, dried in the oven at 60°C for 12 h.

Neonate larvae are introduced singly into the glass vials containing the diet using a sterilised camel hair brush such that the brush does not come in contact with the diet. The vials are closed immediately with tight-fitting sterilised cotton wool. Rearing vials that are contaminated with fungus are immediately discarded. The larvae are allowed to feed *ad-libitum* until pupation.

Fresh pupae are collected weekly and placed in perspex holding cages (24 x 20 x 24 cm) ready for the adults to emerge in two weeks time. Newly emerged adults are collected, the sexes separated and later paired in a metal frame cage (30 x 30 x 45 cm) covered with wire mesh (5 squares cm^{-1}) on the sides and top and a metal base. The sex of the adult is determined by sexual dimorphism of the antennae, females being filiform and males pectinate.

Fresh sorghum stems 6–8 weeks old with intact leaf sheaths are provided diagonally inside the cage daily for moths to oviposit. Adults are fed on distilled water soaked in tissue paper in a Petri dish. The sorghum stems are removed from the oviposition cage daily and portions of the leaf sheath containing eggs are carefully excised, eggs dislodged from the leaf sheath and sterilised in 1% sodium hypochlorite solution for 10 min. A few drops of liquid detergent are added to allow the eggs to sink to the bottom of the solution. The eggs are rinsed in 5 washings of distilled water, dried between two filter papers, and placed in sterilised glass vials (7.5 x 2.5 cm dia.) containing a moist filter paper at the bottom. The vial is tightly closed with sterilised cotton wool wrapped in tissue paper. The eggs are left to hatch at optimum temperature and relative humidity, for egg incubation are 28 ± 2°C and 70 – 80% r.h., respectively.

Young sorghum leaf powder, when incorporated in the semi-synthetic diet, causes high larval mortality, while mature sorghum leaf powder induces a high incidence of diapause. The use of sorghum leaf powder 4–8 weeks old prevents diapause and supports the highest survival. Using the above method, one litre of diet produces an average of 40 pupae; 5–6 generations are completed per year with a total developmental period (egg – egg) of about 68 days, and the peculiar diapause behaviour is overcome. So far, 18 successive generations have been reared at the ICIPE Mbita Point Field Station.

9.8 REARING OF THE DESERT LOCUST *SCHISTOCERCA GREGARIA* AT ICIPE

S. M. Ndugo, J. P. R. Ochieng'-Odero, J. T. Kilori, S. A. Patya, J. H. Ongudha and G. M. Nganga

The stock used to propagate the desert locust colony is the same one which originated from Addis Ababa, Ethiopia and the Red Sea Coast of Sudan in 1989 and 1990, respectively.

The crowded colony is now in its 17th generation. The insects were fed mainly on Serena sorghum seedlings and wheat bran. Mortality was at times as high as 30% due to cannibalism, especially in the late nymphal instars. Fecundity averaged 40–50 eggs/pod. Five generations were completed per year, with F/C and E/F ratios remaining fairly constant over the generations. A total of 26,274 locusts were supplied this year.

The ex-Addis and ex-Red Sea strains of the isolated locusts are in the 14th and 11th generations, respectively. They were previously fed on a diet of Serena sorghum seedlings and wheat bran, however they are now fed on wheat seedlings and wheat bran, on which they have been found to perform better. Mortality was 3% and 10% for ex-Addis and ex-Red Sea strains, respectively. Fecundity was 80 ± 9 eggs/pod over the generations. F/C and E/F ratios for both strains remained constant, showing no significant change between generations. A total of 1254 locusts were supplied this year.

9.9 PRODUCTION AND SUPPLY OF TSETSE AT MPFS

J. A. Ojude, J. K. Gitegi, J. O. Opere, W. O. Oganda, F. O. Onyango and J. P. R. Ochieng'-Odero

The low propensity of *Glossina pallidipes* to mate (see *ICIPE 1991 Annual Report*) continued to hinder the continuous and sustained laboratory rearing of the species in 1992. Similar protracted problems were experienced with *G. fuscipes fuscipes*, introduced from the neighbouring lake shores. However, a total of nearly 30,000 pupae were supplied over the year to initiate a colony at the Duduville insectary. The pupae were obtained from wild flies trapped around the lake shores and held in the insectary at MPFS. The possible cause(s) of low mating propensity and high mortality is the subject of future research at MPFS.

9.10 PRODUCTION AND SUPPLY OF *GLOSSINA MORSITANS MORSITANS* AND *GLOSSINA MORSITANS CENTRALIS*

J. U. Wanyonje, H. K. Banda, E. O. Awuoche, R. G. G. Kariuki, N. M. Mwikya, and J. P. R. Ochieng'-Odero

Glossina morsitans morsitans and *G. m. centralis* were reared and supplied to Livestock Pests Research Programme (LPRP), Behavioural and Chemical Ecology Research Unit (BCERU), Molecular Biology Research Unit (MBRU) and Biotechnology Research Unit (BTRU).

During the year, production and supply of *G. m. morsitans* peaked in February and October while that of *G. m. centralis* occurred in January and October. Compared to the previous year, more *G. m. centralis* were demanded and supplied for research this year. All user demands for both species were supplied without difficulty. Mortality rate was kept below 1.5% throughout the year.

In order to meet the user requirements for the year, the colony of *G. m. morsitans* was maintained at approximately 9000 producing females while that of *G. m. morsitans* was kept at approximately 7000.

9.11 EFFECT OF A BROAD SPECTRUM ANTIBIOTIC ON THE REPRODUCTION OF TSETSE

J. U. Wanyonje, J. M. Kagoiya, I. G. Onyango and J. P. R. Ochieng'-Odero

Three rabbits were each injected with oxytetracycline (Vetmycin) weekly at the recommended dosage for a period of 13 weeks. A similar number of rabbits were untreated. The treated and untreated rabbits were then provided with food and water under identical environmental conditions.

Twenty newly emerged, clean parent tsetse females kept in a cage were allowed to feed per treated or control rabbit. Male flies were similarly treated, used for mating, then killed. The procedure was repeated for two successive generations and reproductive performance observed.

Parent flies on treated rabbits produced comparatively smaller pupae than those flies feeding on untreated rabbits, which produced weaker first generation flies. The pupae from the first-generation flies failed to emerge to perpetuate the second generation offspring. On the other hand, flies fed on untreated rabbits produced healthy pupae and adults during the two generations.

Thus, the use of oxytetracycline (Vetmycin) in treating rabbits for feeding tsetse was found to be detrimental for the reproduction of tsetse.

9.12 PRODUCTION AND SUPPLY OF SMALL LABORATORY MAMMALS IN 1992

J. M. Kagoiya, A. S. Ikhunyalo, R. O. Agan, S. M. Mbugua, J. Otieno and J. P. R. Ochieng'-Odero

Outbred colonies of laboratory rabbits, rats, Swiss mice, hamsters and inbred strain of balb/c mice were maintained and supplied for feeding target haematophagous arthropods and for research work at the ICIPE. The section was able to breed and supply 1770 rabbits, 1845 rats, 1149 Swiss mice, 894 balb/c mice and 324 hamsters. Though the rodents were available, fewer were supplied this year compared to 1991, with the exception of the rabbit supply which increased by 30%.

The section could not breed all the required rabbits due to lack of space and adequate breeding and holding cages. Towards the middle of the year, 100 aluminum rabbit cages were bought in order to ease the space problem.

9.13 EFFECT OF COCCIDIOSTAT COYDEN 25 ON THE PERFORMANCE OF RABBITS AND TSETSE *GLOSSINA MORSITANS CENTRALIS*

J. M. Kagoiya, J. P. R. Ochieng'-Odero and H. K. Banda

Three groups of adult New Zealand white rabbits weighing between 3–4 kg each were maintained under normal conditions. The rabbits were fed *ad libitum* with water containing Coyden 25 at concentrations of 0%, 0.08% and 0.16%, respectively, and rabbits pellets without any coccidiostat. The daily volume of water consumed and food eaten, weekly weights of the rabbits, packed cell volume (PCV) estimation, and the general health of the rabbits were observed.

Coyden 25 at a level of 0.08% and 0.16% given in water did not adversely affect the health of rabbits. The PCV, weight, food and water consumption were also normal. Similarly, *G. m. centralis* maintained on the coccidiostat-treated rabbits were not adversely affected.

10

Social Science Interface Research

10.1 SOCIO-ECONOMIC DIAGNOSTIC SURVEY OF THE KWALE AND KILIFI DISTRICTS

A. W. Oendo and F. G. Kiros

The survey was carried out as part of the Kwale and Kilifi Districts Adaptive Research Project (see also report of this project under IBIRI). The purpose of the Project was to undertake research on integrated pest and vector management technologies which are adapted to the agro-ecological conditions of the area, and which are compatible with the peoples' socio-economic circumstances. The ultimate aim was to enhance food security through control of crop pests and livestock disease vectors, particularly tsetse.

The objective of the socio-economic survey was to facilitate adaptation of technologies by making available to biological scientists basic information on farmers' resource base, practices, perception and knowledge regarding pest management. It also aimed at providing information on costs, preferences and institutional factors which would influence technology adoption.

Three sites were selected from each district representing the three dominant agro-ecological zones (AEZ)—L3, L4 and L5—with the advice and assistance of staff of the Ministry of Agriculture in Kwale and Kilifi Districts. A sample of 30 respondents was taken from each site, making a total of 180 farmers (90 from each district). Interviews of farmers were conducted by combined teams of ICIPE, KARI (Kenya Agricultural Research Institute), and Ministry of Agriculture extension staff over a period of 21 days during March and April, 1992. Entry of data into the computer and analysis was carried out at the ICIPE headquarters, Nairobi.

10.1.1 Population profile

In both districts the majority of the residents are of the Mijikenda ethnic complex, with significant minorities of immigrants, especially Kamba from inland. While in Kwale District Islam predominates (74%), Christianity has more adherents in Kilifi District (56%). Indigenous religions have a significant following in the latter (32%). Levels of illiteracy are quite high, with only a small number having attained more than eight years of formal education (15% in Kilifi and 3% in Kwale) and about half having no form of education. The number of polygamous households was higher in Kwale District, as was the number of female-headed households.

10.1.2 The economy

The majority of the people in the two districts are agricultural producers. Food crops produced are maize, cassava, rice, sorghum, millet and legumes. The main cash crops are cashew nuts, coconuts, cotton, sisal, sugarcane and horticultural products. In the drier hinterland, cattle rearing (mostly Zebu) is carried out to a significant extent. Food crop production, cash crop production, livestock rearing and cottage industries are the main sources of cash income.

10.1.3 Agricultural production

The bulk of agricultural activities are undertaken by women in both districts. However, in the L3 AEZ, men play a relatively greater role than their counterparts in the other zones.

It was also found that although the majority of the respondents practiced intercropping, only a small number (mostly in the L3 AEZ) used it as a method to control pest attacks. Similarly, only a small number of respondents used early planting for such control. Indeed, a significant number, especially in L5, practised late planting for this purpose.

Farmers were familiar with and used many maize, cowpea and sorghum varieties. Nevertheless, it was clear that whatever features they recognised in these varieties, be it resistance or susceptibility to pest attacks, whether in the field or in storage, was not effectively utilised.

About half of the respondents experienced frequent food shortages, with about one-third facing shortages during more than half of the year.

10.1.4 Livestock rearing

Livestock rearing plays a more important role in the less well-watered parts of the two districts. Nevertheless, the tendency is to keep more sheep and goats than cattle. Men play a more important role in cattle-rearing activities, especially in the L3 AEZ. Livestock diseases were regarded as the single most important constraint (67% in Kilifi and 83% in Kwale). Other problems were drought, labour shortage and inadequate support services.

Ticks and tsetse were regarded as the main arthropods affecting cattle. Perceptions differed as to the periods of heightened tsetse activity, while there appeared to be limited knowledge of the diseases transmitted by the fly. Moreover, only a small number of farmers took any measures to protect cattle from tsetse bites, apparently for lack of knowledge of effective methods of doing so.

10.2 FOOD PRODUCTION PRACTICES AND CROPPING CALENDARS IN LAMBWE AND KIBIRI AREAS OF SOUTH NYANZA DISTRICT

P. O. Chitere and A. M. Alghali

This study sought to understand cropping systems and timing of farm operations with a view to adapting IPM technology to the local farming systems of South Nyanza District. The study was based on detailed open-ended interviews of a sample of 68 farmers (33 from Lambwe and 35 from Kibiri). The analysis of the data compiled is still in progress. However, initial findings relating to factors influencing adoption can be reported here.

The dependent variable in this study was adoption of farm inputs and practices recommended by extension workers. The independent variables of the study were: age, gender, wealth status as measured in terms of farmers' material possessions and income earning opportunities, formal education, and awareness of the Ministry of Agriculture's (MOA) extension recommendations on growing of food crops.

The dependent variable, adoption, was assessed from 19 equally weighted indicators, including early planting, proper spacing, clean weeding, insect pest control, and use of fertilizers and improved seeds. Each of these was treated as a score. In Lambwe, 18% had high (8–12), 42.4% had medium (6–7), 15% had low (4–5), and 24.2% had very low (less than 3) scores. In Kibiri, 22.9% had high, 25.7% had medium, 34.3% had very low scores. No significant difference was observed in the scores obtained by Lambwe and Kibiri farmers ($\chi^2 = 4.486$, df = 3, $P < 0.05$).

Among the independent variables that were hypothesised to influence farmers' adoptive behaviour, it was only their awareness of extension recommendations and their wealth status which were significantly related to adoption.

10.3 THE FEASIBILITY OF USING CHICKENS AS PREDATORS OF LIVESTOCK TICKS ON RUSINGA ISLAND

J. W. Ssennyonga and P. Mungai

The biological potential of chickens as predators of livestock ticks has been shown to be high (*ICIPE Annual Reports 1989, 1990*). A study aiming at determining the socio-economic feasibility of using chickens as predators of livestock ticks (FUCPLT) was started in 1991. Four determinants of FUCPLT were identified, namely (i) demographic parameters, (ii) ownership and distribution; (iii) management, and (iv) costs and benefits. Studies of (i) and (ii) have been discussed (*ICIPE Annual Report 1991*). This report discusses investigations of management. (See also a report on this project under Livestock Pests Research).

Management affects the predation capacity of chickens in three major ways: feeding regimes, health care, and shelter arrangements. This report focuses on shelter arrangements with a view to showing how they enhance or constrain the accessibility of cattle to chickens.

Three sets of data were collected from 53 randomly selected homesteads, namely (i) chicken and livestock rearing units; (ii) places where chickens, cattle, goats and sheep are kept; and (iii) measurement of the distances between the sites where chickens are kept and where cattle, goats and sheep are kept.

The findings of this study show that whereas cattle are owned and managed centrally at the homestead level, chickens are managed as units but are owned by more than one individual at the household level. The number of households making up a homestead ranges from 1 to 6, with a mean of 2. Thus, there are 104 chicken-rearing households, and 109 owners in the 53 sample homesteads.

Shelter arrangements for chickens and livestock are complex and vary seasonally and once every 1–2 years. Chickens may be kept in the kitchen, in the sitting room, on the verandah, or in special shelters. During the rainy season they are restricted either in a shelter or are tethered to prevent them from destroying crops. Arrangements for cattle are also complex. In most cases (54.3%), calves are kept away (mostly on the verandah) from the main herd, but in 34.3% of the cases, the entire herd is kept in one open place. In a few instances (8.6%), lactating cows and their calves are kept in the same place, away from the rest of the herd; in rare instances (3%), the herd is kept in three separate places, one each for calves, lactating cows, and the rest of the herd. The place for the main herd is changed once every 1–2 years to enhance soil fertility but the site may be outside the homestead compound.

