ANNUAL REPORT HIGHLIGHTS 1993

ICIPE

Contents

1993 Annual Report Highlights

"Nature will bear the closest inspection.
She invites us to lay our eyes
level with her smallest leaf
and take an insect view of its plain".

Henry Thoreau
American naturalist

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1993 ICIPE Annual Report Highlights
ISBN: 92 9064 070 7

Published by: ICIPE Science Press
P.O. Box 72913, Nairobi, Kenya.

Printed by Regal Press Kenya Ltd.,
P.O. Box 46166, Nairobi, Kenya

Foreword

William T. Mashler

The approach of the twenty-fifth anniversary of the founding of the International Centre of Insect Physiology and Ecology coincides with important changes in the leadership, shape and content of a unique international scientific research institution in Africa, and for that matter, in the world.

ICIPE was the vision of Professor Thomas R. Odhiambo who together with other scientists, brought what was originally a modest institution into being and nurtured it over the years into an institution which came to be recognised for its uniqueness, scientific excellence and innovation. Here was a Centre which long before political leaders and scientists alike did so, recognised fully the importance of the abuses heaped on the environment everywhere and the need to ameliorate them. ICIPE was amongst the first to include in its mandate a focus on studying ways and means of controlling harmful insects by biological means. The Centre thus became a pathfinder and innovator in the area which today has come to be accepted universally as the concept of 'sustainability'. All who over the years have had the privilege of working with Professor Odhiambo take pride in knowing that his concepts and convictions are as valid today as they were a quarter of a century ago, and that they were forged and strengthened by a son of Africa.

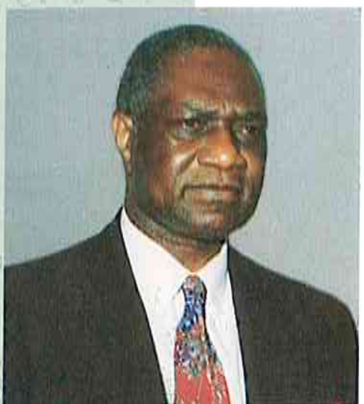
From the seminal days of ICIPE's foundation to the present time, much useful and important scientific work has been done, frequently in difficult and sometimes turbulent conditions created by the ever-present uncertainty of financial support. It is fitting here to pay special tribute to the Centre's loyal and devoted staff who understand clearly their dual responsibilities as scientists and Africans. Their efforts and work, most recently in the area of semiochemicals, and particularly those of locusts, are well recognised internationally. Important work has also been done in the control of crop pests, a good part of it in collaborative arrangements with other research centres. More recently, ICIPE has moved into R&D of neem-based pest and vector control. A major contribution of ICIPE has been its strong focus on human resource development at all levels. Thus, when Professor Odhiambo lays down his responsibilities as ICIPE's first Director in March 1994, he leaves to his successor a wealth of accumulated knowledge upon which ICIPE's future endeavours can be structured.

When ICIPE's new Director designate assumes his responsibilities in the second half of 1994, it will be his challenging task, together with his Governing Council, and his staff, to take a long, reflective, and realistic view of ICIPE's future scientific role, which will simultaneously involve the establishment of high standards of performance and quality of research. At a time when international material support to scientific research has come under increasing scrutiny in terms of its relevance and costs, ICIPE will need to focus on ways and means of optimising its scientific research and training efforts in collaborative arrangements with other international institutions working in the areas of agricultural, medical and environmental investigative research. By so doing, ICIPE's research activities should become truly complimentary and cost-effective within a setting of global scientific partnership aimed at the reduction and ultimate elimination of hunger and disease and the conservation of our natural resource bases.

William T. Mashler
Chairman
ICIPE Governing Council

The Director's Message:

The 1993 divide and the future of ICIPE



Prof. Thomas R. Odhiambo

The year 1993 was a pivotal period for the entire ICIPE community, in at least two senses. It was the final year of a three-year process of ICIPE's restructuring, reprogramming, and replanning to begin to meet the challenges of a contemporary world in which the expected peace dividend arising from the demolition of the Cold-War era did not extend to Africa and its institutions. It was also the year in which I, as the founding Director of the ICIPE, decided to step down from the leadership of what has become a pioneer centre of advanced research in Africa. Consequently, the time was fraught with uncertainties because of strategic realignments, and shrouded in danger because of the imminent change of guard.

At this juncture, one could well ask the question: What were the major problems that the founding fathers of the ICIPE encountered in the design and establishment of the ICIPE as a centre of scientific and educational excellence in the then prevailing geopolitical and intellectual environment of Africa a quarter of a century ago? How were they overcome? And are there new concerns that the contemporary generation will require to address and overcome so as to assure the Centre of an uninterrupted place in the sun?

Three disabling intellectual problems stand out as the most enduring contextual issues of the late 1960s and the succeeding decade. First, the grovelling lack of confidence in self by the great majority of African scientists that they indeed possess the capacity to create and nurture a rich intellectual environment *in situ* for vigorous scholarship and innovative research. Their hunger for working and affiliating with the then existing centres of excellence in Berkeley, Harvard, Cambridge, Paris, and Tokyo was not only organic but also persistent; it was an act of valour even to persuade them to begin the ICIPE adventure into home-grown excellence, presumed to be dormant in the African person. Second, there was an abject lack of confidence of Africa's geopolitical and geoeconomic leadership in Africa-centred scientific research and technological development (R&D) as a means of resolving Africa's priority problems of development. And, third, there was an insistent new-found philosophy that Africa can only develop with the help of human and technical assistance from the industrialised North — in spite of the contrary evidence over the past 500 years of the African Diaspora.

Our approach was to advertise internationally for young scientists at the postdoctoral level, and select the brightest talents from the respondents on exactly the same world-wide scale of scientific quality and productivity. In this way, we almost invariably picked a cadre of first-class African scientists as well as other bright young postdoctorals from around the world. This self-confident young group worked under the general supervision of world-renowned scientists, who visited the ICIPE two or three times a year, helping to design experiments, analyse the results, and get the young scientists known professionally in the world. By the mid-1970s, the ICIPE Research Centre was a hive of productive activity, a highly stimulating intellectual environment, and already giving the promise of approaching the solution of life-size problems of tropical pests. This circumstance opened the ICIPE research community to the experimental introduction of resident programme leaders, and by the beginning of the 1980s, this thrusting and bright community had adequate confidence in its own *in situ* programme leadership and direction to phase out the practice of appointment of non-resident visiting directors of research. Consequently, cooperation on research and education between the ICIPE and other advanced scientific institutions around the world became a reality because of its shared excellence and productivity. But the ICIPE had gone further — by insisting on being relevant to tropical pest and vector management problems, especially the most difficult ones which had previously defied resolution, such as trypanosomiasis and crop borers, malaria and locusts.

The extensive planning and discussion which prefaced the establishment of ICIPE's key educational and partnership networks in the early 1980s — the African Regional Postgraduate Programme in Insect Science (ARPPIS), and the Pest Management Research and Development Network (PESTNET) — brought the African governments and science-oriented institutions in the continent into a realisation that high-level human and institutional building in Africa, as well as science-led development, were not only possible within Africa's own internal resources, but that it was possible to accomplish their set goals in a rewarding and productive manner.

Perhaps one of the most path-blazing accomplishments of ICIPE's R&D was the design, development, and interactive field testing of ICIPE's visually attractive, odour-baited tsetse trap in the late 1980s. The intense, multi-disciplinary research that had preceded the emergence of the 'NGU supertrap' — including the discovery of the blend of urine-associated chemical attractants from the buffalo and other potential tsetse hosts — gave promise that demand-driven R&D, if well-designed, and if informed by social and economic research, may well lead to community-based, cost-effective solutions to Africa-specific pest and vector management problems. That lesson was well learnt, and is being applied to problems of vectors of human tropical diseases (especially leishmaniasis and malaria), to the banana weevil, and to other priority problem areas of ICIPE's concern.

In the intellectual and social environment of the 1980s, ICIPE's management philosophy and technological methodologies have evolved to the point that it can replicate its successes in other science-related concerns — provided the vision and means are congruent with the goals and incentives of the leadership of the ICIPE and its constituents.