Distances from the households where chickens are housed to the various places where livestock are kept are relatively long and appear to increase in line with the number of households. For example, the

mean distances from the first, second and third households to the main cattle sheds are 37.5, 42.1 and 53 metres, respectively, but variation is low (standard values are 23.2–26.9). These findings show that changes will have to be made in the shelter arrangements if chickens are to be used as effective predators of ticks.

10.4 BENCHMARK INFORMATION ON THE COMMUNITY RESOURCE BASE FOR MANAGEMENT OF TSETSE TRAPPING TECHNOLOGY IN LAMBWE VALLEY

J. W. Ssennyonga and P. Mungai

Community-based management of tsetse and trypanosomiasis entails the mobilisation of several kinds of resources on a continuous basis: money to buy materials; labour and skills to make and service traps; management to direct and coordinate activities and to control people and resources. It is therefore important to compile a data base on these resources and to establish a basis for selecting (i) farmers who will play important roles, (ii) a core group to be trained as trainers, (iii) farmers who will keep the sentinel herd for impact assessment and (iv) others who will be assigned management roles.

An area of 80 km^2 straddling Nyaboro thicket where tsetse traps have been deployed on a limited scale for experimental purposes by ICIPE scientists was selected as the tsetse suppression zone. The 38 village headmen (elders) in the area were asked to provide lists of all the homesteads in their area of jurisdiction. Altogether, 311 homesteads (25.6% of the total) were selected by systematic random sampling. Four sets of data were collected from each of these homesteads: gender and residential status of the homestead heads; number of individuals employed and their salary; number of cattle, goats and sheep reared; and number and quality of houses. Stock animals were converted into single stocking units (SSUs) and given market monetary values. Houses were also given monetary values to facilitate the grouping of homesteads by economic strata.

The homestead rather than the household was found to be the most appropriate unit for purposes of trapping technology. The majority (86.8%) of homesteads rear livestock, 78.8% rear cattle and 61% combine two or more species. Stocking units are large and probably growing larger. The majority (71.7%) of homesteads are self-employed, mainly as farmers; the individuals in paid employment are mostly sons and reside outside the study area. Overall economic ranking reveals a skewed pattern; for example, aggregate monetary values for SSUs, salary, and type of house divided by the 311 homesteads yield a top quartile which is twenty times greater than the bottom one. Still, mobilising resources for trapping technology is unlikely to present problems in the study community.

10.5 COMMUNITY MOBILISATION AND TRAINING FOR MANAGEMENT OF TSETSE TRAPPING TECHNOLOGY IN LAMBWE VALLEY

J. W. Ssennyonga, M. M. Mohamed-Ahmed, F. G. Kiros, L. H. Otieno, E. O. Omolo and P. O. Agutu

The objectives of this activity of community mobilisation and training were to cultivate the willingness of the people to participate in trapping technology, to get the community's commitment to take the responsibility for tsetse control, to create a spirit of self-reliance, and to raise the level of the community's understanding of the problems of tsetse. Community mobilisation and training activities specifically tailored to these objectives were therefore planned and carried out.

A project Consultative Group (CG) consisting of the staff closely associated with the project was formed. The CG adopted two principal strategies, namely (a) to train a catalytic group of 40 farmers in two or three batches, and (b) to employ the catalytic group of trainees to mobilise their communities. The first batch of 14 farmers was selected by the leaders of the communities for training during November, 1992.

10.5.1 Training of farmers

Lectures, discussion groups, demonstrations and audiovisuals (posters, video films on tsetse control using the ICIPE trap, etc.) were used extensively as specific methods of training.

The training had a fairly high scientific content because of the previously reported problem that once the tsetse population declines substantially, the interest of the community may wane. It was felt that this is due to an inadequate understanding of tsetse biology and ecology. A science-based training would enable the communities to maintain traps even if few or no flies were to be caught for long periods of time.

Topics selected were as follows: farmers' own assessment of the problems of tsetse and tsetse infestation; history of tsetse invasion in the project area; tsetse biology and ecology; wildlife hosts of tsetse; tsetse-borne diseases; the impact of tsetse infestation on livestock productivity; available solutions to the problems of tsetse; trapping technology and practicals in trap making and servicing; the formation of an effective organisational framework and management for trapping technology; the impact of tsetse control on land use. A field day in the tsetse habitat, Lambwe Valley, for practicals in trap site selection and inspection of traps *in situ* was part of the programme.

Collaborating institutions such as the Ministry of Livestock were involved in the training. Following the completion of the training, the training materials were

translated into the Luo language and handed out to the trained farmers as resource materials for use in community mobilisation.

Although it is still too early to assess the results of the training, those who were trained exhibited a lot of enthusiasm and eagerness to assume the responsibility to train others so that the community would eventually manage tsetse on its own. On their return, the trainees held planning meetings and later drew up a timetable indicating the dates and venues for 15 mobilisation meetings. They sent copies of the timetable and invited the researchers to attend their mobilisation meetings as resource persons. The meetings are due to be completed in March 1993, following which another group will be trained. This will lead to organisation and management activities, to be followed by resource mobilisation and the launching of trapping and trap servicing by the community.

10.6 AGRICULTURAL EXTENSION ORGANISATION, OPERATION AND IMPLICATIONS FOR IPM DEVELOPMENT IN SOUTH NYANZA DISTRICT, KENYA

P. O. Chitere, L. Ngonde and G. Mungai

The study sought to assess the capacity of the extension service in terms of staffing levels and know-how of extension agents about extension methods and the technical aspects of their work, including their understanding of IPM technology. Data were collected from (a) key informant interviews of senior extension personnel, (b) documentary sources, and (c) open-ended interviews of 50 frontline extension agents.

Results of the study show that Oyugis, Kendu Bay and Mbita Divisions have 75 (28 in Oyugis, 22 in Kendu Bay, and 25 in Mbita) frontline agents and 18,420, 18,247 and 17,143 households (average size being 7 persons); extension agent-farmer ratios are 1:658, 1:829, and 1:686, respectively.

Whereas Entomology is covered in the pre-service courses for extension agents, 24% of the frontline agents had not attended such courses. Only 12% of them reported having attended an Entomology course which included grain storage and crop protection using chemicals. Application of insecticides such as Dipterex was recommended to farmers by 62% of the agents, insecticides and cultural practices by 8%, improved seeds by 2%, and cultural methods such as uprooting damaged plants by 16%. The remaining agents did not recommend any method of pest control. About 44% of the agents had heard of the term 'IPM', but were not able to fully explain what it really meant except that it included control of pests using biological, cultural, traditional and chemical methods.

10.7 PRELIMINARY COST-BENEFIT ANALYSIS OF CATTLE PRODUCTIVITY ON RUSINGA ISLAND, SOUTH NYANZA

I. MacNairn, S. Hassan, J. W. Ssennyonga and G. T. Lako

This study was carried out in 1992 based on data provided by biological scientists in the former Livestock Ticks Research Programme. It is the first study where livestock productivity data have been used for performing cost-benefit analysis.

The study evaluated various regimes of treatments including balanced diet, external spraying and internal treatment of tick-borne diseases, internal anthelminthic treatment and a combination of external spraying, and internal treatment of tick-borne diseases and helminths. The sixth category was the control group of animals. Calves used in the experiments were born in either 1989 or 1990 and although their number totalled 75 at one point, roughly 20 remained at the time of the study.

The attrition was attributed to death, sale, slaughter, being given as dowry, being put to grazing freely, or to the farmers' refusal to continue with the treatment.

The costs and benefits of the different treatment regimes were calculated on the basis of a hypothetical Rusinga farm with 10 cows, which is the average number of animals per farm. This was done in order to reduce the effects of likely instabilities of herd structure implicit in the observed attrition rate of experimental animals. The costs included acaricides, veterinary drugs, labour (e.g., services of the animal health assistant), wages of unskilled labour, incidental items such as gloves and bucket, etc. Benefits were based solely on weight gain by the animals under the various treatment regimes. It was not possible to quantify other benefits, e.g., early maturity, increased fertility, increased milk production, or improved hide condition. This fact limits the interpretation of the results somewhat and could potentially alter the conclusions drawn, but it should not prevent us from deriving some tentative conclusions from the weight gain data results alone.

The results show that animals receiving a balanced diet gained the highest weight levels, followed by those that were given internal anthelminthic treatment, then by those that received the external spraying treatment. Those that received internal treatment for tick-borne diseases came next to the last or to the control group in weight gain.

The preliminary results also show that use of the internal treatment of tick-borne diseases method, and the internal anthelminthic treatment technique, provided marginally better weight gains than simply leaving the animals untreated, as was the case in the control group.

11

Reports on Institutional Building, Interactive Research and Information Activities

THE AFRICAN REGIONAL POSTGRADUATE PROGRAMME IN INSECT SCIENCE (ARPPIS)

11.1 THE ARPPIS PHD PROGRAMME

R. N. Runo and V. O. Musewe

The African Regional Postgraduate Programme in Insect Science (ARPPIS) is a unique collaborative PhD research and training programme between the International Centre of Insect Physiology and Ecology (ICIPE) and African Universities. This innovative programme is specifically tailored to meet Africa's needs for insect scientists.

ARPPIS graduates constitute an elaborate network of insect scientists with an excellent training background. The scientific network has continued to expand annually since 1986 when the first ARPPIS scholars graduated from the Programme. Between 1983–1992, 112 scholars from 22 different African countries have been enrolled in ARPPIS. Of these, 57 have graduated from ARPPIS and continue to work in Africa as university lecturers or researchers with national and international agricultural research systems. Currently, 40 scholars (1990–1992 Classes) continue with taught courses, research work, data analysis and thesis writing at the ICIPE.

11.1.1 The Graduating PhD Class

Nine scholars of the ARPPIS 1989 class (see Table 11.1) graduated from the programme in a ceremony held on Monday, 1st March 1992 at the ICIPE headquarters. The Chief Guest was Dr. Babatunde Thomas, Deputy Resident Representative of the United Nations Development Programme (UNDP), Nairobi, Kenya. Dr. Thomas gave the 7th ARPPIS Distinguished Lecture entitled 'Science and Technology: Africa's Dilemma'. The graduation ceremony and the lecture were well attended by a wide cross-section of scientists from the universities around Nairobi, the national agricultural research system, ICIPE scientists and ARPPIS scholars.

11.1.2 The 1992 ARPPIS PhD Class

Sixteen scholars from 10 different African countries joined the ARPPIS 1992 Class. Between March–September, they enrolled in six months of taught compulsory courses and three non-examined courses. Examinations in the six mandatory courses were undertaken between 20th September and 2nd October 1992. During the year, and in addition to taught courses, the students developed their PhD research projects with the assistance of ICIPE scientists. With minor revisions, the research projects and ICIPE Supervisory Committees were approved by the 31st Meeting of the ARPPIS Board of Studies on Wednesday, 9th December 1992 and endorsed by the ARPPIS Academic Board on Monday, 18th January 1993.

Due to ill-health, one student was unable to complete the taught courses and returned to his home country before the end of the 1992 Teaching Semester. The list of courses taught during the 1992 ARPPIS Teaching Semester is indicated in Table 11.2, while Table 11.3 shows the list of scholars, research projects, and registering universities of the 1992 ARPPIS PhD Class.

11.1.3 University participation in ARPPIS

A total of 25 African universities have joined ARPPIS as Participating Universities as of December 1992, after signing a joint agreement with the ICIPE. This marked increase in university demand to join ARPPIS has been experienced mostly in the last three years; the programme started off with only seven universities in 1983. Table 11.4 gives the list of ARPPIS Participating

Table 11.1 1989 ARPPIS Graduating Class* — students, supervisors and research projects

NAME AND COUNTRY	RESEARCH PROJECT TITLE	ICIPE SUPERVISORS	UNIVERSITY SUPERVISORS	REGISTERING UNIVERSITY
Mr. Ali El Badawi (Sudan)	Inheritance and combining ability of resistance to sorghum shootfly (*Atherigona soccata* Rond) and the spotted stemborer (*Chilo partellus* Swinhoe) in sorghum	Dr. R. Pathak Dr. M. Alghali	Prof. El Imam El Khidir	University of Khartoum
Mrs. Dorcas D.S. Bawo (Nigeria)	Oviposition behaviour of *Maruca testulalis* Geyer (Lepidoptera: Pyralidae) with respect to host-plant recognition	Dr. S. Waladde Dr. E. Kokwaro	Dr. B. A. Okwakpam Dr. A. O. Asite	Rivers State University of Science and Technology
Mr. Ali Nur Duale (Somalia)	Biocontrol potential of *Pediobius furvus* (Gah.) for the management of cereal stemborers in Kenya	Dr. J. Chacko Dr. G. Oloo	Dr. B. A. Okwakpam	Rivers State University of Science and Technology
Mr. Henry K. Kiara (Kenya)	Immune protection potential of membrane-bound proteins from *Amblyomma variegatum*	Dr. S. Essuman Dr. E. Osir	Dr. B. A. Okwakpam Dr. A. O. Asite	Rivers State University of Science and Technology
Ms. Rosetta B. Bob-Manuel (Nigeria)	The effect of fungal pathogen *Hirsutella thompsonii* on populations of the cassava green mite *Mononychellus tanajoa* and the predatory mite, *Iphiseius degenerans* on cassava	Dr. M. Odindo Dr. S. Nokoe	Prof. R. Kumar Prof. G. Nachman (DANIDA) Prof. M. Munster-Swendsen (DANIDA)	Rivers State University of Science and Technology
Mr. Alliy S.S. Mbwana (Tanzania)	The host-range, survival and control of *Pratylenchus goodeyi* Sher and Allen on banana	Dr. K. V. Seshu-Reddy	Dr. G. Waudo Prof. R. M. Sikora (GTZ, Germany)	Kenyatta University
Mr. Francis E. Nwilene (Nigeria)	The potential of the predacious phytoseiid mites, *Iphiseius degenerans* (Berlese) and *Neoseiulus teke* (Pritchard + Baker) for biological control of the cassava green spider mite *Mononychellus tanajoa*	Dr. M. O. Odindo Dr. S. K. Nokoe Prof. Z. T. Dabrowski	Prof. R. Kumar Prof. G. Nachman (DANIDA) Prof. M. Munster-Swendsen (DANIDA)	Rivers State University of Science and Technology
Mr. Eric A.R. Ndhine (Kenya)	Studies on bionomics and behaviour of *Tetrastichus sesamiae* and its potential in biological control of legume pod borer, *Maruca testulalis*	Dr. J. M. Chacko Dr. G. W. Oloo	Prof. J. M. Mueke	Kenyatta University
Mr. Boas E.N. Uronu (Tanzania)	The effect of plant resistance and cultural practices on the population densities of banana weevil *Cosmopolites sordidus* (Germ) and banana yield	Dr. K. V. Seshu-Reddy	Dr. G. Waudo Prof. J. M. Mueke Dr. G. Madel (University of Bonn)	Kenyatta University

Universities and their representatives on the *ARPPIS Academic Board*, which is the governing body in charge of policy and management of all ARPPIS academic matters. Two important meetings held under the theme Management Planning Workshop of Network Coordinators of ARPPIS was hosted by the D'Schang University Centre, Cameroon, 16–20th June 1992 followed by the 21st Meeting of the ARPPIS Academic Board (18th June).

The *ARPPIS Board of Studies*, on behalf of the ARPPIS Academic Board, ensures implementation and quality control for the ARPPIS programme. The main functions of the Board of Studies, under the Chairmanship of the ARPPIS Academic Coordinator, are to ensure curricula implementation; monitor students' progress on the programme, conduct and provide for examination; approve students' research projects; and approve Supervisory Committees for student research projects. The ARPPIS Board of Studies holds quarterly meetings each year, and in 1992 met on 14 April (28th meeting), 26 June, 28 August and 9 December.

Table 11.2 Programme of the 1992 teaching semester

DATE	COURSE AND LECTURERS
5–6th March	Documentation and Information Retrieval *(Mr. N. Nsubuga and Ms. D. Barasa, ICIPE)*
9–28th March	Insect Functional Morphology *(Dr. K.J. Mbata, University of Zambia, Lusaka and Dr. W. G. Z. O. Jura, ICIPE)*
30 March to 22nd April	Insect Taxonomy *(Prof. A. E. Akingbohungbe, Obafemi Awolowo University, Ile-Ife, Nigeria and Dr. R. K. Bagine, National Museums of Kenya)*
23rd April to 30th April	Insect Physiology and Biochemistry *(Drs. M. F. B. Chaudhury, R. K. Saini and E. O. Osir, ICIPE)*
1–5th June	Introduction to Microcomputers and Word Processing *(Mr. J. M. Otedo, ICIPE)*
8th June to 3rd July	Biostatistics and Experimental Design *(Dr. S. K. Nokoe and Mr. D. Munyinyi, ICIPE)*
6–31st July	Insect Ecology *(Prof. H. Morgan, University of Sierra Leone; Drs. Mutero and C. Kyorku, ICIPE)*
3–22 August	Biological Control *(Drs. W. A. Overholt, G. P. Kaaya, and M. O. Odindo, ICIPE and Dr. Gary Hill, CAB International Institute of Biological Control, Kenya Station)*
24–25th August	The Role of Social Sciences in Insect Pest Management *(Prof. Fassil Kiros, Drs. J. Ssenyonga and G. T. Lako, ICIPE)*
26–29th August	Project Identification, Formulation, Evaluation and Budgeting *(Mrs. R. A. Odingo, Dr. W. A. Otieno and Mr. J. R. Kapkirwok, ICIPE)*
31st August to 4th September	Insect Taxonomy (Seminars and Practicals on Insect Identification) *(Dr. R.K. Bagine, National Museums of Kenya)*
14–19th September	Examinations

11.1.4 Award of PhD degrees

Six scholars were awarded PhD degrees in 1992. Table 11.5 shows the names, research titles, awarding universities and dates of their Convocation.

11.2 THE ARPPIS MSC SUB-REGIONAL PROGRAMME

The proposal for the establishment of the ARPPIS MSc Sub-regional Programme was endorsed by the Vice-Chancellors Planning Meeting held at the Jomo Kenyatta University College of Agriculture and Technology (JKUCAT), Juja, Kenya, between 5–7 August 1991. In principle it was agreed that sub-regional centres would be established at selected ARPPIS Participating Universities for the implementation of the programme.

11.2.1 The ARPPIS MSc Sub-Regional Centres

It is with the above mandate from the JKUCAT meeting, and following intensive consultations with universities and national governments, that the ARPPIS Academic Board selected the four hosting universities for the ARPPIS MSc Sub-Regional Programme as follows:

- Southern Africa Sub-region *(University of Zimbabwe, Harare)*. Countries represented include Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, Swaziland, Zambia and Zimbabwe.
- Anglophone West Africa Sub-region *(University of Ghana, Legon)*, representing the following countries: Ghana, Nigeria, Liberia, Sierra Leone.
- Francophone Africa Sub-region (D'*Schang University Centre, D'schang, Cameroon*), representing Benin, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Congo, Côte d'Ivoire, Gabon, Guinea, Madagascar, Mali, Mauritania, Rwanda, Senegal, Togo and Zaire.
- Eastern and North-Eastern Africa Sub-region *(Addis Ababa University, Ethiopia)*. For Ethiopia, Kenya, Somalia, Sudan, Tanzania and Uganda.

11.2.2 Implementation of the ARPPIS MSc Sub-regional Programme

The University of Zimbabwe. The Southern Africa ARPPIS MSc Sub-Regional Programme was the first to take off, under Dr. Joseph M. Gopo, ARPPIS MSc Sub-Regional Coordinator. In March 1992, the first class of seven students were admitted to the programme. Between March and November 1992, the students undertook the following taught courses in fulfillment of Part I of the MSc in Tropical Entomology (MTE) at the University of Zimbabwe, Harare, and on

Table 11.3 List of scholars, research projects, and registering universities for ARPPIS incoming 1992 PhD Class

NAME OF COUNTRY	TITLE	REGISTERING UNIVERSITY
J. Magyembe-Mwesigwa (Uganda)	Interaction effects of banana weevil *Cosmopolites sordidus* Germar and nematodes in bananas	Makerere University
Joseph Alfred Sumani (Zambia)	Biology of the banana weevil on rhizomes of different banana varieties and types and mechanisms of resistance	University of Zambia
Charles J. H. Mutinda (Kenya)	Genetic variability and responses to selection for *Chilo partellus* (Swinhoe) resistance in a maize (*Zea mays* L.) population	University of Nairobi
Habte Tekie (Ethiopia)	Biological effects of neem seed derivatives on the management of maize stalk borer *Busseola fusca* (Fuller) in pest management	Addis Ababa University
Sekouba Bengaly (Mali)	Cellular and humoral immune responses of the tropical bont tick *Amblyomma variegatum* F. and the brown ear tick *Rhipicephalus appendiculatus* (Ixodidae: Acari) to pathogens	University of Ghana
Loise Njeri Gichuru (Kenya)	The biology of *Ixodiphagus hookeri* Howard (Hymenoptera: Encyrtidae), a parasitoid of the tropical bont tick, *Amblyomma variegatum* Fabricius (Acari: Ixodidae) in Kenya	Kenyatta University
Freddie Masaninga (Zambia)	Adaptation of *Trypanosoma congolense* types to different hosts and transmission by *Glossina* species	University of Zambia
Ibrahim S. T. Jalloh (Sierra Leone)	Pheromone and plant odour perception in *Busseola fusca*	Rivers State University of Science and Technology
Yousif O. H. Assad (Sudan)	The role of host plants in maturation of the desert locust *Schistocerca gregaria* (Forskal) (Orthoptera: Acrididae)	University of Gezira
Arop Leek Deng (Sudan)	Studies on the factors that influence phase dynamics of the desert locust *Schistocerca gregaria* (Forskal)	University of Khartoum
Mohamed Ali Mohamed Ali (Sudan)	Influence of additives and ultraviolet protectants on *Bacillus thuringiensis* for control of *Chilo partellus* infesting some sorghum cultivars	University of Gezira
Bakari Kaoneka (Tanzania)	Acaricidal properties of active principles from *Commiphora swynertonii* Burtt. and one Meliaceae species against the brown ear tick *Rhipicephalus appendiculatus* Neuman	Moi University
Margaret Nabasirye (Uganda)	Statistical inference on pest resistance indices	Makerere University
Edward Kinyua Nguu (Kenya)	Effect of host blood and its digestive products on trypanosome differentiation in tsetse fly *Glossina morsitans*	University of Nairobi
Timothy T. Epidi (Nigeria)	Mechanisms of resistance in selected sorghum genotypes to the spotted stemborer, *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae)	Rivers State University of Science and Technology

satisfactory completion, started on thesis research work as Part II of the Programme:

MTE 501 - Biostatistics, experimental design and modelling (9 weeks). Lecturers: Mr. R. Crust and Prof. B. Campell, University of Zimbabwe

MTE 502 - Insect functional morphology and systematics (11 weeks). Lecturers: Mrs A. R. Mabveni and Mr. G. Chikwenhere, University of Zimbabwe, and Dr. K. Mbata, University of Zambia

MTE 503 - Insect physiology and biochemistry (8 weeks). Lecturers: Mr. E. Zitsanga and Mr. S.Z. Sithole, University of Zimbabwe.

MTE 504 - Insect ecology and behaviour (3 weeks). Lecturers: Prof. L. McClain, University of Namibia, Windhoek.

MTE 505 - Pest management (6 weeks). Lecturers: Dr. P. Tongoona and Dr. D. Giga, University of Zimbabwe, and Dr. K. Mbata, University of Zambia.

Table 11.4 Members of the ARPPIS Academic Board and ARPPIS Participating Universities in 1992

REPRESENTATIVE		UNIVERSITY
1.	Prof. Hector 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 and Technology, Nigeria
6.	Dr. I. Parh	D'Schang University Centre, Cameroon
7.	Prof. El Imam el Khidir	University of Khartoum, Sudan
8.	Dr. M. H. Zeinelabdin	University of Gezira, Sudan
9.	Dr. Teferi Gemetchu	Addis Ababa University, Ethiopia
10.	Prof. J. N. Situma	Makerere University, Uganda
11.	Prof. J. M. 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 at 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.	to be appointed	University of Maiduguri, Nigeria
25.	to be appointed	Enugu State University of Science and Technology, Nigeria

Table 11.5 ARPPIS scholars awarded the PhD in 1992

NAME AND COUNTRY	THESIS TITLE	AWARDING UNIVERSITY	DATE OF AWARD
Dr. John O. A. Davies Cole (Sierra Leone, 1987 Class)	Some aspects of the mating behaviour of *Glossina morsitans morsitans* Westwood and *G. pallidipes* Austen	University of Sierra Leone	19-12-1992
Dr. Hassane M. Hassane (Chad, 1987) Class	The biochemical taxonomy of phlebotomine sandflies (Diptera: Psychodidae) in Kenya	University of Sierra Leone	19-12-1992
Dr. Salah M. Kheir (Sudan, 1988 Class)	Mechanisms of cutaneous reactions in cattle infested with *Rhipicephalus appendiculatus*	University of Khartoum	28-5-1992
Dr. Alian M. A. Malik (Sudan, 1988 Class)	Studies on some pathological aspects of the fungus *Beauveria bassiana* on the legume pod borer *Maruca testulalis*	University of Khartoum	18-3-1992
Dr. Charles Mugoya (Uganda, 1988 Class)	Feeding behaviour of *Maruca testulalis* larvae on cowpea (*Vigna unguiculata*)	Rivers State University of Science and Technology	4-4-1992
Dr. Angus Onyido (Nigeria, 1988 Class)	Ecology of *Sergentomyia garnhami*, a vector of leishmaniasis in Kenya	Rivers State University of Science and Technology	4-4-1992

MTE 506 - Economic entomology (9 weeks). Lecturers: Dr. D. Giga, University of Zimbabwe, Prof. Phelps and Mr. N. Sheeni, Dept. of Vet, and Prof. C. B. Cottrell, Tobacco Research Board.

The Germany Academic Exchange Service (DAAD) has provided fellowships to four students from Zimbabwe (2) and Namibia (2) on the MSc programme at Harare. The Ford Foundation is also supporting the programme through a grant released to the university through the ICIPE Headquarters.

The ARPPIS MSc programme at Harare plans to admit students on alternate years; the next class is planned to start in March 1994.

University of Ghana. The University of Ghana, hosting university for the Anglophone West Africa Sub-Region, has appointed Prof. J. N. Ayertey, Head, Crop Sciences Department as the Sub-Regional Coordinator for the Programme. He has completed the sensitisation mission and consultations with several universities, concentrating mainly on non-ARPPIS participating universities in the sub-region. The funding for the sensitisation mission was provided jointly by the University of Ghana and the ICIPE.

Since then, the University of Ghana has made tremendous progress in the planning and implementation process of the ARPPIS MSc programme. It has (i) appointed Prof. J. N. Ayertey, Head, Crop Science Department as Regional Coordinator for the Programme; (ii) organised two meetings of the Inter-University Consultative Group (IUCG). The second meeting was held at the D'Schang University Centre, Cameroon on Wednesday 17th June 1992 and was attended by representatives from six West African universities; (iii) developed the curriculum and syllabus including a list of potential academic staff at each university drawn up ready for submission to the Academic Board of the University of Ghana for approval.

Lack of funding for the programme constrains implementation. However, the University plans to admit the first students on the Programme by the 1994 Academic Year starting in September, depending on availability of funds.

Addis Ababa University. The President of Addis Ababa University has appointed Dr. Teferi Gemetchu of the Department of Biology, Faculty of Science at Addis Ababa University as the Coordinator for the ARPPIS MSc Programme for the Eastern and North-Eastern Africa region.

Dr. Gemetchu has started consultations with universities in Ethiopia, and Ethiopia-based regional and international organisations. It is expected that Dr. Gemetchu will start a sensitisation mission to the Eastern and North-Eastern region in the near future, depending on availability of funds.

D'Schang University Centre. The D'Schang University Centre, hosting university for the French-speaking Africa region, is at the preliminary planning stages for the ARPPIS MSc programme. The ARPPIS Academic Board will be sending a select committee to visit universities in French-speaking African countries later this year or early next year, subject to availability of funds.

CONSUMER-BASED INTERNATIONAL GROUP TRAINING

11.3 GROUP TRAINING COURSES FOR SPECIALISTS

J. J. Ondieki and R. Runo

Four Group Training Courses were offered to practitioners from the National Research and Extension Service (NARES) and the universities. Seventy-one scientists and senior technicians from 19 countries participated in the following courses: tsetse and livestock tick management, taxonomy and identification of *Cotesia* stemborer parasitoids, and insect mass rearing. These courses were relevant to the mandate of the ICIPE and in direct support of the implementation of the IPM/IVM technologies. A number of donors cooperated in funding the courses.

The list below shows the number and distribution of trainees at the four group training courses:

Country	*No. of Participants*
Angola, Cameroon, India Netherlands, Swaziland	5 (1 each)
Burundi, Burkina Faso Nigeria, Zimbabwe	8 (2 each)
Ethiopia	6
Kenya	27
Malawi, Rwanda, Senegal Sudan, Tanzania, Uganda, Zambia	21 (3 each)
Mozambique	4
Total countries 19	Total participants 71

11.3.1 Taxonomy and identification of stemborer parasitoids

This four-day course was held at the ICIPE, Nairobi from January 13–16, 1992. It was attended by 20 participants from the following five countries: Cameroon, Kenya, India, Netherlands and Tanzania. The course objectives were to acquaint participants working on biological control of stemborers with the necessary techniques in the taxonomy and identification of the various stemborer parasitoids of the *Cotesia* spp.

The course was funded by the Netherlands Government through the ICIPE/WAU Crop Pests Biological Control Project.

11.3.2 Insect mass rearing for IPM/IVM

The course was of three weeks' duration and was held at the ICIPE, Nairobi from March 16–April 3, 1992. It was attended by 21 participants, including six women, from 13 African countries: Angola, Burkina Faso, Ethiopia, Kenya, Malawi, Mozambique, Nigeria, Rwanda, Swaziland, Tanzania, Uganda and Zambia. The funding for the course was provided through a

Netherlands Government grant to ICIPE on the project 'Human Resources Development for Scientific and Technological Capability in Africa'.

The course topics covered included insect rearing technologies; methods of colonisation and quarantine procedures; quality control in insect rearing systems; artificial diets in mass rearing; rearing procedures for insects and mites; identification of common insect pathogens in insectaries; requirements for a successful insectary; breeding of laboratory manuals for use in rearing of arthropods.

This course was designed to help participants develop their own insect-rearing facilities for research work in their own countries.

11.3.3 Group Training Courses on Ticks and Tsetse Management

Two of the Short Practitioner Courses held during 1992 are a continuation of similar courses held at the ICIPE under the theme of 'Management of Vectors for the Control of Trypanosomiasis and East Coast Fever in Livestock Production for the Developing World'. The course on Ticks Management was sponsored through funding by the UNDP whilst that of Tsetse Management was funded by the EEC.

Ticks Management Course. This year's course was attended by 14 participants from eleven African countries: (Ethiopia, Kenya, Malawi, Mali, Mozambique, Nigeria, Rwanda, Sudan, Uganda, Zambia and Zimbabwe). The four weeks' course provided the tick scientists and technicians with the current strategies being used in tick control.

The course covered theory, laboratory and field practicals on various subjects comprising of tick biology, anatomy, physiology, ecology, tick/host relationships, etc. It also included such specialised areas as tick-immunology, identification, natural enemies of ticks, introduction to computers, and the use of computer simulated models for tick management.