But the constituents are changing rapidly — becoming progressively impoverished and directionless. The financial means and foreign partnerships are fast becoming threadbare as a result of loss of foreign interest in Africa. The emerging challenge for the ICIPE — that of creating a new horizon for the dawning sun of the 21st century — is to initiate steps for the Centre to have an Africa-centred, self-confident governance, just as it has already mobilised an outstanding, self-confident African scientific, technical, and managerial staff.

Over the last 15 years, the ICIPE staff have become very largely African, while maintaining a world-class research productivity and excellence; the Centre has, at the same time, continued to have a porous system of recruitment, which has guaranteed the selection of first-class extra-African staff. In the same manner, the membership of the highest governing bodies of the ICIPE should boldly go out to transform themselves into a preponderantly African institution, while still deliberately selecting a certain number of key extra-African members to provide a measure of piquant flavour and singular wisdom.

Nonetheless, in the last analysis, ICIPE must continue its chosen path of undertaking excellent scientific research, important technological development, and demand-driven productivity in regard to the type of science-led development work that the ICIPE and other R&D institutions are beginning to undertake in Africa.

The continent is now ready for science-led, knowledge-intensive production and trade. The ICIPE beacon is there for all to see, and the ICIPE should have the self-confidence and manifest courage to lead the way. It is what the founding fathers of the ICIPE would earnestly wish to bequeath to the contemporary staff, the incoming directorship, and the yet-to-be-transformed governance.

THOMAS R. ODHIAMBO
Outgoing Director, ICIPE

ICIPE Governing Council 1993

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1993

ICIPE Donors

- African Development Bank (ADB)
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- Danish International Development Agency (DANIDA)
- Directorate for NGO, International Education and Research Programmes (DPO) — Netherlands Government
- European Economic Union (European Development Fund)
- Finnish Government
- The Gatsby Charitable Foundation
- German Academic Exchange Service (DAAD)
- German Academic Ministry for Economic Cooperation (BMZ)
- Institute of Molecular Biology and Biotechnology — Greece
- International Bank for Reconstruction and Development (World Bank)
- International Development Research Centre (IDRC)
- International Fund for Agricultural Development (IFAD)
- Japan Society for the Promotion of Science (JSPS)
- Kenya Government
- Norwegian Government
- The Rockefeller Foundation
- Swedish Agency for Research Cooperation with Developing Countries (SAREC)
- UK Natural Resources Institute (NRI)
- UK Overseas Development Administration (ODA)
- United Nations Children's Fund (UNICEF)
- United Nations Development Programme (UNDP)
- United Nations Environmental Programme (UNEP)
- The Wellcome Trust
- World Wildlife Foundation

What are ICIPE's concerns as an Africa-based international research organisation working in insect science?

Ensuring food and economic security, especially in tropical regions, through limiting damage caused by insect pests to crops and livestock

Improving the health of rural communities by controlling insect vectors of diseases

Promoting sustainable agriculture and rural development by the use of relevant and manageable technologies and eschewing the use of chemical pesticides

Advocating sustainable management of natural resources, including biodiversity conservation

Developing scientific leadership in Africa, particularly in insect science, for competency in finding indigenous solutions to the continent's problems

Catalysing the adoption of science and technology as keys to national development

What does ICIPE do to accomplish these objectives?

Interactive, mission-oriented research, starting from basic scientific principles to end-user applications

Integrated pest and vector management (IPVM) technology development and adaptation to suit local conditions

Development of simple, affordable technologies for pest control: *traps for tsetse, banana weevils, stemborers; Mbu cloth for mosquito and sandfly control; Dudustop* Bt *formulations for houseflies and filthflies; banana tissue sterilisation techniques, etc.*

Technology dissemination and adoption, in partnership with local communities

Incorporation of indigenous knowledge and agricultural practices into refined and improved technologies

Networking and collaboration with national agricultural and extension services for most effective and speedy implementation

Education and training from PhD level to farmer-based IPVM practitioner courses

1993 Calendar Highlights

3–5 May. The 23rd Annual Research Conference reviews the 'Role of Population Biology in IPM' in 18 papers and posters presented by ICIPE scientists. The Conference closed with the Annual Guest Lecture, delivered this year by Dr. Mark Byung Moon Suh, a noted economist and political scientist, who riveted the audience with his talk, entitled 'The Science and Technology Policy of Japan and Korea: From Copy to Self-Reliance', about the carefully planned industrial revolution in Asia.

5 May. Mr. John C.P.Olela wins the 1993 ICIPE Medal for Innovative Research for his serendipitous discovery of a beautiful butterfly, *Junonia orithya* whose larvae preferentially feed on young shoots of *Striga hermonthica*. *Striga* (the witch weed) is the scourge of farmers in Africa. The parasitic weed strangles graminaceous crops, as well as sugarcane; thus far, no conventional method of control, including weedkillers, is effective against *Striga*. In field experiments conducted after his normal working day, Mr. Olela demonstrated that mass-reared larvae are able to control up to 80% of the weed. Here, Mr. Olela receives his award from the Hon. Z.T. Onyonka, as Prof. Odhiambo (left), Dr. Suh and the Hon. Dr. Awetahegne Alemayehu, Minister for Agriculture of Ethiopia, look on.

1 June. ICIPE appoints a new Deputy Director for Research in Prof. Kailesh N. Saxena, who for nearly a decade has served as Programme Leader of the Crop Pests Research Programme. Saxena, Professor of Zoology at the University of Delhi for over 17 years, was recently honoured by the International Biographical Centre, Cambridge, U.K. as 'International Man of the Year' 1992–1993, and was listed in 'Men of Achievement' (1992). Prof. Saxena is pictured here in the screenhouse at the Mbita Point Field Station discussing sorghum selection with a staff member.

In another important appointment, Mr. Vinod Tandon was appointed Financial Manager at ICIPE. Prior to his appointment, Mr. Tandon was the Director of Finance with Zambia's Forestry and Forest Industries Corporation Limited.

13 June. A 15-man international media team spends three days at ICIPE, travelling as far as the Nguruman and Marigat field sites to gather information for a series of features focusing on the fight against rural poverty in Africa. Arising from this visit, a number of documentaries broadcast in Europe and Asia and feature articles on tsetse and desert locust control have generated great interest in ICIPE's work.

18 June. Mass release of *Cotesia flavipes*, a natural enemy of the stemborer *Chilo partellus* that attacks maize and other cereals, occurred in three locations along the Kenya coast. About 30,000 of the tiny wasps, which lay their eggs in the borer larvae, were released at each site between May–July, 1993. Here, Project Leader Dr. W. A. Overholt (2nd left) opens up the vials containing the wasps. Looking on are Mr. W. Malinga, Director of the Kenya Agricultural Research Station at Mtwapa (centre), Dr. P. Pats of the Swedish Agricultural University and ICIPE technician K. Gitonge (left). Recoveries of the wasp through December, 1993 indicate that *C. flavipes* has reproduced in the field for at least 8 generations without additional releases.

8 October. A well-attended Banana Farmers Field Day, organised by the Crop Pests Research Programme at Oyugis in western Kenya, exposed farmers to improved cultural practices and farm management techniques developed by ICIPE to reduce loss from serious banana pests. The farmers were introduced to new varieties of banana and to simple farming implements for banana cultivation. Prof. T.R. Odhiambo (left) and Programme Leader Dr. K.V. Seshu Reddy show the Hon. Simeon Nyachae, Kenya Minister for Agriculture some useful products made from banana fibre, as Dr. L. Otieno (far right) looks on.

A Tsetse Management Field Day at Ole Karamatian and Shompole Group Ranch, Nguruman in SW Kenya provides an occasion for ICIPE scientists and cattlemen of the ranch to renew their joint commitment to controlling tsetse in this nagana-endemic region of East Africa. Dr. L. Otieno, Programme Leader presents a copy of the 1989 Award for Innovative Research to the Chairman of the ranch. The award was shared by the tsetse research group at ICIPE and members of the ranch for development of the community-based tsetse programme.