The first two weeks were devoted to theory, laboratory practicals and visits to some national and international livestock research institutions in and around Nairobi. The third and fourth weeks were used for field ecological studies. This was composed of practicals and further theoretical taxonomy and identification.

Tsetse Management Course. This was the ninth of a series of International Group Training Courses on Tsetse Management to be offered at the ICIPE, Nairobi from November 2–28, 1992. Sixteen participants, including one woman, were drawn from 12 African countries: Burkina Faso, Burundi, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Senegal, Sudan, Tanzania, Zambia and Zimbabwe.

The objectives of the course were to acquaint participants with the theory and practical aspects of tsetse management and how they interact in supporting integrated pest and vector management. The first week of training was devoted to lectures on basic tsetse biology, followed by another week of lectures on applied tsetse biology. Afternoons of the first two weeks were devoted to laboratory work and demonstrations. These included basic tsetse taxonomy, methods for isolating and characterising trypanosomes, the use of DNA probes for trypanosome identification, the use of ELISA technique for bloodmeal identification, and the use of wind tunnels and EAGs for odour bait assessment. A three-day afternoon workshop on trap design was held, wherein participants were encouraged to make their own traps for use in field testing.

The last two weeks of the training programme were spent on field work at the Kenya Coast, in an area where three species of tsetse — *Glossina pallidipes, G. brevipalpis* and *G. austeni* — are found. In the field, participants were expected to test both conventional traps as well as those designs developed during the trap design workshop. Field trapping experiments and tests with electric screens were used to illustrate features of the behaviour and ecology of tsetse. Techniques of tsetse dissection and trypanosome isolation were also taught in the field.

11.4 PROFESSIONAL DEVELOPMENT TRAINING

Up to 21 postdoctoral research fellows (PDF) and 8 visiting scientists worked at the ICIPE during the period. Five of the PDFs completed their contracts and left during the year. One of the visiting scientists, Dr. Quentin E. Paynter visited the ICIPE on the ICIPE/Royal Society Collaboration in the John Pringle Scientist Exchange Scheme; Dr. W.G.Z.O. Jura of the ICIPE worked at the Royal Postgraduate Medical School, Department of Histochemistry, Hammersmith Hospital, University of London, for a period of nine months on the same collaborative arrangement. Due to financial constraints, there were no visits to the ICIPE on the ICIPE/Third World Academy of Sciences research associateship scheme.

There was heightened activity under the ICIPE's Training Attachment/Internship Schemes, which saw a total of 27 interns training at the ICIPE during the year, including three young attachees from the Netherlands visiting under ICIPE/WAU collaboration, and one trainee from the USA.

Due to financial constraints, staff development training was limited during the year.

11.5 INTERNATIONAL COOPERATION

The laboratories and institutions collaborating in research with the ICIPE are reported under each research programme or unit. In addition, the IBIRI had specific collaborative arrangements with the following organisations:

- Association of African Universities (AAU) — on joint projects; ICIPE is an associate member of the AAU.
- International Federation of Institutions for Advanced Studies — on joint projects; ICIPE is a member.

- The Royal Society, London, — on scientist exchange programme.
- Third World Academy of Sciences (TWAS) — on a joint research associateship scheme for scientists from developing countries.
- ARPPIS Participating Universities — 25 African universities cooperating with the ICIPE in postgraduate training in insect science and pest management
- Donor Agencies — in support of educational programmes including ARPPIS and/or consumer-level group training. These include: Deutscher Akademischer Austauschdienst (DAAD); Ministry of Foreign Affairs, Directorate General for International Cooperation, Netherlands (DSO); Ford Foundation, IFAD, UNDP, EEC, UNESCO, BMZ, NORAD, ODA, Rockefeller Foundation, PEW Trust and SAREC.

PEST MANAGEMENT RESEARCH AND DEVELOPMENT NETWORK (PESTNET)

11.6 PESTNET COORDINATION AND COLLABORATIVE ACTIVITIES

J. J. Ondieki

The objectives of PESTNET have remained the same as in previous years, namely to support and strengthen the National Research and Extension Services in the area of insect science and pest management through interactive technology development, training and information exchange. However, due to unforeseen financial constraints and coupled with political upheavals in some of the PESTNET collaborating countries, PESTNET Research and Development activities were active in three countries only: Kenya, Zambia and Ethiopia. It is not possible to hold the yearly PESTNET Technical Advisory Committee Meeting due to lack of funds.

Information and training activities were continued, although at a reduced pace. In conjunction with the ARPPIS Network, PESTNET produced and circulated four issues of the *NETWORK News* as well as three issues of the *PMDISS Bibliography* on information and documentation.

11.6.1 PESTNET research and development activities

During 1992, components of IPM technologies developed by ICIPE scientists were validated and demonstrated in Kenya and Zambia where currently PESTNET resident scientist teams are located. It is hoped that in the future, resident scientist teams will serve both regional and national PESTNET activities. Reports on PESTNET research projects are to be found under Crop Pests Research.

11.6.2 Planning Meeting/Methodology Workshop in Kenya

In March 1992, a three-day Workshop on Determination of Economic Injury Level (EIL) of Stalkborers on Maize for on-farm research was held at the Bandari College, Mombasa. It was attended by KARI entomologists working on maize, as well as by ICIPE scientists. The highlights of the workshop will appear in *NETWORK News*, while all the presentations will be compiled as a Proceedings.

On-field training was imparted to KARI entomologists and the technicians participating in PESTNET activities on how to carry out the single plant analysis sampling method for determining EILs, as well as on the identification of stalkborers. Immediately after the Workshop, a Planning Meeting was held at the same venue, to discuss the PESTNET research activities for 1992.

11.6.3 Training activities in Zambia

In line with PESTNET objectives, especially as it relates to strengthening national agricultural capabilities through training, and as a response to the need for microcomputer training for research and extension staff in Luapula Province, PESTNET organised a computer course for Research and Extension officers working with word processing, data collection and analyses. The course was held between June 22–July 3, 1992 at the Luapula Regional Research Station (LPRS). Mansa, Zambia.

The course was attended by 16 participants (including six women) from the Ministry of Agriculture, Food and Fisheries Research and Extension departments in Mansa District. The course comprised of lectures, demonstrations and hands-on computer exercises. Participants received hand-outs of lecture notes and backups of software such as MSTAT-C, Wordperfect 5.1, Quartro, DBase IV and LOTUS 123.

11.7 THE KWALE-KILIFI ADAPTIVE RESEARCH PROJECT: LINKAGES, PROGRESS AND POTENTIAL*

S. Sithanantham, C. Kyorku and A. Oendo

The Kwale-Kilifi Adaptive Research Project (KKARP), is a component of the Kwale-Kilifi District Development Project. In this project, the Kenya Agricultural Research Institute (KARI) is the executing agency for the Government of Kenya, while ICIPE is the implementing agency. It is a 'transfer of technology' activity involving ICIPE and the NARS (National Agricultural Research System). The present phase of the project is for two years (1992–93).

The two major objectives of the project are: (a) to increase food production and cash incomes of resource-poor farmers in Kwale and Kilifi Districts through increased knowledge and use of improved pest and vector management practices for selected crops and livestock, and (b) to develop IPM adaptive research capabilities of KARI.

11.7.1 Background to the Project

The people of Kwale and Kilifi Districts in the Coastal Province of Kenya are predominantly agrarian. The

average size of land held by farmers in the two districts is 0.9–1.8 hectares. The ecological zones closer to the coast (L3, L4) support more food crop production, while the hinterland (L5, L6) is suitable for livestock production. The warm humid conditions, together with the bimodal rainfall, tend to favour the multiplication and activity of most insects, which include some destructive pests of crops and vectors of livestock diseases. Among the food crops growing in these districts, maize and sorghum are known to suffer substantial yield loss due to stalk borers, while cowpeas are often attacked by several major insect pests, especially flower thrips, spotted (*Maruca*) borer and pod sucking bugs. On the other hand, tsetse (*Glossina* spp) serves as the vector of a major cattle disease (nagana, or animal trypanosomiasis) regarded as important, especially in Kwale District.

The technologies presently available for managing these pests are either ineffective or uneconomical. Improved technologies which are environment-friendly as well as affordable by resource-poor farmers have now been identified. These include the use of pest resistant crop varieties and cultural practices such as intercropping against crop pests and use of traps against the tsetse. It is therefore important to test (and if required refine) these improved and sustainable pest and vector management technologies developed at ICIPE and elsewhere, with the aim of facilitating their adoption by resource-poor farmers in this region.

11.7.2 Linkages and coordination

The linkages between the project and the different institutions as well as the clients (farmers) are established at different levels. At the local level, these are the advisory panels which include extension officials and farmers' representatives in Kwale-Kilifi districts for planning and implementation of the project activities. At the provincial level, the local coordinating committee involves officials of Ministries of Agriculture and Livestock Development as well as farmers' representatives. At the national level, a national coordinating committee, involving ICIPE, KARI and concerned Ministries, provides guidance on policy issues.

11.7.3 Project management

The project management is guided by a committee of supervisory officials, including research, administration, planning and finance. The Coordinator acts as the local link for components teams, as well as with KARI, and the ministries of agriculture and livestock development (MOALD). The three component teams of the project are crop pests, tsetse and social science, each consisting of a team leader (ICIPE scientist), a deputy team leader, additional scientists and/or support staff (all seconded from/through KARI). The crop pest and social science teams are based at the KARI Regional Research Centre, Mtwapa (in Kilifi District) while the tsetse team is based at the Veterinary Investigations Laboratory (VIL), Ukunda (in Kwale District).

11.7.4 Problem diagnosis/verification

Socioeconomic diagnostic survey of 180 farmers (90 per district; 30 per zone in L3–L5 of each district) was undertaken in March–June, 1992. The majority of the farmers were found to recognise pests as a source of substantial yield loss, but very few adopted any practice aimed at controlling them.

Most farmers confirmed that they recognised the local prevalence of tsetse flies and their adverse role on cattle health, but few took any preventive measures against them. On-farm monitoring of plots of maize and sorghum showed significant infestation by stalk borers, especially in the short rainy season, thus confirming their importance as pests in the region.

Trap catches in Shimba Hills (Kwale District) confirmed that two species of tsetse — *Glossina brevipalpis* and *G. pallidipes* are predominant locally. Monthly sampling of cattle in the same area for trypanosomiasis since September 1992 has shown that the disease incidence tends to be greater at sites near to the game reserve, which is the known breeding site of the tsetse vector.

11.7.5 Technology testing and refinement for local suitability and acceptability

The results of research to identify locally adaptable maize, sorghum and cowpea genotypes, and to develop appropriate cultural practices for pest reduction are reported under Crop Pest Research. The potential acceptability of the promising pest resistant genotypes of maize, sorghum and cowpea are being investigated.

In terms of technology refinement, a series of field experiments resulted in an improved tsetse trap design over NG2B, which includes acetone as the most effective odour source for attracting the two major tsetse species in the area — *G. pallidipes* and *G. brevipalpis*.

11.7.6 Training

On-the-job training was provided for technical/support staff (KARI/MOA) in IPM/IVM methodologies. Three short courses (3–6 days), one each on insect mass rearing techniques, IPM components in adaptive research, and social science survey methodology were organised for KARI/MOA officials involved. One KARI official was trained in a 5-week International Training Course on Tsetse Management.

Several groups of farmers were trained on evaluating pest resistant varieties and cultural practices for IPM during on-farm field days, on-station visits and a training workshop held in September 1992. Two KARI officials have been sponsored for PhD training under support from the project.

11.7.7 Interacting project scientists

The interacting scientists assigned full time to the project during 1992 are as follows:

ICIPE

Dr. S. Sithanantham, Coordinator — Team Leader (Crop Pests)

Dr. C. Kyorku, Team Leader (Tsetse)

Dr. Oendo, Team Leader (Social Science)

KARI/MOALD
Mr. M. Kiarie, Entomologist — Deputy Team Leader (Crop Pests)
Mr. B. Muli, Agronomist
Ms. E. Wekesa, Research Officer (Social Science)
Dr. F. Mukendi, Veterinarian — Deputy Team Leader (Tsetse)

*More information about this project can be found in Section 1 on Crop Pests Research

11.8 THE PEST MANAGEMENT DOCUMENTATION AND INFORMATION SYSTEM AND SERVICE (PMDISS)

N. Nsubuga and D. Barasa

PMDISS, which was created to give informational support to the Pest Management Research and Development Network (PESTNET), had a fairly quiet year due to limited funding. However, activities pertaining to information exchange continued throughout the year.

Following the favourable publicity that was given to PMDISS in 1990, the PMDISS headquarters was bombarded with information requests and we were unable to provide all the publications that were being requested for. We tried to encourage users to request for information through their designated centres rather than as individuals, in order to reduce costs.

In-house, work contained on developing the computerised database and input of records on the database grew from less than one hundred the previous year to over a thousand records.

11.8.1 Publications

The long-awaited *Proceedings of the PMDISS/PESTNET Planning Workshop for Eastern and Southern Africa*, held in November 1989, Lusaka, Zambia, were published and distributed to participants of the workshop.

PMDISS Bibliography. This is a current awareness quarterly publication listing bibliographic details of all publications received that are of interest to the network participants. Four issues of the bibliography were produced during the year containing abstracts and for the first time, including material from the National Coordinating Centres. Our main problem was funds for mailing, so we were not able to provide the publications to as many centres as we would have liked.

11.8.2 Other PMDISS services

PMDISS continued to provide the following services: questions and answer services, computer searches, identification and location of information sources, and depository services for documents.

11.9 TRAINING AND EDUCATION FOR PESTNET COUNTRIES

J. J. Ondieki

PESTNET collaborating countries continue to benefit from education and training offered at the ICIPE and also within individual countries. Three trainees sponsored through PESTNET have undergone PhD training under the ARPPIS programme: Mrs. M. Taguma (Zambia) completed in 1991, Mr. Ali-Nour Duale (Somalia) completed in 1992 and Mr. J. Kayitare is due to complete his studies in early 1993.

In addition to formal training, practitioner courses were conducted for staff of PESTNET collaborating countries during 1992. Fifty-five participants out of a total of 71 in the Group Training Courses described earlier were from PESTNET collaborating countries. Attachment training was also organised for four Somalia staff for periods ranging from six months to one year. These were staff who were displaced as a result of the civil strife in Somalia.

INFORMATION RESOURCES

11.10 THE INFORMATION RESOURCE CENTRE

N. Nsubuga

One of the major means by which ICIPE enhances its mandated activities is the provision of a strong information resource base. The biggest landmark and reward in the Centre's efforts in this regard came in 1989 when ICIPE and the Swiss Development Corporation (SDC) signed an integrated funding agreement which provided money not only for the building, furniture and fixtures for a purpose-designed information resource centre, but also for the purchase of books, computers, a photocopier, and selective training of staff. Although 1992 was a lean year, the completion and commissioning of the new Information Resource Centre in April 1991 and successful implementation of the funding agreement had already set into motion a number of activities which continued in 1992.

11.10.1 Acquisition of reading materials

As a result of the grant provision of US$20,000 for the purchase of books over the grant period, there was a sizeable boost in acquisitions. About 300 books were received and accessioned plus 600 reprints relating to pest management. It is regrettable, however, that by the time the money was remitted it was too late to renew all the subscriptions. Therefore only about half of the 130 subscriptions were renewed. In addition 50 other titles continued to come in through donations and exchange.

11.10.2 Computerisation

The IRC maintains a computer database which serves not only the needs of the ICIPE users but also the partners in the Pest Management Research and Development Network (PESTNET). The database was designed to carry not only descriptive information on document acquisitions, but also data on relevant personnel, institutions and projects. About 1000 records were entered on the computer using the UNESCO-sponsored software CDS/ISIS. Work was also started on the inputting of personnel information and the collection of the other types of data.

A local area network (LAN) was established in the IRC using LANSMART. Now the computer data in the IRC can be accessed from any one of its microcomputers scattered in the IRC. This networking was considerably assisted by the release from UNESCO of the networking edition (version 3.0) of the database software CDS/ISIS which the IRC uses.

The IRC also acquired, installed and tested ISIS/CIRC, the commercially available circulation system software that is designed to work with CDS/ISIS. The E-mail facility which has linked ICIPE to the CGNET since 1988 was transferred from the Biomathematics Research Unit to be managed and operated in the IRC. ICIPE became a participating centre in AGRIS, the International Agricultural Information System of FAO. The IRC as the Centre's executing agent, regularly submits data on the Centre's publications to AGRIS and in return receives the AGRIS database on CD-ROM as well as the printed AGRINDEX.

11.10.3 Pest Management Documentation and Information System and Service (PMDISS)

The success of the first PMDISS, methodology workshop held in Entebbe, Uganda, in August 1991 ushered in the active participation of national programmes in the implementation of PMDISS, as recommended in the planning meeting of 1989 (whose Proceedings were also published during the year). PMDISS National Coordinating Centres started submitting their data to the central database at the headquarters and received the quarterly *PMDISS Bibliography* for current awareness.

11.10.4 Services

The emphasis in this regard continued to be on current awareness based on the indexing and abstracting of journals and databases (on CD-ROM) subscribed, the PMDISS database and quarterly bibliography, and the in-house *Library and Documentation Bulletin*. Work started on the entry of personnel data is also expected to enhance our current awareness service, especially selective dissemination of information (SDI). About 80 retrospective computer searches were done, all of them in-house, thanks to the acquisition of databases on CD-ROM. In addition about 1600 document supply requests were satisfied.

11.10.5 Professional training and travel

Staff training under the Swiss funding agreement was finalised with the following scholarships:

- The Senior Librarian spent the period 20 January-9 February as a visiting scholar at the US National Agricultural library in Beltsville, MD. He was to observe and get hands-on experience with modern information technologies.
- The MPFS Librarian, Miss Dorothy Achieng attended the Training Course on Agricultural Information Management at C.A.B International, Wallingford, U.K. 20 July–7 August 1992.

The IRC hosted five student attachments, one from the Faculty of Information Science, Moi University, another from Kenyatta University, and two from the Department of Information and Liberal Studies, The Kenya Polytechnic.

COMMUNICATION, EDITING AND PUBLISHING

11.11 COMMUNICATION AND PUBLISHING

R. Washika

11.11.1 The 1992 ICIPE Annual Research Conference

The 1992 Annual Research Conference marked a significant departure from the traditional structure and format of ICIPE's previous research conferences. Instead of reviewing a few selected programmes, the Conference focused on a fairly broad scientific theme that cut across a number of research areas within ICIPE's programmes and units: 'Insect Behaviour and Chemical Ecology in Integrated Pest Management (IPM)'. Papers presented at the Conference highlighted how research in insect behaviour and chemical ecology is providing a strong base for the development of environmentally friendly and technologically feasible and sustainable IPM technologies.

Another new feature of this year's Annual Research Conference was the introduction of discussion forums following each of the sub-themes selected for the presentations. Prof. P. Esbjerg, Chairman of the Programme Committee of the Governing Council, guided the discussions on questions ranging from strategies in the use of parasitoids, plant-insect relationships, regulation of existing genomes to studies at the biosynthetic level, dispersal, learning behaviour and mass trapping.

Another discussion forum focused on future directions in behaviour and chemical ecology research of haematophagous arthropods, including ticks, tsetse, mosquitoes and sandflies. The third discussion forum centered on what can be done to keep the locust in its solitarious phase. It underlined the fact that much more research in behaviour and chemical ecology of the desert locust needs to be done before we can interfere with the gregarisation process and confine the pest to its solitarious state. Other research activities not directly linked to chemical ecology were reviewed through poster presentations.

The conference was opened by Mr. F. Stephen O'Brien, Chief of the World Bank's Regional Mission in Eastern Africa, a practicing economist for over 30 years. He spoke authoritatively on 'Transformation of African Agriculture: The Challenges', and set the tone for the next three days of conference deliberations.

The 1992 forum was particularly successful in that the donor community was well represented and an array of pertinent issues were discussed freely. The forum was chaired by Professor Constantina Safilios-Rothschild, a social scientist from the Wageningen Agricultural University, Netherlands, who is also a member of the ICIPE Governing Council. Donors present included ADB, DANIDA, FINNIDA, IFAD,

the Kenya Government, National Research Institute (NRI) — UK, ODA, The Rockefeller Foundation, USAID, UNEP and the World Bank.

The last day of the Conference saw the annual presentation of the ICIPE Medal for Innovative Research. This year the winner was Mr. Francis Omeno Onyango, for his pioneering work on successful colonisation and rearing of the maize and sorghum stem borer, *Busseola fusca*, on a semi-synthetic diet. (More information about Mr. Onyango's award-winning work is reported under Section 9 on Insect and Animal Breeding).

Preceding the medal presentation was the 1992 Special Guest Lecture, which this year was delivered by Professor F.S. Idachaba, Vice-Chancellor of the University of Agriculture at Makurdi, Nigeria. Professor Idachaba's lecture will be published at a later date by ICIPE Science Press.

11.11.2 Launching of the ICIPE's Vision and Strategic Framework for the 1990s

On Friday 2nd October 1992 at a colourful ceremony at Duduville, ICIPE's *Vision and Strategic Framework for the '90s* was launched. The occasion was witnessed by a cross section of ICIPE's supporters and constituency including the donor community, the scientific community, national programme representatives, and the diplomatic corps, as well as the farming community.

This planning document evolved through a series of consultations at various levels including the user community, the international R & D collaborators, the donor community and the national R & D partners in Africa, culminating in a two-day meeting held in Nairobi in September 1991 and attended by Directors of Research in agriculture, livestock development, health and national planning from over 50 countries in Africa.

The central theme of the document highlights the crucial role that insects play in reducing agricultural production, hindering the development of the livestock industry, and transmitting major tropical diseases in Africa. The document advocates a strong movement towards developing pest management technologies which are environmentally benign, technically-effective (but socio-culturally acceptable), high technology-based but simple in application), while anchored on traditional knowledge.

The document places a high premium on capacity building, especially at scientific leadership level, as an assurance for sustainable science-led development in Africa. As part of the launching ceremony, live demonstrations of ICIPE's NGU trap for tsetse control as well as other novel approaches to pest control using the pest's own specific natural enemies, were demonstrated. ICIPE's training activities and achievements over the years were presented through poster displays.

11.11.3 ICIPE receives award of the International Saint Francis Prize for the Environment "Canticle of all Creatures"

The Prize on Education and Communication of the 1992 International Saint Francis Prize for Environment was awarded to ICIPE at a ceremony organised by the Franciscan Centre of Environmental Studies in Assisi, Italy on 22nd October, 1992 (Fig. 11.1). The prizes are awarded to persons or institutions that have distinguished themselves at the highest international level, for their contribution to the improvement, protection or conservation of the environment.

Fig. 11.1 Acting ICIPE Deputy Director Professor K. N. Saxena receives the St. Francis Prize for the Environment on behalf of the Centre at the Franciscan Centre of Environmental Studies in Assisi, Italy.

In selecting ICIPE for the award in the field of Communication and Education, the jury, composed of eminent persons representing the humanities, science and international organisations, recognised the tremendous effort ICIPE has made in the sphere of education and communication on insect pest management. The jury noted that ICIPE's training programmes are firmly based on the development of innovative pest management systems that contribute

to maintaining and enhancing the quality of the environment, conserving natural resources and promoting the earth's biodiversity. These principles are in harmony and conform to the values and ideals as expressed in the St. Francis "Canticle of all Creatures".

11.12 SCIENTIFIC EDITING

A. Ng'eny-Mengech

Following the reorganisation of ICIPE's programmes and units which occurred in September 1992, the position of Senior Science Editor was transferred from the ICIPE Science Press (ISP), to the newly-formed programme of IBIRI. The re-defined duties of the editor are to internally edit the scientific manuscripts originating from ICIPE's research programmes prior to their submission to international journals; to edit and compile the Annual Report; to assist in any other editorial work as may be required, such as conference proceedings, reports of seminars and meetings, project proposals, donor reports, etc.

In 1992, over 75 scientific manuscripts passed through the office of the Senior Science Editor, as well as reports and Proceedings of several workshops and conferences. ICIPE also houses the office of the scientific editor of the journal *Insect Science and its Application*, which is published by the ICIPE Science Press. Volume 13 (6 issues) was produced this year.

The editing unit of the ICIPE was further strengthened in early 1992 by the addition of a Senior Publications Officer, who is responsible for the editing of two of ICIPE's major publicity tools, *Dudu* newsletter and *Network News*, as well as coordinating all of the other newsletters and publicity material emanating from the individual programmes.

The end of 1992 marked the retirement from ICIPE of the Principal Science Editor, Dr. M.F.B. Chaudhury, who served the Centre in several capacities for 17 years, first and foremost as an insect physiologist of international repute, and as the Programme Leader of the Sensory Physiology Research Unit. Dr. Chaudhury was re-assigned as the Principal Science Editor at the ISP in 1991. He finished off his tenure at ICIPE by compiling and editing a manual for *Insect Physiology and Biochemistry*, the first manual in the PEW Africa Ecology Series, and editing of a second PEW manual, *Insect Population Ecology: An African Perspective* (compiled by Prof. J. S. Elkinton of the University of Massachusetts), both of which are currently in press at the ISP.

11.13 ICIPE SCIENCE PRESS

A. Katama and W. Oyuko

1992 was a transitional year for ICIPE Science Press (ISP). The Press began operating on a more market-oriented basis, as opposed to being an entirely service-oriented department. The ISP continues to be involved in high quality production of journals, proceedings, books, illustrations, and posters, to list a few. This includes the whole gamut of production procedures involved, such as conceptualisation, design, typesetting, layout and printing. Over 80% of our printing needs are now handled in-house. Subcontracted outside are procedures such as perfect binding.

ISP equipment and staffing levels remain very modest, considering the volume of work generated. Production schedules as a result are very tight, but we manage to meet most of our deadlines. In order to bridge the shortfall in staffing, ISP has introduced the University Student Attachment Programme (USAP), a collaborative programme between ISP and university students within the region. The attachment programme is brief, rarely exceeding three months, and is aimed at exposing students to the production of manuscripts, documents and books. The USAP programme facilitates cutting down of costs at ISP and helps clear the backlog of work as well as speeding up production.

Some of the titles produced during the year are:

- *1991 ICIPE Annual Report* (ISBN 92 9064 046 4)
- Volume 13 of *Insect Science and its Application* (6 issues)
- *Vision and Strategic Framework for the 1990s.* (ISBN 92 9064 048 X)
- *Maintaining and Servicing of Scientific Equipment in Africa.* (ISBN 92 9064 049 9)

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Reprints of articles with a call number at the end of the citation can be ordered from the Documentalist, ICIPE.

MISCELLANEOUS PUBLICATIONS BY ICIPE STAFF

A. CONFERENCE PROCEEDINGS

Inayatullah, C.; Ojwang, D. O.; Hassanali, A.; El Bashir, S. Visual responses of the desert locust, *Schistocerca gregaria*, to reflectance from surfaces of different colours. p 124. In: *Proceedings of the XIX International Congress of Entomology*, Beijing, China, 1992.

Kaaya, G. P.; Mwangi, E. N. Pathogenicity of *Beauveria bassiana* and *Metarhizium anisopliae* for larvae of tsetse *Glossina morsitans* and adult tick *Rhipicephalus appendiculatus*. In: *Proceedings of the Society for Invertebrate Pathology Conference*, Heidelberg, Germany, August 16–21, 1992.

Lux, S. A. Ethological analysis and simulation of behaviour as a tool in applied entomological research. p. 217. In: *XIX International Congress of Entomology*, Beijing, China, June 28–July 4, 1992.

Lux, S. A. Pheromonal traps — a tool for monitoring pest population or just for trapping insects? In: *XIX International Congress of Entomology*, Beijing, China, June 28–July 4, 1992.

Meena, H.; Nokoe, S. Assessment of ICIPE's involvement in electronic networking, including its experiences with CGNET. In: *Proceedings of Joint American Association for the Advancement of Science & African Academy of Sciences Workshop on Science and Technology Communication Networks in Africa*, Nairobi, Kenya, August 27–29, 1992.

Munyinyi, D. M. A systematic approach to the evaluation and procurement of statistical packages for biological investigations. pp. 61–72. In: *Proceedings of 2nd Meeting of the Biometric Society East, Central and Southern Africa Network*, Harare, Zimbabwe, November 23–28, 1991.

Nokoe, S. Analyses of multivariable entomological trials. pp. 91–104. In: *Proceedings of 2nd Meeting of the Biometric Society East, Central and Southern Africa Network*, Harare, Zimbabwe, November 23–28, 1991.

Nokoe, S. Research protocol for effective biometric advice. pp. 20–28. In: *Proceedings of 2nd Meeting of the Biometric Society East, Central and Southern Africa Network*, Harare, Zimbabwe, November 23–28, 1991.

Nokoe, S. Role of biomathematics in pest and vector management. pp. 19–21. In: *Proceedings of the 1st Conference of the Kenya Mathematical Society*, Nairobi, Kenya, August 19–21, 1992.

Nokoe, S. Status of statistics and computing in western and eastern Africa. pp. 123–136. In: *Proceedings of Invited Papers, XVIth International Biometric Conference*, Hamilton, New Zealand, December 7–11, 1992.

Odindo, M. O.; Ochoggo, L. W.; Obilo, J. O.; Ongoma, J. A.; Ogwang, J. A. Field evaluation of *Hirsutella thompsonii* (Hyphomycetes) for the control of cassava green spider mite. In: *Proceedings of African Association of Insect Scientists Conference*, Accra, Ghana, September 23–27, 1991.

Odulaja, A.; Nokoe, S. Design and analysis of experiments for comparing the efficiency of different tsetse traps—Preliminary investigations. In: *Proceedings XVIth International Biometric Conference*, Hamilton, New Zealand, December 7–11, 1992.

Odulaja, A.; Nokoe, S. Mathematical models for the analysis of uniformity trial data. In: *Proceedings of the 1st Conference of the Kenya Mathematical Society*, Nairobi, Kenya, August 19–21, 1992.

Osir E. O.; Magoma, G. N.; Vundla, M. W.; Kenya E. *Bacillus thuringiensis* endotoxins active against *Chilo partellus* and *Glossina morsitans*. In: *Proceedings of the International Symposium on Management of Insect Pests: Nuclear and Related Molecular and Genetic Techniques*, Vienna, Austria, October 1992.

Owino, J. O. A. Comparison of educational characteristics of males and females. In: *Proceedings of the 1st Conference of the Kenya Mathematical Society*, Nairobi, Kenya, August 19–21, 1992.

Saxena, R. C. Biointensive management of insect pests of rice. p. 351. In: *Proceedings of the XIX International Congress of Entomology*, Beijing, China, June 28–July 4, 1992.

Saxena, R. C. Botanical pest control in rice-based cropping system in Asia. p. 557. In: *Proceedings of the XIX International Congress of Entomology*, Beijing, China, June 28–July 4, 1992.

B. ARTICLES IN NEWSLETTERS

Ajala, S. O. Selection for resistance to the spotted stemborer *Chilo partellus* in maize. *Annual Plant Resistance to Insects Newsletter* 18:124, 1992.

Chitere, P. O. On the concept of the 'resource-poor' farmer. *Dialogue*, ICIPE, 4–6 1992.

Kiros, F. G. Coming to terms with the issues of development and the environment. *Whydah* (African Academy of Sciences), 3 (1), September 1992.

Kiros, F. G. Criteria for assessing technological fit in traditional agricultural systems. *Dialogue*, ICIPE, 3–1 1992.

Kiros, F. G. For Earth's Sake, Commission on Developing Countries and Global Change. *Discovery and Innovation*, African Academy of Sciences, 4 (3), September 1992.