25 November. Tokyo and Tsukuba, Japan's 'Science City', were the sites of the 5th ICIPE Mobile Seminar. Mobile seminars provide ICIPE with a forum to get its message across to well-wishers and collaborators around the world. Previous seminars have taken place in Stockholm, Brussels, New York and Addis Ababa. It is fitting that this first seminar in the Far East should take place in Japan, whose eminent scientists and institutions have lent support to ICIPE, from the early planning meetings (attended by Prof. Koji Nakanishi), to membership of the ICIPE Foundation and the Governing Council. The theme of the seminar was 'From Entomological Sciences to Biorational Insect Pest Management'. The programme included presentations from eight ICIPE scientists (including the Director, Prof. Thomas R. Odhiambo), and from Japanese researchers in universities, institutions and industry.

CPRP

Crop Pests

1993 overview of research on ICIPE's target pests

Improving food security is the cornerstone of ICIPE's mandate. Although world grain production increased favourably to 1,745 million tonnes in 1992, these global figures mask the harsh reality of food scarcity in Africa, South Asia, and many other tropical developing regions: in 1993, the world's poor were spending between 60 to 80% of their incomes on food; over 184 million malnourished children of preschool age are to found in the developing countries. At current rates of population growth, yields of food crops per hectare must increase by at least 40% in the next two decades if the current level of food availability is to be maintained, even at its presently unsatisfactory level. In addition to drought and land degradation, damage to crops by insect pests, whether in the field or during storage, is a major cause of food loss.

Native natural enemies are important mortality factors in the life histories of stemborers. This Chilo partellus larva was ambushed by ants during migration between host plants. Application of insecticides would have killed the ant predator.

ICIPE's Crop Pests Research Programme (CPRP) has been active at the global level in contributing to the search for new paradigms of pest management. The biointensive pest management (BIPM) strategy that ICIPE advocates is based on the premise that pest populations can be reduced to, and maintained at, levels below the economic thresholds by manipulating the agro-ecosystem, while eschewing the use of chemical pesticides. By promoting natural regulating mechanisms, ICIPE's approach is in tune with the current global concern to conserve biological diversity, at the same time recognising that pest control is only part of the total effort needed to obtain sustainable yields.

The BIPM approach includes an integrated application of IPM strategies such as host plant resistance, cultural practices, biological control, botanical control, and supportive tactics such as the application of pheromonal biology and crop loss assessment. In 1993 ICIPE's CPRP concentrated on four major tropical food crops and their insect pests: maize, sorghum, cowpea and banana. Highlights of this research, and that carried out by scientists in PESTNET (see IBIRI section of this Report) are reported herein.

MAIZE & SORGHUM

The introduction and widespread cultivation of maize has undoubtedly led to an increase in abundance of stemborers by providing a highly nutritious and readily available food source with little natural resistance to borer attack.

Maize (*Zea mays*) was introduced into West Africa about 400 years ago and into East Africa at the end of the last century; maize is now the most widely grown cereal in Kenya and many other parts of East Africa. Sorghum (*Sorghum bicolor*) is indigenous to Africa and is considerably more drought resistant and nutritionally balanced than maize. Both of these important coarse grain crops are attacked by a complex of stemborers, two of which are target pests of the CPRP: *Chilo partellus* (the spotted stemborer) and *Busseola fusca*. The introduction and widespread cultivation of maize has undoubtedly led to an increase in abundance of stemborers by providing a highly nutritious and readily available food source with little natural resistance to borer attack. Yield losses due to stemborers are estimated at 20–40% in maize and sorghum in Africa.

Assessing crop losses

Before deciding on the BIPM control measures to be applied, and whether they are worth the anticipated cost, the farmer needs to know at what larval densities grain yield will suffer significant losses and consequently when intervention is needed; this is called the economic injury level (EIL). A mathematical model was developed during

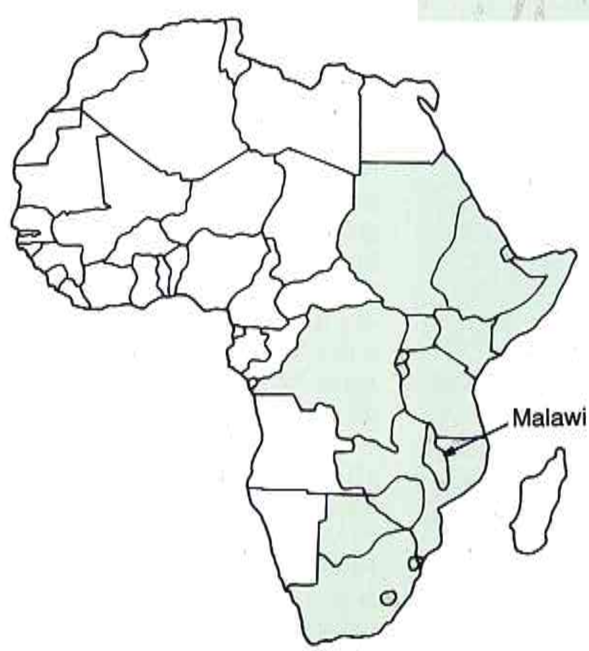
RESEARCH HIGHLIGHTS

1. Two maize populations, four elite sorghum hybrids and three open-pollinated varieties that combine resistance to the spotted stemborer, *Chilo partellus* and good grain yield potential are at the pre-release testing stage in Kenya.
2. Research on developing varieties with multiple resistance to different borers in maize has been launched, while work on developing sorghum genotypes with combined resistance to stemborers and shootfly is being strengthened.
3. Among several new options evaluated as cultural practices for pest management, strip-relay cropping of maize with cowpea was shown to reduce insect pest severity and enhance productivity while allowing more intensive cropping.
4. For effective biocontrol of maize/sorghum stalkborers with the pathogen *Bacillus thuringiensis*, new formulations which can stimulate larval feeding and offer protection from UV inactivation are being developed.
5. An exotic parasitoid, *Cotesia flavipes*, introduced from Pakistan and released in coastal Kenya, has shown good potential for establishment on *Chilo partellus*.
6. Two botanicals, *Azadirachta indica* and *Tephrosia vogelii* have been shown to provide good control of stemborers on maize, the latter also providing some protection from the leafhopper, *Cicadulina* spp., which transmits maize streak virus.
7. Continuous use of inexpensive pseudostem traps for the banana weevil, *Cosmopolites sordidus* was shown to substantially enhance banana yields.
8. Multidisciplinary teams are collaborating with NARES in developing suitable adaptive research methodologies and strategies for farmer-participatory pest management in coastal Kenya.

the year, based on a simple binomial sampling (presence or absence of the damage) method, that relates the proportion of plants infested with the mean larval population density for the whole field and with the projected grain yield. This model will form the basis for a rapid sampling technique for farmers that will allow them to decide if the EIL has been reached by sampling only a few plants in each field.

Using plants' natural resistance

Investigations into the mechanisms by which maize and sorghum resist attack by their major pests, and development and improvement of crop cultivars that combine pest resistance with other desirable attributes, such as high yield, continued in 1993. In maize, consolidating the gains made in 1992, a third cycle of selection was completed in two populations. Selected S_6 lines showed high levels of resistance to different types of damage caused by *C. partellus.* Two of the maize populations developed are at the pre-release stage in Kenya, while work on multiple borer resistance, important in areas where more than one borer species is a threat, is being initiated.



Current known distribution of the spotted stemborer, Chilo partellus, *in Africa. This destructive pest of graminaceous crops was first reported from Malawi in 1932.*

Screening maize genotypes for resistance against *B. fusca* has been done by PESTNET scientists working in Zambia. Of 16 recommended for testing by the national maize breeding team, two were resistant to foliar damage and three to stem tunnelling.

Sorghum improvement and development activities concentrated on improving the level of stemborer resistance in high-yielding and adapted sorghum varieties and hybrids. The work on developing multiple resistance to stemborer and shootfly

Short, early-maturing, high yielding sorghum hybrid HYD-6 developed by ICIPE scientists (150 cm height, average yield of 6.5 t/ha).

(*Atherigona soccata*) continued. Four elite sorghum hybrids and three open pollinated varieties are now in the pre-release stage of evaluation in Kenya. This focus on sorghum, a traditional crop often neglected by researchers, stresses ICIPE's concern for the welfare of subsistence farmers, particularly in marginal areas, who often lack the cash needed to purchase the fertilisers required to bring about high maize yields.

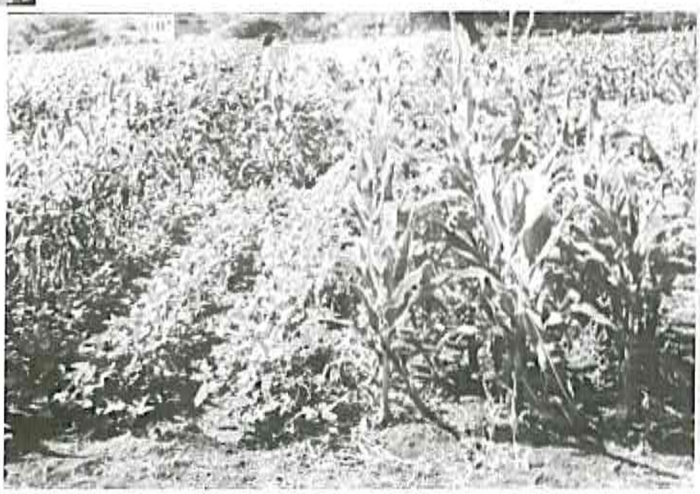
A methodology for eliciting *Busseola fusca* ovipositional response has been developed, using a surrogate stem made of wax paper. Gravid females laid more eggs on the surrogate stems than on susceptible INB-A maize stems. The methodology can facilitate both the mass rearing of *B. fusca*, and bioassays of plant allelochemicals for insect oviposition response.

Stressing the 'culture' in agriculture

Research in cultural approaches to pest management aims at improving crop health by reducing insect pest density and damage through a better understanding and management of cultural practices. Cassava, cowpea, groundnut and beans all proved to be suitable non-host crops in intercropping. The three legumes effectively reduced stemborer attack on maize by 28% compared to the monocrop.

A new cropping pattern alternative, strip-relay intercropping, whereby a cereal is planted simultaneously in strips of 3–4 rows with an earlier-maturing legume followed by a second crop of legume in the same season, was designed by CPRP scientists this year. This system reduces insect pests and increases productivity, while allowing more intensive cropping.

This focus on sorghum, a traditional crop often neglected by researchers, stresses ICIPE's concern for the welfare of subsistence farmers, particularly in marginal areas, who often lack the cash needed to purchase the fertilisers required to bring about high maize yields.



Strip widths of 3 or 4 rows of cereal alternating with similar rows of legumes offer the same insect pest reduction potential as the traditional single alternate row intercrop, but are easier to manage. Shown here are maize variety ICZ-5 (high yielding, pest-resistant) and cowpea variety ICV-2 (aphid-resistant).

The effect of strip relay cropping on the yield of first and second cowpea crops and on land use intensification in coastal Kenya

Cropping System	Maize Yield (kg/ha)	Cowpea Yield (kg /ha)	
		1st Crop	2nd Crop
Maize + cowpea/cowpea (strip relay cropping)[1]	4838	1004	311
Maize + cowpea/cowpea (Single alternate row)[2]	4784	267	58
Maize cowpea relay[3]	4682	0	270
Maize monocrop	4808	0	0

[1]Strip relay cropping in 3:3 row ratios (see text)
[2]Relay intercropping with 1:1 row ratios
[3]Relay planting where cowpea is planted at about 8 weeks after maize

Biocontrol for beating the borers

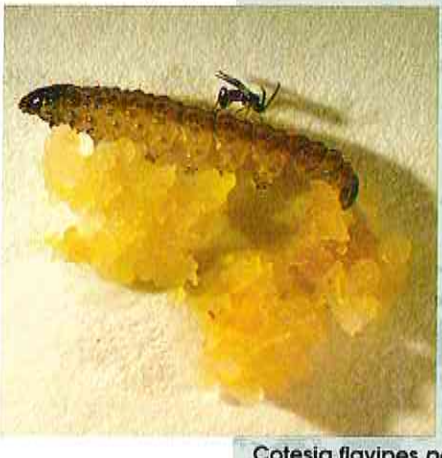
Two major groups of biological control agents, parasitoids and pathogens, have been studied in CPRP for the management of cereal pests.

Pathogens. Use of microbial pesticides, such as bacteria, fungi and viruses, which are pathogenic to insects, is now an established practice in IPM. The formulation and timing of application of the entomopathogenic agent in the field are two of the most important factors which determine the pathogen's effectiveness. Once the emerging stemborer larvae penetrate the stems, they will be protected from any pesticide applications. Field evaluations were carried out on the bacterium *Bacillus thuringiensis* (*Bt*) and the fungus *Metarhizium anisopliae*. Aqueous formulations of *Bt* gave higher levels of protection than granular formulations made from ground sorghum flour and *Bt*. However, since granular formulations are likely to be popular with farmers living in areas lacking a clean water supply for pathogen preparation, or in sites with multiple generations of insects, work on formulating granules is continuing. New formulations of *Bt* with enhancing agents (to stimulate larval feeding) and with UV protectants (to prolong field persistence) are being developed.

The larval feeding of stemborers disrupts translocation in maize plants, thereby decreasing the availability of nutrients and water for grain production. In young plants. Stemborer feeding can cause a condition known as 'dead heart', which results in death of the plant before grain formation.

Parasitoids. A 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. The ICIPE and Wageningen Agricultural University (WAU) in the Netherlands are jointly implementing a project to introduce exotic parasitoids of *C. partellus* into Africa. One promising exotic natural enemy of *C. partellus* is *Cotesia flavipes* (Cameron), a small braconid wasp imported by the project into Kenya in 1991 from Pakistan. *Cotesia flavipes* is a gregarious endoparasitoid that attacks stemborer larvae in the plant stems. The female parasitoid injects about 40 eggs in the host which eclose (hatch) after about 3 days. The emerging parasitoid larvae feed internally for 10–12 days and then exit the host by chewing through its integument.

Sampling of maize, sorghum, and three species of large-stemmed wild grasses revealed that *Chilo partellus* was the most abundant stemborer, and may be displacing the two indigenous stemborers in the coastal region. Field releases of *C. flavipes* were made at three locations on the coast from May to July in 1993. Continued recoveries of *C. flavipes* indicate that the parasitoid population developed through at least 11 generations on its own after release in the field. If recoveries are made during the long rains of 1994, it will be strong evidence that *C. flavipes* has been successfully established in Kenya. Sampling of several wild perennial grasses showed that *Sorghum arundinaceum*, in particular, may serve as a reservoir and favourable site for egg-laying (oviposition) for the stemborers during the dry season, thereby ensuring a steady supply of host larvae for sustaining the parasitoid.



Cotesia flavipes *parasitoids locate suitable hosts by responding to odours emanating from infested plants and stemborer frass (waste products). Once the host is found, the female wasp injects about 40 eggs into the stemborer.*

The role of semiochemicals in host-finding behaviour of *Cotesia* spp. is being studied, and morphological and biochemical studies are being conducted to clarify the taxonomic systematics of three *Cotesia* species that cannot easily be distinguished by their external appearance. In addition to the above, the mating behavior, population genetics, and pheromonal biology of *C. flavipes* are topics for study in the ICIPE-WAU project.

In Zambia, *Busseola fusca* was found to be the most abundant borer species in the Mt. Makulu area. The percentage of borers parasitised by *Cotesia sesamiae* in sorghum were as follows: *B. fusca* (33%), *C. partellus* (10%) and *S. calamistis* (9%). In maize, these were *B. fusca* (25%) and *C. partellus* (20%), showing that *B. fusca* is the most highly parasitised borer, and that sorghum favours a higher parasitism than maize.

Botanical control of stemborers

Resource-limited farmers in developing countries need low cost, non-polluting pest control agents if they are to achieve sustainable management of pests. Natural plant-derived substances (botanicals) can provide a renewable and locally available supply of IPM control agents. One such botanical, already well known for its pest control properties, is neem (*Azadirachta indica*). This tree, which thrives even in marginal zones, is widespread in both Africa and Asia. Although neem is not toxic, it hampers the growth, development, reproduction and fecundity of *C. partellus*.