Kiros, F. G. Kenya: Monitoring living conditions and consumption patterns. *Whydah* 3 (2), December 1992.

Kiros, F. G. Technology impact assessment and the environment: The need for a multidisciplinary approach. *Dialogue*, ICIPE, 5–10 1992.

Lako, G. T. On technological and economic efficiency. *Dialogue* 4–6 1992.

Nour, A. M. Incorporation of resistance to stemborer *Chilo partellus* into elite sorghum lines. *Annual Plant Resistance to Insect Newsletter* 18, 1992.

Oendo, A. W. On the social acceptability of technology in African rural settings. *Dialogue* 4–6 1992.

Overholt, W. A. Classical biological control of *Chilo partellus*: An ecologically rational approach to pest management. *DUDU*, 14, 1992.

Saxena, K. N.; Odindo, M. O.; Ampong-Nyarko K.; Seshu Reddy K. V. Compatibility of stemborer-resistant/tolerant sorghum lines with intercropping and biocontrol agents for IPM. *Annual Plant Resistance to Insects Newsletter* 18:18 1992.

Ssennyonga, J. W. Incorporating sustainability in the IPM research agenda. *Dialogue* 4–6, 1992.

1992 Seminars at ICIPE

SPEAKER	TOPIC
Dr. D. Obeng-Ofori Locust Research Programme ICIPE	Use of Pheromones in Stored Product Pest Management Systems
Dr. Annett Walker Hymenopterist, International Institute of Entomology, UK	The Bulletin of Entomological Research—Its Policies and Procedures
Prof. K. N. Saxena Programme Leader, Crop Pests Research Programme ICIPE	Crop Pests Research Programme: Activities and Plans
Dr. Wendimagegn Mammo Department of Chemistry Addis Ababa University Ethiopia	Pigments from *Araliorhamus vaginata*
Dr. Jan N. C. Van der Pas Syntech, Netherlands	Chemical Communication—A Dynamic Process
Dr. S. Lux Crop Pests Research Programme ICIPE	Economy of the Khapra Beetle Reproductive Behaviour
Prof. S. El-Bashir Programme Leader, Locust Research Programme ICIPE	Locust Research Programme: Its Research and Activities
Dr. S. K. Raina Locust Research Programme ICIPE	From Grub to Glamour: Sericulture for Resource-Poor Farmers
Dr. M. J. Mutinga Programme Leader, Medical Vectors Research Programme, ICIPE	Medical Vectors Research Programme: Its Research and Activities
Dr. M. F. B. Chaudhury Principal Science Editor ICIPE Science Press	The Art of Science Writing

Dr. T. S. Dadhialla Department of Entomology Michigan State University, USA	The Biochemical and Molecular Basis of Egg Production in Insects
Mr. Alwin Hoegerle Proprietor, Integrated Systems	Screen Machine and Visual Information
Prof. Mariam Sticklen Michigan State University, USA	Improving African Crops for Pest Resistance
Dr. Philip M. Nkunika Head, Department of Biology University of Zambia	Termites as Major Pests of Building Timber, Forestry and Agriculture in Zambia: An Overview
Dr. Laura Brezinsky International Centre for Research on Animal Diseases (ILRAD), Nairobi	Molecular and Evolutionary Characterisation of a Transposable Element from the Endemic Hawaian *Drosophila*
Dr. Keith James ILRAD, Nairobi	Molecular Approaches to the Isolation and Characterisation of Genes Encoding Immunogenic Proteins: The Case of *Theileria parva*
Mr. Dona Dakouo ARPPIS Class of 1990 ICIPE	Development and Implementation of IPM in an Irrigated Rice Environment—A Successful Case in Burkina Faso
Dr. Gary Bernon USDA-APHIS, USA	Colorado Potato Beetle—A Global Perspective
Dr. Ebenezer J. Asimeng Medical Vectors Research Programme, ICIPE	The Effect of Rice Husbandry on Mosquito Breeding at Mwea Rice Irrigation Scheme with Reference to Biocontrol Strategies
Dr. Samuel M. Waladde Sensory Physiology Research Unit, ICIPE	Mating Behaviour of *Maruca testulalis* Geyer (Lepidoptera: Pyralidae)
Prof. J. W. Smith Texas A & M University, USA	Foraging Strategies of Parasites of Stalk Borers of Tropical Graminaceous Crops
Dr. Franz Bigher Swiss Federal Research Station for Agronomy, Zurich, Switzerland	Quality Control in *Trichogramma*
Dr. Michael Welling Institut fur biologischen Pflanzenshutz, Darmstadt, Germany	Possibilities of Biological Control of Locusts with Bacterial and Fungal Pathogens
Dr. Geolinde Nachtigale Institut fur biologischen Pflanzenshutz, Darmstadt, Germany	Control of Cryptic Living Insects in Orchids with Entomopathogenic Nematodes
Ms. Jane Rees Research Fellow, Oxford University, UK	Investigations into Bee Immunity and the Evolution of Immune Systems

Dr. Mary R. W. Vundla Chemistry and Biochemistry Research Unit, ICIPE	The Molecular Basis for Selective Toxicity in *Bacillus thuringiensis* Endotoxins
Dr. Marcel Dicke Department of Entomology Wageningen Agricultural University, The Netherlands	Infochemicals in Tritrophic Interactions: Do Plants Cry for Help?
Prof. C. S. Prakash Plant Molecular Genetics, Tuskegee University, USA	Genetic Engineering of Sweet Potato: Potential for Insect Resistance
Mr. Silas Ita Chief Executive Export Processing Zone (EPZ) Authority, Nairobi	EPZ: Conceptual Framework and Philosophy
Dr. Asanzi Mbey-Yame Christophe Maize Entomologist, Service National de Recherche, Zaire	Some Aspects of Maize Streak Virus Epidemiology in some Ecological Zones in Nigeria
Dr. Nimrod M. Tole Dept. of Diagnostic Radiology, University of Nairobi	Radiation Hazards and the Law in Kenya
Mr. A. A. Andanje Kenya Posts and Telecommunications, Nairobi	Electronic Networking and Computer Communication Systems in Kenya with Special Reference to KENPAC
Dr. Curtis Powell Public Health Research Institute, New York, USA	Experimental Immunity Against Trypanosomiasis
Dr. Oswald N. Morris Agriculture Canada Research Station, Winnipeg, Canada	Insect-Related Biotechnology and Applied Microbiology
Dr. Bill S. Hansson Department of Ecology, Lund University, Sweden	From Antenna to Brain-Structure and Function in Insect Olfaction
Dr. P. G. N. Njagi Locust Research Programme ICIPE	The Desert Locust *S. gregaria* and its Host Plant Volatiles: A Perspective
Mr. L. O. Sese Kenya Industrial Property Organization, Nairobi	Industrial Property, Patenting and the Kenyan Scientist
Dr. M. Rai Locust Research Programme ICIPE	Incidence of the Microsporidian *N. locustae* in the Paddy Grasshopper: Its Mass Production, Screening and Application in Paddy Fields of Vidarbha Region, India
Mr. Herbert Seaforth Electronic Data Processing Unit, UNCHS (Habitat), Nairobi	Design and Management of Large Data Base Systems in Institutions using PCs: Some Important Considerations

Dr. Phelix A. O. Majiwa ILRAD, Nairobi	Gene Manipulation for a Better Understanding of Parasitic Protozoa
Prof. Kunthala Jayaraman Director, Centre for Biotechnology, Ann University, Madras, India	Biopesticides: From Cloning to Commercialisation Biotechnology
Prof. R. W. Mwangi Dean, Faculty of Science, University of Nairobi	Potential of Natural Products in Insect Pest and Vector Control
Dr. C. Inayatullah Locust Research Programme, ICIPE	IPM of Rice Stem Borers in Pakistan
Dr. F. O. Otieno University of Nairobi	Science and Technology Policy as an Impetus to Industrialisation: The Case of Kenya
Dr. F. X. Gichuru Basic Education Resource Centre, Kenyatta University	Making Education the Engine of Development
Dr. Mark J. Whitten Chief of the Entomology Division, CSIRO, Australia	Recent Advances in Research at CSIRO's Division of Entomology
Dr. Ian S. MacNairn Johns Hopkins University Washington D.C., USA	Cost-benefit Analysis of Cattle Productivity on Rusinga Island
Mr. Leonard Nwoke ARPPIS Scholar, ICIPE	Potential Odour Attractants for Mosquitoes
Prof. Gladys N. Opinya College of Health Sciences, University of Nairobi	Fluorides and the Kenyan Child
Prof. Celia Nyamweru Kenyatta University and St. Lawrence University, USA	Earthquakes and Seismological Disasters in Kenya — Where Will the Next Strike be?
Dr. N. Oguge Kenyatta University, Nairobi	The Role of Fertility Control in Management of Animal Over Population
Dr. Pedro Sanchez Director General, International Council for Research in Agroforestry (ICRAF), Nairobi	ICRAF's Strategy to Mitigate Deforestation, Land Depletion and Rural Poverty
Dr. Philip O. Owuor Tea Research Foundation of Kenya, Kericho	Tea: The Chemistry in Your Cup

1992 Personnel*

*(as at 31 December, 1992)

MANAGEMENT AND FINANCE

OFFICE OF THE DIRECTOR

Prof. T. R. Odhiambo, *Director*
Mrs. R. A. Odingo, *Chief Planning Officer*
Dr. W. A. Otieno, *Principal R & D Planning Officer*
Mr. V. S. Mutisya, *Principal Internal Auditor*
Mrs. D. W. Njoroge, *Senior Internal Auditor*
Mrs. G. M. A. Ochola, *Personal Assistant to the Director*
Mr. J. R. Kapkirwok, *Planning Officer*
Miss S. M. Kagondu, *Senior Administrative Secretary*
Mrs. H. A. Masibo, *Senior Secretary*
Mrs. Y. Obiero, *Senior Secretary*
Mrs. S. A. O. Madowo, *Secretary*
Mrs. G. O. Obwanda, *Secretary*
Mr. O. Aoko, *Clerical Assistant*
Mr. J. K. Kibor, *Principal Driver*
Mr. O. Ogallo, *Driver*
Mr. S. O. Okiri, *Driver*
Mr. J. M. Mutinga, *Driver*
Mr. J. O. Aroko, *Driver*
Mr. F. O. Ujiji, *Driver*
Mr. D. J. M. Mwawasi, *Driver*
Mr. J. L. Mwangai, *Messenger/Clerk*
Mr. H. O. Agonyo, *Messenger/Clerk*

ADMINISTRATION AND INFORMATION DIVISION

Mr. L. Okola, *Administration Manager*
Mr. J. F. Omange, *Principal Administrative Officer*
Mrs. S. N. Govedi, *Secretary*
Mr. F. J. Utanje, *Travel Officer*

Human Resources
Mrs. P. A. Ogada, *Principal Administrative Officer*
Mrs. A. M. Mulei, *Administrative Officer*
Mrs. M. R. Opande, *Office Management Supervisor*
Mrs. G. A. Kwanya, *Senior Administrative Secretary*
Mrs. M. M. Onyach, *Secretary (Pool)*
Ms. R. A. Okoth, *Data Input Clerk*
Mr. J. M. Mwendar, *Clerical Assistant*
Mr. E. E. O. Obuya, *Clerical Assistant*

FINANCE DIVISION

Accounting Services (Duduville-Based)
Mr. R. M. P. Okura, *Chief Accountant*
Mr. G. W. Kanza, *Principal Accountant*
Mr. R. Otieno, *Senior Accountant*
Mrs. W. N. K. Ssebunnya, *Senior Systems Analyst*
Mr. A. A. M. Oguda, *Accountant*
Mr. V. M. Kamanyi, *Accountant*
Mr. P. O. Ngugi, *Accountant*
Mr. P. O. Okune, *Assistant Accountant*
Mr. G. J. Rugendo, *Assistant Accountant*
Mrs. L. W. Muchene, *Assistant Accountant*
Mr. S. M. Aritho, *Assistant Accountant*
Mr. C. T. Maingi, *Accounts Assistant*
Mr. N. K. Mulwa, *Accounts Assistant*
Miss F. Ojode, *Senior Administrative Secretary*
Mrs. M. M. Butali, *Secretary*
Mr. A. O. Kirimba, *Driver*
Mr. A. Bubusi, *Senior Cleaner/Messenger*

Stores and Supplies (Duduville-Based)
Mr. C. M. Oloo, *Controller for Supplies and Stores*
Mr. T. O. Oloo, *Assistant Supplies Officer*
Mr. P. N. K. Kathenya, *Supplies Assistant*
Mr. D. O. Olalo, *Senior Storekeeper*
Mr. J. B. Oyondi, *Senior Driver/Messenger*
Miss S. M. Matiku, *Assistant Secretary*

CORE RESEARCH AND TRAINING PROGRAMMES

CROP PESTS RESEARCH PROGRAMME (CPRP)

Prof. K. N. Saxena, *Senior Principal Research Scientist/ Programme Leader*
Dr. R. C. Saxena, *Senior Principal Research Scientist*
Dr. R. S. Pathak, *Principal Research Scientist*
Dr. K. V. S. Reddy, *Principal Research Scientist*
Dr. Z. R. Khan, *Senior Research Scientist (leave of absence)*
Dr. E. O. Omolo, *Senior Research Scientist/R & D Field Coordinator*
Dr. M. O. Odindo, *Senior Research Scientist*
Dr. S. A. Lux, *Senior Research Scientist*
Dr. H. Kumar, *Research Scientist*
Dr. N. K. Maniania, *Research Scientist*
Dr. A. M. Nour, *Scientist-in-Residence*
Dr. K. Ampong-Nyarko, *Postdoctoral Research Fellow*
Dr. S. O. Ajala, *Research Associate*
Dr. S. Oghiakhe, *Scientific Officer*
Mr. L. Ngode, *Associate Scientific Officer*
Mr. R. M. Onyango, *Associate Scientific Officer*
Mr. P. R. Speijer, *Graduate Research Scholar*
Mrs. N. E. M. Smit, *Graduate Research Scholar*
Mr. K. S. Sum, *Senior Research Assistant*
Mr. Z. N. Otieno, *Senior Research Assistant*
Mr. J. C. Olela, *Chief Technician*
Mr. S. M. Othieno, *Principal Technician*
Mr. P. O. Ollimo, *Principal Technician*
Mr. M. C. Lubega, *Principal Technician*
Mr. M. W. Obondi, *Graphics Technician*
Mr. F. D. O. Odawa, *Senior Technician*
Mr. S. O. Paye, *Senior Technician*
Mr. E. K. Ngugi, *Senior Technician*
Mr. R. O. Okello, *Senior Technician*
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Mr. E. L. Kidiavai, *Technician*
Mr. P. M. Chiliswa, *Technician*
Mr. M. Kithokoi, *Junior Technician*
Mr. S. M. Otieno, *Technical Assistant*
Mr. G. O. Asino, *Technical Assistant*
Mr. D. O. Nyagol, *Technical Assistant*
Mr. J. O. Ochieng', *Technical Assistant*
Mr. I. O. Mayoga, *Laboratory/Field Assistant*
Mr. P. O. Ochanjo, *Laboratory/Field Assistant*
Mr. J. A. O. Mwanda, *Laboratory/Field Assistant*
Mr. W. O. Owuor, *Laboratory/Field Assistant*
Mr. I. O. Odhul, *Laboratory/Field Assistant*
Mr. L. M. Origa, *Laboratory/Field Assistant*
Mr. J. A. Adero, *Laboratory/Field Assistant*
Mr. P. O. Okello, *Laboratory/Field Assistant*
Mr. P. O. Akello, *Laboratory/Field Assistant*
Mr. P. O. Omolo, *Laboratory/Field Assistant*
Mr. J. O. Ogoro, *Laboratory/Field Assistant*
Mr. J. O. Ondijo, *Laboratory/Field Assistant*
Mr. P. A. Oreng, *Laboratory/Field Assistant*
Mr. D. A. Atieno, *Laboratory/Field Assistant*
Mr. J. O. Ngare, *Laboratory/Field Assistant*
Mr. J. O. Obara, *Laboratory/Field Assistant*
Mr. S. A. Ondiek, *Laboratory/Field Assistant*
Mr. R. O. Oluoch, *Laboratory/Field Assistant*
Mrs. T. A. Odero, *Laboratory/Field Assistant*
Mr. M. Y. Oriwo, *Laboratory/Field Assistant*
Mr. T. O. Onyango, *Laboratory/Field Assistant*
Mr. J. A. Orwa, *Driver/Technical Assistant*
Mr. S. G. Ogechi, *Senior Driver*
Mr. J. Mokaya, *Driver*
Mr. R. O. Musa, *Driver*
Mr. K. O. Onyango, *Driver*
Mrs. H. A. Abade, *Senior Secretary*
Mrs. J. A. Ojijo, *Secretary*