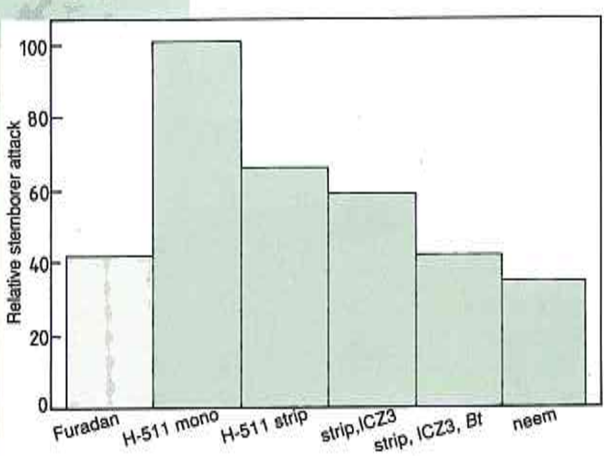
Neem seed powder (NSP), prepared manually by using traditional mortars and pestles, is being tested by CPRP scientists against stemborers, particularly *Chilo partellus*. In field trials, foliar application of a NSP and sawdust mixture significantly reduced foliar damage, stem tunnelling and tassel breakage, and increased plant vigour in both maize and sorghum; it also reduced *Eldana saccharina* infestations. Grain yield in neem-treated maize plots was equal to that obtained with insecticide (Furadan 5G) treatment, and was 1.5 times higher than controls in sorghum.

Grain yield in farmers' *Chilo partellus*-infested sorghum plots treated with neem formulations compares with that from insecticide-treated plots

Treatment (No. of applications)	Grain yield (t/ha) Main tillers	Secondary tillers	Total tillers
Neem powder (1)	2.48	3.15	5.63
Neem powder (2)	2.56	3.49	6.05
Neem extract (1) + neem powder (2)	2.27	3.38	5.65
Dipterex	2.41	3.30	5.71
Untreated (Control)	1.25	2.56	3.81

PESTNET scientists working in Zambia are testing the use of *Tephrosia vogelii* aqueous extracts as botanical insecticides. Field trials this year showed that a 15% w/v extract conferred the best protection against stemborers and the *Cicadulina* spp. leafhoppers which transmit the maize streak virus (MSV), however the disappearance of *Cotesia sesamiae* parasitoids from treated fields indicates this strength of extract was also killing non-target organisms. Work on this aspect is continuing. A simple extraction method, suitable for adoption by small scale farmers has been developed.

Combining three IPM components reduces stemborer attack in maize to levels obtained after insecticide application. H-511:susceptible variety, ICZ3:stemborer-resistant variety, mono:monoculture, strip:strip-cropping, Bt: insect pathogen, neem:botanical agent.



Designing an IPM menu

Farmers' adoption of technology is a step-wise process, in which the farmer eventually selects the technology that best suits his/her socio-economic circumstances. ICIPE has emphasised in the past decade several alternative crop pest management strategies: host plant resistance, cultural practices, biological control, and use of botanicals. How will the farmer make use of these IPM components — singly, on 'a la carte' basis, or 'cafeteria style', by combining the components in different ways? When strip cropping, use of an insect-resistant maize variety, and application of *Bt* and neem were combined, these components were able to protect the crop to the same level as application of the systemic insecticide, carbofuran.

COWPEA

Cowpea (*Vigna unguiculata*) is an important intercrop with cereals in the tropics. The major pests of cowpea include the pod borer (*Maruca testulalis*), the aphid (*Aphis craccivora*) and thrips (*Megalurothrips sjostedti*).

Studies on 14 cultivars of cowpea in 1993 showed that aphid resistance is simply inherited (monogenic) with resistance being dominant to susceptibility. Some morphological traits, such as peduncle colour, determinancy, etc., were found to be loosely associated with aphid resistance, and linkage studies indicated that the genes controlling these traits are in the same linkage group as the aphid resistance gene, *Rac*. This information should therefore enable plant breeders to select aphid-resistant lines based on these morphological traits.

In the Kwale-Kilifi Adaptive Research Project (see below), coastal farmers expressed their preference for growing three pest-tolerant cowpea genotypes in on-farm tests, because of their readily apparent higher grain yield. The three genotypes tested showed a superior performance over local checks in terms of aphid and to some extent, *Maruca* pod borer infestations. Early-planted cowpea suffered from foliar damage due to *Ootheca* beetles but the damage could be minimised by planting in larger areas. 'Early' intercropping of maize with cowpea proved to be an acceptable improvement over the local practice of 'relay' intercropping; the former practice involves simultaneous planting of both crops.

BANANA

Banana-based IPM for the Lake Victoria Basin

Bananas are the primary source of dietary carbohydrate for over 400 million people worldwide. Of the 69 million tonnes global production, about 35% originates in Africa. In eastern Africa, two important banana pests, the banana weevil, *Cosmopolites sordidus* and the root lesion nematode, *Pratylenchus goodeyi* are major constraints to banana production. The former pest can cause yield losses of up to 100% when it tunnels into the rhizome and sometimes the pseudostem, causing it to fall over with its unripe bunch, and as studies conducted by ICIPE in 1993 at the Agricultural Research Institute (ARI) in Maruku, Tanzania show, even low infestations of weevils severely affect the sprouting and establishment of banana corm.

Banana weevils attack the plant's pseudostem producing deadheart and toppling.

Under a BMZ-funded collaborative project, ICIPE has been working to quantify and reduce yield losses in banana from pests, using a non-chemical IPM approach in the Lake Victoria Basin countries. CPRP scientists are developing suitable cultural practices and cropping systems that will ultimately result in higher yields by reducing the weevil and nematode populations.

Intercropping with groundnuts resulted in a decrease in groundnut yield at 3 x 3 m spacings, as compared to 5 x 5 spacings, suggesting that a leguminous intercrop is best planted during early seasons of banana establishment to avoid excessive shading. However, banana yields were higher at the closer spacing because of an increase in the number of bunches per unit area. On the other hand, ICIPE researchers advise caution when selecting a suitable intercrop or when practicing crop rotation in banana-based cropping systems. Sampling of plants in a *P. goodeyi*-infested field showed that sorghum, maize, potatoes, and tomatoes act as hosts to this nematode.

Also implicated as host was the popular agroforestry species *Leucaena leucocephala*, as well as nine herbaceous weeds. A low-cost hot water treatment of banana suckers has been developed which is effective in disinfecting the banana planting material from weevils and nematodes.

Stocking the banana germplasm bank

Dr. A. S. S.. Mbwana outlines the benefits of one of the 176 banana cultivars kept in the ICIPE germplasm bank to Hon. Simeon Nyachae, Minister for Agriculture of Kenya (left), Drs. Seshu Reddy and Prasad look on.

During 1993, another 30 diverse banana cultivars were added to ICIPE's germplasm collection at Ungoye in Western Kenya, making a total of 167 cultivars. Re-classification of the 294 entries held at the ARI in Maruku left 151 taxonomically distinct cultivars being maintained. Of these, 14 have been identified as being resistant to both weevils and nematodes. The cooking types of banana were found to be generally more susceptible to these pests.

Banana-based trapping technology

Cosmopolites sordidus is one insect pest that is especially difficult to control with insecticides. The weevil larvae that do the damage are deep inside the plant tissue, and are therefore inaccessible to spraying. Furthermore, the weevil is unusually long-lived, with an average lifespan of over two years. Therefore, trapping is a more efficient and environmentally benign method of reducing weevil numbers.

Banana pseudostem (the non-woody false stem that supports the leaves) has been shown by ICIPE scientists to emit a blend of volatile compounds, some of which the weevil responds to. Continuous use of a simple trap, made by splitting the pseudostem into two pieces, and laying them at the base of the banana mat in a field of a susceptible cultivar brought about a 42% increase in the number of bunches and a 26% increase in bunch weight over a one-year period.

Socio-economic aspects of banana culture

A socio-economic survey of farms in three areas in Western Kenya showed that although sale of bananas provided about 42% of their income, poor management practices were reflected in high infestations of both weevils and nematodes, resulting in low yields. ICIPE is addressing all of these issues, through its research and technology dissemination activities. As an outreach activity of the BMZ/ICIPE project, distribution of over 2000 clean suckers from a banana nursery in Kenya to 150 farmers in Bukoba District in Tanzania was done in 1993. The farmers had first been familiarised with the technologies developed by the project in a seminar.