ICIPE/WAU Collaborative Project

(i) Duduville-Based
Dr. W. A. Overholt, *Visiting Research Scientist*
Dr. G. W. Oloo, *Senior Research Scientist*
Dr. C. O. Omwega, *Postdoctoral Research Fellow*
Mr. R. C. Odhiambo, *Technician*
Mr. J. O. Okello, *Junior Technician*
Mr. J. A. Otieno, *Technical Assistant*
Mr. M. O. Odoyo, *Laboratory/Field Assistant*
Mrs. B. M. Opiyo, *Secretary*

(ii) Mtwapa-Based
Mr. P. M. Lammers, *Research Associate*
Mr. K. Ogedah, *Senior Research Assistant*
Mr. S. P. Ojwang', *Laboratory/Field Assistant*

(iii) Bamburi-Based
Mr. P. O. Agwaro, *Technician*
Mr. J. O. Awendo, *Field Assistant/Driver*

Cypress Aphids Project
Dr. S. H. B. Okech, *Senior Scientific Officer*

LIVESTOCK PESTS RESEARCH PROGRAMME (LPRP)

(i) Duduville-based
Dr. L. H. Otieno, *Principal Research Scientist/Programme Leader*
Dr. G. P. Kaaya, *Principal Research Scientist*
Dr. K. S. Nokoe, *Senior Research Scientist*
Dr. O. A. Mongi, *Senior Research Scientist*
Dr. S. Mihok, *Senior Research Scientist*
Dr. L. C. Madubunyi, *Senior Research Scientist*
Dr. S. Essuman, *Research Scientist*
Dr. H. Sasaki, *Visiting Scientist*
Dr. R. O. Olubayo, *Postdoctoral Research Fellow*
Dr. J. O. Davies-Cole, *Postdoctoral Research Fellow*
Dr. Q. E. Paynter, *Research Associate*
Mrs. M. L. A. Owaga, *Senior Scientific Officer*
Dr. D. K. Punyua, *Senior Scientific Officer*
Dr. E. Mwangi, *Scientific Officer*

Miss N. F. Darji, *Principal Research Assistant*
Dr. I. G. Onyango, *Resident Veterinarian/Senior Research Assistant*
Mr. J. G. Kabii, *Principal Technician*
Miss R. Chesang, *Principal Technician*
Mr. M. M. Malonza, *Principal Technician*
Mr. S. S. Ole-Sipala, *Senior Technician*
Mr. E. M. Ng'ongo, *Senior Technician*
Mr. E. Mpanga, *Senior Technician*
Mr. S. S. Wakape, *Senior Technician*
Mr. D. F. Uvyu, *Senior Technician*
Mr. P. M. Mwamisi, *Technician*
Mr. J. K. Kiilu, *Technician*
Mr. J. G. Mugane, *Technician*
Mr. F. M. Thuo, *Technician*
Mr. P. P. Muteria, *Technician*
Mr. J. Likhanga, *Technician/Senior Driver*
Mr. M. G. Kimondo, *Junior Technician*
Miss E. A. Ouna, *Junior Technician*
Mr. D. K. Mungai, *Junior Technician/Driver*
Mr. S. O. Maramba, *Technical Assistant*
Mr. G. M. Hindi, *Technical Assistant*
Mr. G. K. O. Ochung', *Technical Assistant*
Mr. M. G. Kinyua, *Technical Assistant*
Mr. A. D. O. Nyangasi, *Field Asst. /Animal Attendant*
Mr. H. H. Onzayi, *Field Asst. /Animal Attendant*
Mr. M. J. Khadiakala, *Laboratory/Field Assistant*
Mr. P. S. Muchisu, *Laboratory/Field Assistant*
Mr. J. K. Njuguna, *Laboratory/Field Assistant*
Mr. R. K. Njonjo, *Laboratory/Field Assistant*
Mr. J. N. Ndungu, *Laboratory/Field Assistant*
Mr. E. N. Njamura, *Laboratory/Field Assistant*
Miss E. Afandi, *Senior Secretary*
Mrs. A. K. Ogoti, *Secretary*
Mr. P. O. Owuor, *Senior Driver*
Mr. G. M. Kinyanjui, *Driver*
Mr. A. Mwangi, *Driver*

(ii) MPFS-Based
Dr. S. M. Hassan, *Research Associate*
Dr. M. J. Wabomba, *Associate Scientific Officer*
Mr. P. O. Ngoko, *Senior Technician*
Mr. J. N. Odhiambo, *Technical Assistant*
Mr. J. A. Arus, *Laboratory/Field Assistant*
Mr. J. O. Odida, *Laboratory/Field Assistant*
Mr. H. M. P. Gesicho, *Senior Security Guard*
Mr. J. M. Owili, *Security Guard*
Mr. D. O. Muok, *Driver*

(iii) Mariakani (Kilifi-Based)
Mr. R. Ojowa, *Senior Technician*

(iv) Nguruman (Kajiado-Based)
Mr. J. N. Olekobai, *Laboratory/Field Assistant*
Mr. T. Toroke, *Laboratory/Field Assistant*
Mr. S. M. Pukare, *Laboratory/Field Assistant*
Mr. J. N. Tanchu, *Laboratory/Field Assistant*
Mr. M. L. Parirong, *Laboratory/Field Assistant*
Mr. J. O. Kobaai, *Senior Security Guard*

ODA Special Project

MPFS-Based
Dr. M. M. Mohamed-Ahmed, *Research Scientist*
Mr. P. O. Agutu, *Chief Technician*
Mr. J. M. Muchiri, *Junior Technician*
Mr. J. O. Abudi, *Laboratory/Field Assistant*
Mr. S. E. Mokaya, *Driver*

ICIPE/WAU Special Project

Muhaka-Based
Dr. I. M. I. Abu Zinid, *Postdoctoral Research Fellow*
Ms I. J. M. de Groot, *Research Associate*
Mr. C. O. Machika, *Technician*
Mr. H. Simba, *Laboratory/Field Assistant*
Mr. S. T. Oseur, *Laboratory/Field Assistant*

UNDP Kwale/Kilifi Special Project

Muhaka-Based
Dr. C. A. Kyorku, *Research Scientist*
Mr. A. M. Macharia, *Senior Technician*
Mr. J. Mwandandu, *Technician/Driver*

LOCUST RESEARCH PROGRAMME (LRP)

Duduville-Based
Prof. S. El Bashir, *Principal Research Scientist/Programme Leader*
Dr. S. K. Raina, *Senior Research Scientist*
Dr. C. Inayatullah, *Senior Research Scientist*
Dr. B. Torto, *Research Scientist*
Dr. H. Mahamat, *Postdoctoral Research Fellow*
Dr. D. Obeng-Ofori, *Postdoctoral Research Fellow*
Dr. P. G. N. Njagi, *Scientific Officer*
Dr. M. M. Rai, *Scientific Officer*
Mr. S. M. Ndugo, *Associate Scientific Officer*
Mr. H. Odongo, *Research Assistant*
Mr. D. O. Ojwang', *Research Assistant*
Mr. J. T. Kilori, *Principal Technician*
Miss J. R. Wawiye, *Technician*
Mr. F. O. Odhare, *Technician*
Mr. H. A. Chanzu, *Technical Assistant*
Mrs. K. Yaa, *Secretary*
Mr. M. A. Mbeke, *Driver/Technical Assistant*
Mr. J. M. Onyango, *Laboratory/Field Assistant*

Sudan-Based
Mr. H. El-Tigani Abdel-Rahman, *Associate Scientific Officer*

MEDICAL VECTORS RESEARCH PROGRAMME (MVRP)

Duduville-Based
Dr. M. J. Mutinga, *Principal Research Scientist/Programme Leader*
Dr. C. M. Mutero, *Research Scientist*

Dr. M. Basimike, *Research Scientist*
Dr. E. J. Asimeng, *Postdoctoral Research Fellow*
Dr. A. E. P. Mnzava, *Postdoctoral Research Fellow*
Mr. C. C. Kamau, *Associate Scientific Officer*
Mr. B. N. Odero, *Associate Scientific Officer*
Mr. F. A. Amimo, *Senior Research Assistant*
Mr. M. P. Nyamori, *Chief Technician*
Mr. F. M. Kyai, *Technician*
Mr. D. M. Omogo, *Technician*
Mr. F. M. Masika, *Technician*
Mrs. E. M. Wahome, *Junior Technician*
Mr. D. M. Mativo, *Technical Assistant*
Mr. M. M. Miti, *Technical Assistant*
Mr. J. M. Ndambuki, *Laboratory/Field Assistant*
Miss I. N. Nzuve, *Secretary*
Mr. R. M. Mogaka, *Driver*

Marigat (Baringo) West Pokot-Based
Mr. D. K. Mbavu, *Technical Assistant/Driver*
Mr. S. M. Mutua, *Technical Assistant*
Mr. P. K. Munguti, *Technical Assistant*
Mr. B. M. Muia, *Technical Assistant*
Mr. W. M. Kilonzo, *Laboratory/Field Assistant*
Mr. S. M. Singi, *Laboratory/Field Assistant*
Mr. P. B. Chepkoimet, *Laboratory/Field Assistant*
Mr. K. J. Kisilu, *Laboratory/Field Assistant*
Mr. P. O. Manyuanda, *Laboratory/Field Assistant*
Mr. R. K. Leitich, *Security Guard*

Tseikuru (Kitui)-Based
Mr. P. K. Wandei, *Laboratory/Field Assistant*
Mr. R. K. Muoki, *Laboratory/Field Assistant*

INSTITUTIONAL BUILDING, INTERACTIVE RESEARCH AND INFORMATION PROGRAMME (IBIRI)

Education Programme

Dr. V. O. Musewe, *Programme Leader*
Prof. Z. T. Dabrowski, *Training Coordinator*
Miss R. Runo, *Training Assistant*
Miss V. K. Manene, *Senior Technician*
Mrs. M. G. A. Odera, *Senior Secretary*
Miss I. K. Monyancha, *Secretary*
Mr. J. K. arap Mutai, *Junior Technician/Driver*

ARPPIS Students

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Mr. S. Dossa, *Ph.D. Scholar Year 3*
Mr. S. Gebre, *Ph.D. Scholar Year 3*
Mr. J. Kayitare, *Ph.D. Scholar Year 3*
Mrs. E. U. Kenya, *Ph.D. Scholar Year 3*
Mr. S. K. Meressa, *Ph.D. Scholar Year 3*
Mr. A. S. Mohamed, *Ph.D. Scholar Year 3*
Mr. M. Mugunga, *Ph.D. Scholar Year 3*
Miss A. R. Mutambara, *Ph.D. Scholar Year 3*
Mr. L. O. Nwoke, *Ph.D. Scholar Year 3*
Mr. R. P. Uzakah, *Ph.D. Scholar Year 3*
Mr. D. O. Ogoyi, *Ph.D. Scholar Year 3*
Mr. K. K. Oyugi, *Ph.D. Scholar Year 3*
Mr. E. F. Rwekika, *Ph.D. Scholar Year 2*
Mr. A. O. Ahmed, *Ph.D. Scholar Year 2*
Mr. S. G. Mwangi, *Ph.D. Scholar Year 2*
Mr. S. I. Kamara, *Ph.D. Scholar Year 2*
Miss S. W. Kimani, *Ph.D. Scholar Year 2*
Mr. S. F. Kutua, *Ph.D. Scholar Year 2*
Mr. J. C. Mbapila, *Ph.D. Scholar Year 2*
Ms. A. J. Ngi-Song, *Ph.D. Scholar Year 2*
Mrs. J. A. Kongoro, *Ph.D. Scholar Year 2*
Mr. E. O. Omolo, *Ph.D. Scholar Year 2*
Mr. B. J. Adgeh, *Ph.D. Scholar Year 2*
Miss L. N. Gichuru, *Ph.D. Scholar Year 1*
Mr. B. S. K. Kaoneka, *Ph.D. Scholar Year 1*
Mr. J. M. Mwesingwa, *Ph.D. Scholar Year 1*
Mr. C. J. M. Mutinda, *Ph.D. Scholar Year 1*
Mrs. M. Nabasirye, *Ph.D. Scholar Year 1*
Mr. I. S. T. Jalloh, *Ph.D. Scholar Year 1*
Mr. H. Tekie, *Ph.D. Scholar Year 1*
Mr. T. T. Epidi, *Ph.D. Scholar Year 1*
Mr. E. K. Nguu, *Ph.D. Scholar Year 1*
Mr. S. Bengaly, *Ph.D. Scholar Year 1*
Mr. F. Masaninga, *Ph.D. Scholar Year 1*
Mr. I. Bizimana, *Ph.D. Scholar Year 1*
Mr. A. J. Sumani, *Ph.D. Scholar Year 1*
Mr. M. A. M. Ali, *Ph.D. Scholar Year 1*
Mr. A. L. Deng, *Ph.D. Scholar Year 1*
Mr. Y. O. H. Assad, *Ph.D. Scholar Year 1*

PESTNET

PESTNET Secretariat

Mr. J. J. Ondieki, *PESTNET Coordinator*
Miss D. W. Barasa, *PESTNET Documentalist*
Mr. J. A. Lago, *Senior Technician (Data-Input)*
Mrs. S. M. A. Otieno, *Secretary*
Mr. D. Isoso, *Driver*

Country Resident Teams

PESTNET Kenya: Mtwapa-Based
Dr. S. Kyamanywa, *PESTNET Resident Scientist*

PESTNET Somalia: Mogadishu-Based
(Vacant), *Scientific Officer/PESTNET Resident Scientist*
Mr. M. H. Mohamed, *Research Assistant (On training)*

PESTNET Zambia: Lusaka-Based
Mr. C. F. Mugoya, *Scientific Officer/PESTNET Resident Scientist*
Mr. C. Kazhila, *Research Assistant*

PESTNET Ethiopia: Addis Ababa-Based
Mr. G. Tikubet, *Scientific Officer*

UNDP Project

Dr. S. Sithanantham, *Senior Research Scientist*
Dr. A. W. Oendo, *Senior Postdoctoral Research Fellow*

Library, Information and Documentation Services

Miss R. A. Washika, *Chief Communications Officer*
Dr. A. N. Mengech, *Senior Science Editor*
Miss M. H. Bugembe, *Senior Planning and Publications Officer*
Mr. N. S. M. Nsubuga, *Senior Librarian*

Mrs. R. A. Oyoko, *Librarian*
Mrs. R. P. Ortega, *Senior Communications Officer*
Mrs. L. A. Aduke, *Documentalist*
Miss J. A. Nyambare, *Secretary*
Miss N. N. Zani, *Secretary*
Mr. A. Shisoka, *Clerical Assistant*
Mr. J. Elegwa, *Clerical Assistant*

RESEARCH SUPPORT UNITS

BEHAVIOURAL AND CHEMICAL ECOLOGY RESEARCH UNIT (BCERU)

Prof. A. Hassanali, *Principal Research Scientist/Unit Head*
Dr. R. K. Saini, *Senior Research Scientist*
Dr. S. M. Waladde, *Senior Research Scientist*
Dr. W. Lwande, *Senior Research Scientist*
Mr. D. O. Nyarango, *Associate Scientific Officer*
Mr. B. O. K. Wanyama, *Associate Scientific Officer*
Mr. N. K. Gikonyo, *Associate Scientific Officer*
Mr. W. P. Ouma, *Senior Research Assistant*
Mr. H. M. Kahoro, *Chief Technician*
Mr. E. Nyandat, *Principal Technician*
Mr. S. A. Ochieng', *Principal Technician*
Mr. J. A. Andoke, *Senior Technician*
Mr. P. O. Ahuya, *Technician*
Mr. L. M. Moreka, *Technician*
Miss M. W. Wafula, *Senior Administrative Secretary*

Banana Weevil Semiochemicals (Norway)
Dr. W. J. Budenberg, *Postdoctoral Research Fellow*
Dr. I. O. Ndiege, *Postdoctoral Research Fellow*
Miss F. Karago, *Research Assistant*
Mr. D. O. Otieno, *Senior Technician*

MOLECULAR BIOLOGY RESEARCH UNIT (MBRU)

Dr. E. O. Osir, *Senior Research Scientist/Unit Head*
Dr. N. N. Massamba, *Senior Research Scientist*
Dr. W. G. Z. O. Jura, *Research Scientist*
Dr. M. K. Limo, *Research Scientist*
Dr. M. Imbuga, *Postdoctoral Research Fellow*
Dr. R. M. W. Vundla, *Senior Scientific Officer*
Mr. F. O. Oduol, *Associate Scientific Officer*
Mr. M. M. B. Chimtawi, *Research Technologist*
Miss L. A. Owuor, *Research Assistant*
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Mrs. J. K. Muriithi, *Chief Technician*
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Mr. L. V. Labongo, *Principal Technician*
Mr. J. O. Adino, *Senior Technician*
Mr. R. K. Rotich, *Technical Assistant*
Mrs. P. N. Owitti, *Senior Secretary*

BIOMATHEMATICS RESEARCH UNIT (BMRU)

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Dr. J. O. Owino, *Postdoctoral Research Fellow*
Mr. D. M. Munyinyi, *Senior Computer Applications Specialist*
Mr. J. M. Otedo, *Senior Computer Applications Specialist*
Mr. M. D. M. Gathoga, *Computer Technologist*
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Mrs. G. N. Gathura, *Secretary*

MPFS-Based
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Dr. M. Makayoto, *Postdoctoral Research Fellow*
Dr. M. R. A. Mohamed, *Postdoctoral Research Fellow*
Mrs. M. A. Oketch, *Scientific Officer*
Mr. J. A. Nyawach, *Laboratory/Field Assistant*

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Mr. A. Majanje, *Laboratory/Field Assistant*
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Mr. F. O. Onyango, *Associate Scientific Officer*
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Mr. M. D. O. Bungu, *Senior Technician*
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Mr. J. O. Maoro, *Laboratory/Field Assistant*
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Mr. A. G. Nyagwara, *Laboratory/Field Assistant*
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Mr. M. O. Chacha, *Laboratory/Field Assistant*
Mr. D. J. O. Okode, *Laboratory/Field Assistant*

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Mr. D. Murali, *Electronics and Instrumentation Engineer*
Mr. M. S. Nakitare, *Electronics and Instrument Technologist*
Mr. G. S. Kidunda, *Electronics and Instrument Technologist*
Mr. A. R. S. Abdalla, *Refrigeration Technologist*
Mr. P. O. Nyachieo, *Chief Technician*
Mr. J. M. Maina, *Principal Technician*
Mr. P. O. Auma, *Maintenance Foreman*
Mr. J. B. Omullo, *Senior Technician*
Mr. J. O. Ogalo, *Senior Technician*
Mr. P. A. Oluya, *Senior Technician*
Mr. K. Kinuthia, *Technician*
Mr. A. M. Wanyama, *Technician*
Mr. J. K. Gadonya, *Junior Technician*
Mr. J. O. Omondi, *Junior Technician*
Mr. M. O. Odada, *Junior Technician*
Mr. T. O. Ochieng', *Junior Technician*
Mr. M. M. O. Orwe, *Workshops Assistant*
Mr. P. N. Muasa, *Driver*

MPFS-Based
Workshops and Maintenance
Mr. J. K. Alwala, *Electronics and Instrumentation Engineer*
Mr. P. M. Alianda, *Senior Technician (Water Works)*
Mr. P. M. Okwanyo, *Senior Technician (Carpentry)*
Mr. T. L. Ngutu, *Senior Technician (Metal Works and Machines)*
Mr. K. G. Ogweno, *Senior Technician (Power Supply)*
Mr. M. Likhanga, *Senior Technician (Refrigeration)*
Mr. E. E. Okello, *Technician (Electronics)*
Mr. J. O. A. Wasinda, *Technician (Electrical)*
Mr. R. M. Nzioka, *Technician (Plumbing)*
Mr. S. M. Karanja, *Technician (General Maintenance)*
Mr. J. O. Okech, *Technician (Masonry)*
Mr. D. O. Wanjara, *Junior Technician (Carpentry)*
Mr. W. O. Omonge, *Junior Technician (Welding)*
Mr. P. O. Gati, *Technical Assistant (Oxidation Ponds)*
Mr. C. A. Otuta, *Workshops Assistant*
Mr. N. O. Otengo, *Workshops Assistant*

Ungoye-based
Mr. Z. B. Ooko, *Janitorial/Technical Assistant*

Transport
Mr. J. H. Ohato, *Senior Driver/Mechanic*
Mr. W. N. Omino, *Coxswain*
Mr. P. O. Mbuya, *Senior Driver*
Mr. L. O. Otieno, *Driver*
Mr. J. O. Otunge, *Driver*
Mr. E. O. Ndiao, *Mechanic Assistant*
Mr. S. O. Haira, *Mechanic Assistant*

MBITA POINT FIELD STATION AND SATELLITE FIELD RESEARCH SITES

Station Management
Prof. K. N. Saxena, *Manager for Research Policy and Resources*
Mrs. R. A. Okoth, *Senior Secretary*

Accounts and Supplies Section
Mr. M. Kawaka, *Accountant*
Mr. E. O. D. Odhiambo, *Accounts Assistant*
Mr. M. T. Kanyara, *Accounts Assistant*
Mr. J. O. Gombe, *Assistant Supplies Officer*
Mr. E. O. Jasor, *Stores Clerk*

Administrative and Janitorial Services
Mr. E. O. Anyango, *Officer-in-Charge*
Mr. C. A. Amolo, *Gardener*
Mr. Z. O. Nyandere, *Cleaner/Messenger*
Mrs. M. O. Walter, *Janitorial/Gardening Assistant*
Mr. G. O. Ogero, *Janitorial/Gardening Assistant*
Mr. T. A. Owiti, *Janitorial/Gardening Assistant*
Mr. S. M. Mkamba, *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*
Mr. R. Y. Owawa, *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', *Assistant Secretary*
Mr. G. K. Khisa, *Telephonist/Receptionist*
Miss M. A. Okoth, *Telephonist/Receptionist/Typist*
Mrs. D. T. Ongondo, *Typist*
Mr. R. R. Nyaridi, *Clerical Assistant*

Security Section
Mrs. P. A. Oriwa, *Senior Security Officer*
Mr. J. K. N. Birir, *Security Supervisor*
Mr. J. Omogi, *Security Supervisor*
Mr. J. O. Musingo, *Security Guard*
Mr. M. O. Omom, *Security Guard*
Mr. N. N. Omurumba, *Security Guard*
Mr. E. P. Achenya, *Security Guard*
Mr. E. O. Raringo, *Security Guard*
Mr. G. M. Kinyuah, *Security Guard*
Mr. J. T. Rege, *Security Guard*
Mr. G. O. Aunga, *Security Guard*
Mr. N. Odhiambo, *Security Guard*
Mr. S. O. Mboga, *Security Guard*
Mr. N. O. Mbija, *Security Guard*
Mr. A. O. Omondi, *Security Guard*
Mr. J. M. Chacha, *Security Guard*

Farm Services
Mr. P. Nyongesa, *Farm Supervisor*
Mr. P. O. Ouma, *Senior Farm Assistant*
Mr. P. L. Rakwach, *Tractor Driver/Mechanic*
Mr. E. O. Ogutu, *Tractor Driver*
Mr. J. O. Ojunga, *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. F. O. Bwire, *Farm Assistant*
Mr. H. O. Abongo, *Farm Assistant*
Mr. W. J. O. Odhiambo, *Farm Assistant*
Mr. P. C. K. Wanyonyi, *Farm Assistant*
Mr. J. O. Obilo, *Farm Assistant*

UNGOYE FIELD STATION

Farm Services
Mr. E. G. Kabiru, *Farm Foreman*
Mr. D. O. Oyoo, *Senior Farm Assistant*

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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*
Mr. P. R. Manga, *Security Guard*

KUJA RIVER FIELD STATION

* Security Staff listed under LPRP

MUHAKA FIELD STATION

Mr. B. S. Masyanga, *Farm Development Officer*
Mr. J. C. Wanga, *Security Officer*
Mr. S. Abdalla, *Security Guard*

Library Section
Miss D. Achieng, *Librarian*
Mr. E. A. Sonye, *Clerical Assistant*

AMENITIES AND SOCIAL SERVICES

INTERNATIONAL GUEST CENTRE SYSTEM

Duduville International Guest Centre (DIGC)
Mr. J. A. Achilla, *Principal Business and Catering Controller*
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. J. M. Mwakisha, *Cook*
Mr. E. M. Aosa, *Assistant Storekeeper*
Mr. P. A. Omollo, *Senior Barman/Waiter*
Mr. L. M. Mulae, *Room Steward*
Mrs. P. A. Ochola, *Assistant Housekeeper*
Mr. H. O. Onyango, *Barman/Waiter*
Mrs. R. M. Wekesa, *Senior Telephonist/Receptionist/Cashier*
Mrs. T. A. Ogongo, *Room Steward*
Mr. J. O. Mukhobi, *Janitorial Assistant*
Mr. S. Obondo, *Janitorial Assistant*
Mr. K. K. Omari, *Janitorial Assistant*
Mrs. J. A. Awich, *Laundry Assistant*
Mr. J. N. Kipserem, *Laundry Assistant*
Miss J. W. Weru, *Laundry Assistant*
Mr. J. W. Mburu, *Kitchen Assistant*
Mr. G. S. O. Omondi, *Kitchen Assistant*
Mr. J. N. Chege, *Kitchen Assistant*
Mr. P. Mungithya, *Waiter*
Mr. G. O. Oketch, *Waiter*
Mr. W. O. Odera, *Waiter*
Mr. G. O. Odero, *Housekeeping Assistant*
Mr. L. M. Maki, *Guest House Attendant*
Mr. D. O. Resa, *Front Office Assistant*
Miss C. W. Mwangi, *Secretary*

MPFS International Guest Centre
Mr. J. A. Kooro, *Business and Catering Controller*
Mr. S. Nyangi, *General Assistant*
Mr. M. N. E. Asudi, *Assistant Accountant*
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. K. O. Orwa, *Kitchen Assistant*
Mr. E. J. Odero, *Gardening Assistant*
Mr. C. O. Nyagaya, *Housekeeping Assistant*
Mr. H. O. Omala, *Housekeeping Assistant*
Miss M. A. Nalo, *Housekeeping Assistant*
Mr. J. A. Oloo, *Guest House Attendant*
Mr. W. M. Esirenyi, *Guest House Attendant*
Mr. H. O. Wara, *Guest House Attendant*
Mr. F. N. Omutsembi, *Laundry Assistant*
Mrs. H. A. Ouma, *Laundry Assistant*
Miss L. A. Olack, *Front Office Assistant (On leave of absence)*

Ungoye Guest House
Mrs. R. Osuna, *Guest House Attendant*
Mr. S. O. Odhako, *Guest House Attendant*

Marigat Guest House
Miss S. J. Cheboiywo, *Guest House Attendant*

Muhaka Guest House
Mr. S. O. Ojwang', *Guest House Attendant*
Miss N. Ifire, *Guest House Attendant*

MEDICAL AND CLINICAL SERVICES UNIT

St. Luke's Clinic — Duduville
Dr. R. W. Kimokoti, *Medical Officer*
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Mrs. I. A. Wadundwe, *Nurse*
Mrs. C. E. Okoth, *Nurse*
Mr. S. Kirera, *Laboratory Technologist*
Mr. J. K. Awino, *Pharmaceutical Technologist*
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Mr. J. M. Asitiba, *Janitorial Assistant*

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Mrs. C. A. Abonyo, *Janitorial Assistant*

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Mrs. C. O. M. Ndiege, *Teacher*
Mr. P. W. Mburu, *Teacher*
Mr. P. W. Mitugo, *Teacher*
Mrs. L. G. Chacha, *Teacher*
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Miss V. Olwali, *Teacher (French)*
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Miss S. A. Omune, *School Attendant*
Mrs. O. A. Ojwang', *School Attendant/Cleaner*

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Mr. T. Oloo, *Credit Committee*
Mrs. W. Oyuko, *Credit Committee*
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Mr. J. L. Kasiera, *Book-keeper*
Mr. L. O. Kwelu, *Clerical Assistant*

**Paid from DUSCO funds*

CENTRAL ADMINISTRATIVE SERVICES AND UTILITIES

Mr. L. Okola, *(In charge)*
Mr. W. W. Wapakala, *Principal Administrative Officer I*

Utilities Section
Mrs. G. M. Weya, *Telephonist/Receptionist Supervisor*
Mrs. M. B. Mohochi, *Senior Receptionist/Telephonist*
Miss S. O. Onani, *Senior Receptionist/Telephonist*
Mrs. M. Assetto, *Receptionist/Telephonist*
Mr. E. Asami, *Mail Clerk*
Mr. N. Okumbe, *Machine Operator*

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. S. A. Otila, *Cleaner/Messenger*
Mrs. M. A. Ochanda, *Cleaner/Messenger*
Mrs. S. Onyango, *Cleaner/Messenger*
Miss T. D. Makero, *Cleaner/Messenger*
Miss L. W. Kabiru, *Cleaner/Messenger*
Mr. F. O. Athula, *Cleaner/Messenger*

Security Section
Mr. A. M. Bwana, *Senior 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. A. A. Ogaja, *Senior Security Guard*
Mr. A. M. Muhindi, *Security Guard*
Mr. C. K. Mulela, *Security Guard*
Mr. E. H. Otieno, *Security Guard*
Mr. D. M. Mwilu, *Security Guard*
Mr. W. Mayienga, *Security Guard*
Mr. J. A. Vudavira, *Security Guard*
Mr. P. O. Apodo, *Security Guard*
Mr. Z. Otieno, *Security Guard*
Mrs. M. N. Muiruri, *Security Guard*
Mr. M. O. Otiende, *Security Guard*
Mr. J. N. Aburi, *Security Guard*
Mr. G. O. Omondi, *Security Guard*

Transport Section
Mr. V. O. Odhiambo, *Transport Assistant*
Mr. J. O. Madero, *Data In-put Clerk*
Mr. J. O. Oduol, *Automobile Foreman*
Mr. A. J. Ombija, *Senior Mechanic*
Mr. R. M. Kiboi, *Senior Mechanic/Driver*
Mr. P. N. Mahogo, *Senior Driver*
Mr. U. Ibrahim, *Driver/Mechanic*
Mr. R. M. Mugi, *Driver/Assistant Mechanic*
Mr. A. Kathoka, *Driver*
Mr. H. N. Njachi, *Driver*
Mr. J. K. Nzioki, *Driver*