ADAPTIVE RESEARCH: IMPLEMENTING TECHNOLOGY DISSEMINATION

Wedding the social and biological sciences

Two ICIPE projects to enhance the methodology and models of interaction among social and biological scientists for effective technology dissemination have been initiated since 1992. For effective dissemination of new technologies, a step-wise adoption process is necessary. At each step, social scientists and biological scientists work together, to ensure that farmer participation and understanding is maximised. Three phases of the dissemination process which ICIPE uses are as follows:

- In the first phase, ICIPE scientists collaborate with scientists from the national network 'on-station' (in this case, the Kenya Agricultural Research Institute [KARI] stations) to test the IPM combinations best suited for local conditions.

- In the second phase, the most successful combinations are taken 'on-farm', to the small holdings of coastal farmers, and tested in partnership with the farmers themselves. Fine tuning of the technologies to local conditions is done at this stage, and comparisons between the farmers' traditional practices and the 'new' technologies can easily be made.

- In the third phase, the farmer herself/himself manages the trial with only occasional advice from the scientists.

The Interactive Socio-Economic Research for IPM Development (ISERIPM) Project

Funded by the Rockefeller Foundation, this project is a collaboration among scientists from CPRP, the Ministry of Agriculture of Kenya, and the Kenya Agricultural Research Institute (KARI) with the ICIPE's Social Science Interface Research Unit (SSIRU) staff. The project is based in the Coast Province of Kenya, and uses three IPM technologies developed at ICIPE's Mbita Point Research Station: improved maize and sorghum genotypes, strip cropping, and use of a biological control agent, *Bt.* A new cropping system, 'strip-relay intercropping', described earlier, was developed to enhance indigenous coastal relay cropping practices. Further studies have demonstrated that cassava, a popular food at the Coast, has the same potential for reducing stemborer attack when used as a companion crop with maize.

In two other studies aimed at manipulating common intercropping systems, the appropriate timing and combinations for relay planting are being examined. Indications are that farmers' current practice of relay cropping cowpea 6–8 weeks after maize has no stemborer reduction potential. Preliminary results with the use of stemborer-resistant maize indicate that three genotypes can serve different categories of farmers provided the farmers can be properly grouped according to their management capabilities. Testing 16 sorghums indicate that the genotypes react differently in different locations; three have been selected for phase 2 of the project.

Evaluating the biological control agent, *Bacillus thuringiensis* on cultivars of maize or sorghum infested with natural populations of stemborers and testing the acceptability of the different formulations by small-scale farmers is another ongoing activity of the ISERIPM project.

The Kwale-Kilifi Adaptive Research Project

Launched in 1992, this UNDP-funded project focuses on farmer-participatory evaluation and adaptation of two of ICIPE's IPM strategies for minimising crop losses due to insect pests in two districts of coastal Kenya. Pest-resistant or pest-tolerant genotypes of maize, cowpea and sorghum, as well as cultural practices such as intercropping, are being tested on-station at KARI and on-farm in 20 small holdings.

Ten farmers participated in on-farm testing of five of ICIPE's most promising maize genotypes, under three fertiliser regimes. The farmers themselves evaluated three of these to be acceptable from their point of view. Qualities that were judged most favourable, in addition to yield and pest resistance, were cob size, early maturity and husk cover.

On-station testing of four resistant/tolerant sorghum genotypes showed a tendency for levels of stalkborer incidence to increase with fertiliser regime level, but with the stalkborer-tolerant entries best withstanding pest attack. The relationships of crop production practices with crop protection are being studied further. In on-farm testing of three promising sorghum genotypes identified last year, two showed 15–30% higher yield potential than the local variety; farmers also evaluated the relative resistance to bird attack favourably.

See also BCERU, IABU, MBRU, BMRU, SSIRU, BTRU and IBIRI sections of this report.

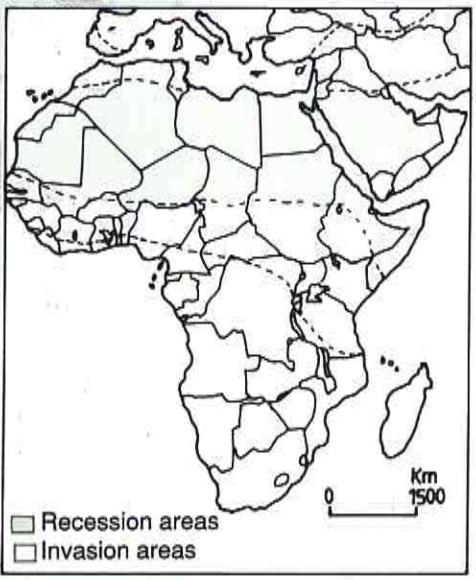
Research in crop pests was funded in 1993 by BMZ, Rockefeller, UNDP and donors to the Core Fund.

LRP

Locusts

Locusts and grasshoppers pose a major threat to agricultural production and food self-sufficiency, especially in Africa and Asia. Locust plagues commonly follow periods of drought, at times when reserves of food and human resources are minimal. Localised crop losses of 100% are possible, and regional losses of 20% are not uncommon. The long-term social and political costs of locust plagues, which can bring financial ruin to the poorest of farmers, are harder to assess.

Distribution of the desert locust, Schistocerca gregaria in Africa and the Middle East.



The solitarious-phase locusts, whose recession zones extend over millions of square kilometres, are compelled by biological and climatic forces to congregate as gregarious-phase forms. The flightless immature hoppers crowd together in marching bands, and the adults in swarms that can fly over 300 km a day. Combating the enormous swarms containing hundreds of millions of individuals with pesticides is expensive, and often not cost-effective. Furthermore, the application of pesticides over such vast areas results in incalculable damage to the environment and to non-target organisms in particular.

The primary objective of ICIPE's Locust Research Programme (LRP) is to develop an environmentally sustainable locust management and control strategy. In 1993, the LRP concentrated its efforts on the desert locust, *Schistocerca gregaria* ; LRP plans to extend its activities to cover other species in future. Of the nine major species of locusts and grasshoppers, the desert locust has the highest potential for agricultural destruction. This single species has the potential to invade 29 million square kilometres, posing a threat to 60 countries in Africa and Asia holding over 10% of the world's population.

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The integrated pest management (IPM) approach to locust control is not an entirely new concept. Here again, the locust makes history. The first use of classical biological control (use of a natural enemy) was recorded from Mauritius in 1792, when the mynah bird was introduced onto that island to control the red locust (*Nomadacris septemfasciata*) Two centuries later, the ICIPE

RESEARCH HIGHLIGHTS

1. **Two distinct desert locust aggregation pheromone systems, one for nymphs and the other for adults, have been identified.**
2. **Identification, characterisation and synthesis of the main components of the aggregation pheromone system of adult locusts have been accomplished. This pheromone appears to have a primer activity of speeding maturation of young adults.**
3. **One of the active components of the mature male pheromone blend is specific and can be used as a marker for this state.**
4. **The nymphal aggregation pheromone system has been discovered to have a primer activity, retarding adult maturation.**
5. **Behavioural bioassays have demonstrated the release of a sex pheromone by mature solitary-reared desert locust females.**
6. **The occurrence of an oviposition aggregation pheromone system inducing group laying by gravid *S. gregaria* females has been demonstrated.**

is using state-of-the-art techniques to discover the keys to locust biochemistry and behaviour which will in turn provide the biorational basis for new control strategies. The target now is to keep the desert locust permanently solitarious by interfering with its gregarisation process. This requires a thorough understanding of the intra- and inter-specific signals modulating behavioural and phase changes in the insect as well as of the ecological conditions evoking such transformations.

Getting in synch

The key to swarm formation is the synchronised behaviour of millions of insects at the same stage of development. Synchronisation must occur at several crucial stages in the life cycle of the locust: moulting, maturation, mating, egg-laying (oviposition). All of these activities appear to be regulated by semiochemicals — chemical messages sent from one organism that produce a response in another. During 1993, major steps have been made in fitting together the pieces of the puzzle of locust synchronous behaviour. Scientists from LRP in collaboration with the Behavioural and Chemical Ecology Research Unit (BCERU) of ICIPE, have made substantial progress in characterising and identifying locust semiochemicals.

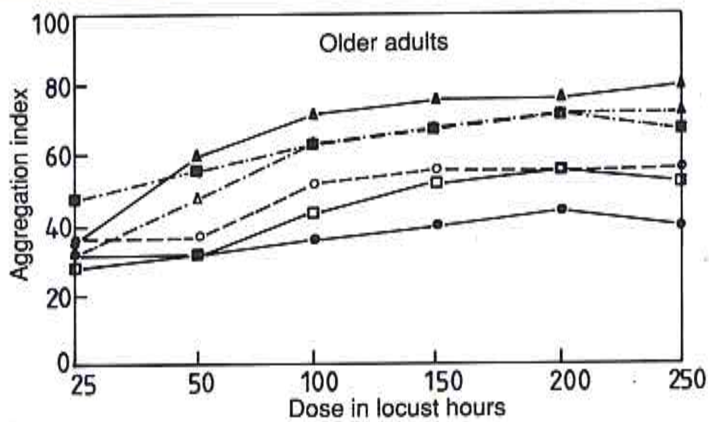
Oviposition. The desert locust hatches from frothy pods of cylindrical eggs laid in moist sand by the gravid females. The egg froth contains volatile substances ('volatiles') which ICIPE scientists have now shown to evoke a response in the antennae of other gravid females, indicating the presence of olfactory receptors for these semiochemicals. Behavioural bioassays show that the volatiles are very potent in stimulating an egg-laying response: 82% of gravid females oviposited when exposed to the volatiles as compared to 18% in response to untreated moist sand. Aggregation and synchronised egg-laying behaviour of females is therefore the result of chemical communication *via* oviposition aggregating pheromones (semiochemicals produced and perceived by members of the same species).

The Red Sea Coast of Sudan is where ICIPE conducts its studies on the ecology of the desert locust. This vast semi-arid recession zone holds the clues to gregarisation behaviour.

Late instar nymphs of the desert locust feeding on Heliotropium *sp., one of their preferred host plants.*

Moulting. After hatching, the hoppers (nymphs) undergo five moults; each successive stage between moults is called an 'instar'. Experiments conducted to study moulting show that synchronisation is low for first instars (38–45% moulting within 24 h), but increases progressively, with 75–92% undergoing synchronous moulting from the 5th instar into the immature adult or fledgling stage.

Maturation. After the last moult, the immature locust adults have developed wings and are able to fly. Last year, ICIPE researchers demonstrated that mature males produce a volatile phermone signal that accelerates the maturation of the immatures. The substances in this signal are emitted about six days earlier by immature males when they are exposed to the mature males than when they are kept alone, confirming the maturation-accelerating effect of the male adults.



Aggregation response of sexually mature desert locust adults to four components of the volatiles emitted by older adult males. (▲= crude volatile blend, ■ = phenylacetonitrile, ○= guaiacol, □ = phenol, ● = benzaldehyde, △ = guaiacol plus phenol).

Mating. Sexual communication in the solitarious desert locust has been studied in two different experiments this year. The volatiles collected from mature virgin females initiated male sexual response, as shown in bioassays. Several compounds eliciting this behaviour have been detected by GC-EAD analysis. Two of these have already been identified as being important in aggregation/cohesion behaviour of gregarious locusts. These are produced in the greatest amount by females 20–28 days after the last moult. The role of acoustic signals emitted by females as a form of sexual communication has been ruled out in another experiment. Males were able to successfully locate females, even when their wings were glued together, supporting the pheromonal method of sexual signalling.

Gregarisation

Outbreaks of gregarious groups follow successful breeding. Population size can increase 10–30 times in each generation. As their numbers increase and they become more crowded, changes in the behaviour and physiology of the insects occur. ICIPE scientists working on gregarisation behaviour have discovered that volatiles emitted by sexually mature males produce an aggregation response in both male and female adults, but not in nymphs. Six electrophysiologically active substances have been identified in the blend, with phenylacetonitrile comprising 75–85% of the volatiles.

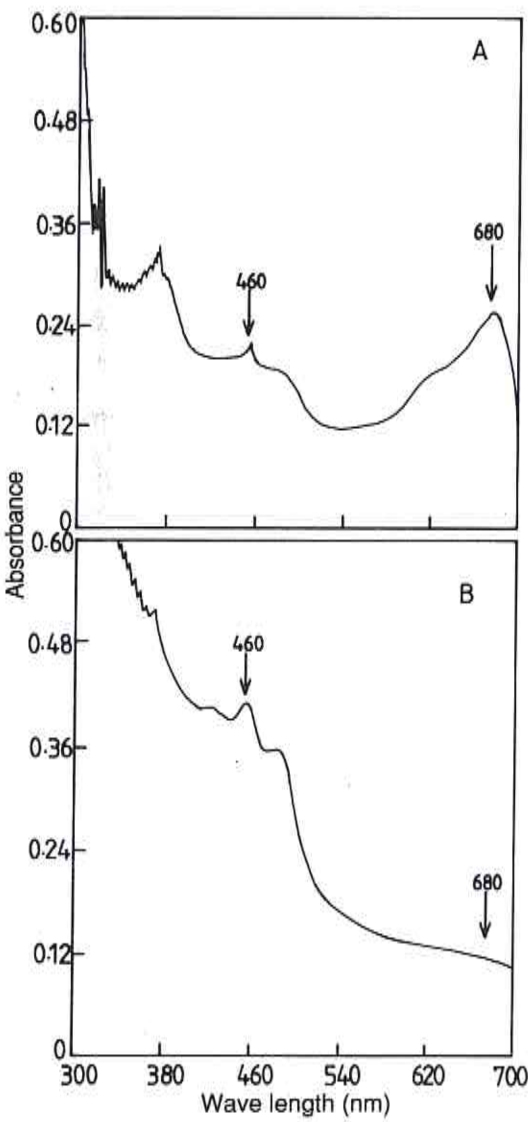
It is now apparent that there is a distinct pheromone system operating in nymphs, and that the juvenile aggregation pheromone is produced by both sexes. Adult insects do not respond to the nymphal pheromone, indicating the presence of one or more components inhibitory to adults. In olfactometric bioassays, nymphs of crowded locusts also responded to volatiles derived from the faeces of young adults, but not to those of sexually mature adults. This suggests that faecal volatiles are part of the aggregation pheromone complex of *Schistocerca gregaria*, which includes the pheromone blends produced by the nymphs and older adults. GC-EAD and GC-MS analysis showed that the predominant components of the volatiles of the faeces of nymphs and young adults are guaiacol and phenol, whereas the faecal volatiles of sexually mature adults contain a third important component, phenylacetonitrile.

Investigations of pheromone production by field populations of the desert locust were conducted at the field base at Port Sudan on the Red Sea Coast. Comparable data were obtained from both field and laboratory-reared locusts. In addition, population dynamics studies were carried out and models to estimate population densities of late instar nymphs and fledgling adults have been developed.

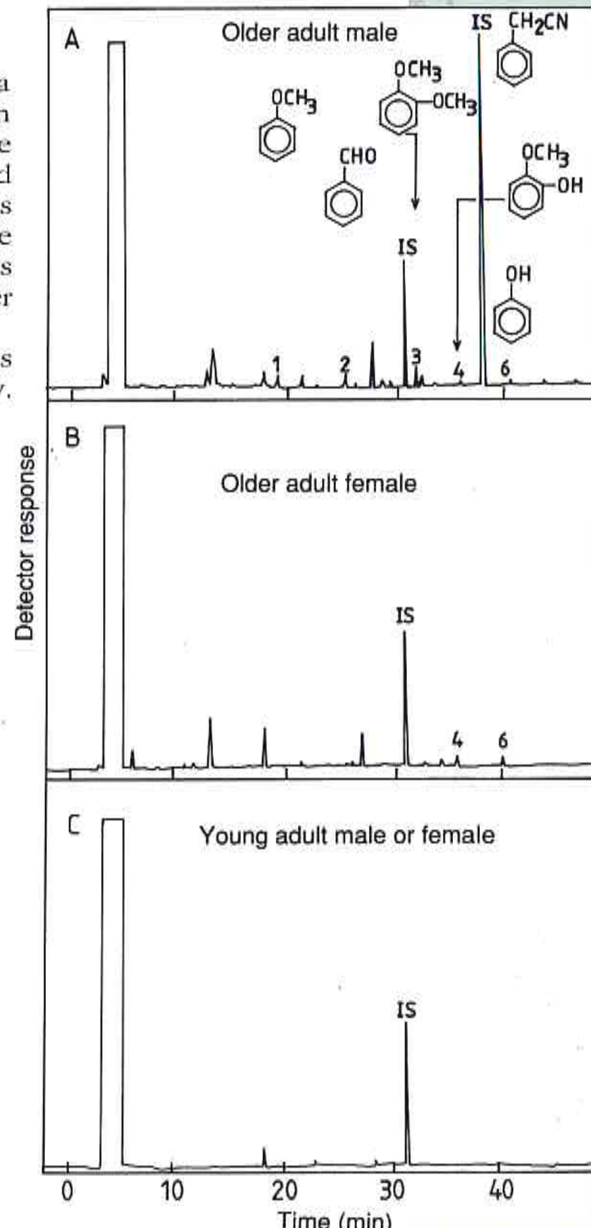
Marking maturation and gregarisation

Gregarisation is a physiological process as well as a behavioural pattern. In order to assess what phase an individual locust is in, a 'marker' can be used. One of the volatiles produced by mature gregarious males and found also in their faeces, appears to be specific for this physiological state. Another tentatively identified volatile appears to be associated with the gregarious state, but its identity and role in the pheromone blend await further investigation.

The colour of the haemolymph of solitarious locusts is greenish whereas that of the gregarious phase is yellow.



The UV-visible spectra of solitary-reared (A) and crowded (B) male locust haemolymph. The presence of an additional component absorbing at 680 nm gives a greenish hue to this fluid of the solitarious insects.



Gas chromatogram of Schistocerca gregaria aggregation pheromone.

Visible absorption spectroscopy has been used to differentiate these colours and an index relating the absorbance values at 460 and 680 nm is being developed to reliably distinguish the solitarious from the gregarious forms. Vitellogenin titres have been correlated with the onset of maturation in adult females.

Locust-host plant relationships

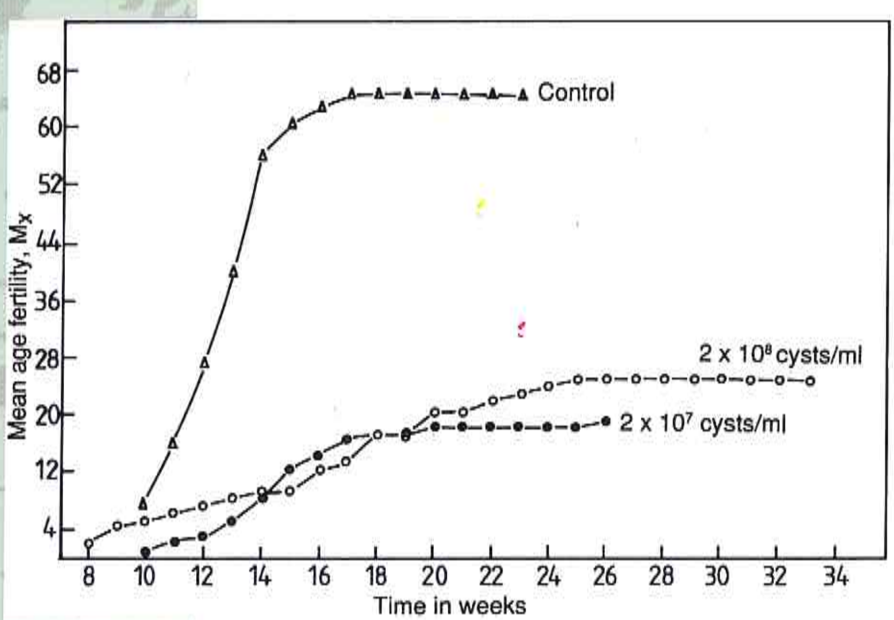
Desert locusts eat a variety of foods, and observations of locust feeding in the Red Sea coastal plain show that locusts prefer annual grasses and forbes to *Panicum turgidum*, which has always been considered an important host plant. Locusts move from grasses to *Panicum* tussocks when the former dry up. The volatiles emitted by host plants contain several groups of compounds to which the insects respond, shown by GC-MS to be mainly acetates, propionates, alcohols and aldehydes. EAG analysis has shown the acetates and/or their corresponding alcohols to be the most stimulatory.

Work is continuing to determine what effect, if any, desert plants have on locust feeding response and gregarisation behaviour. Raising locusts on wheat produced the most fecund and the most solitarious individuals, which developed to the adult stage in a shorter time than when they were raised on kikuyu grass, *Pennisetum cladestenum* or on cabbage. When vegetation dries up, locusts may turn to cannibalism, as field and laboratory tests have shown. This is particularly true of older nymphs and fledgling adults.

Biocontrol of locusts

Locust pathogens are found in natural populations, and probably serve to retard the insect in the wild. The protozoan parasite, *Malamoeba locustae* shows great potential as a biocontrol agent, because of the high mortalities it can inflict (80–85% in 7–9 weeks) and because of its persistence within the population by transovarial transmission from one generation to another. Studies to assess the reproductive potential of locusts infected with *M. locustae* have demonstrated that the pathogen causes a decrease in the maturation, fecundity and longevity of locusts who survive its lethal effects. The precipitin band of vitellogenin, an indicator of reproductive health, decreased in diseased individuals, and ovarian weight and development was retarded. Although egg laying continued in five infected filial generations (F_1 to F_5), the age-specific fertility index (M_x) was considerably lowered, and the survivorship curve showed a gradual decline; this indicates that a chronic infection with the protozoan could act in reducing locust population build-up.

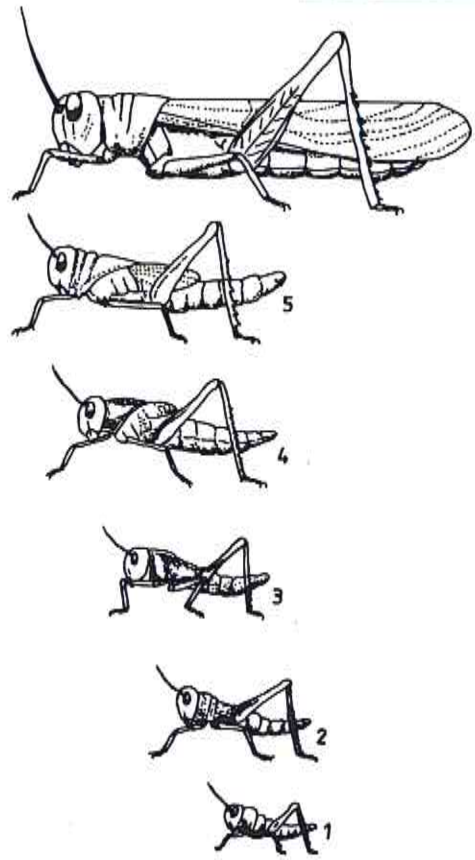
Studies on the defense mechanism of *S. gregaria* to *M. locustae* indicate that phagocytosis, involving type 3 granular haemocytes, is responsible for clearance of the pathogen. The cellular response to infection is associated with humoral factors, such as phenoloxidase and lectin. The lectin showed bands at 80kD and 650kD, and is similar to that isolated from *Locusta migratoria*; antiserum to the lectin inhibits agglutination of *M. locustae* cysts.



A 5–50% reduction of fertility occurred over five generations of locusts when the parents were infected with the protozoan parasite Malamoeba locustae. The pathogen was transferred into succeeding generations via the ovaries of the mothers.

Another entomopathogen, the fungus *Beauveria bassiana* is being studied for its capacity to control the desert locust. Spraying of an oil-formulated suspension on nymphs brought about an LT_{50} of 10 days in the field cage trials. After 20 days, a mortality of 85% was attained with the oil-based spray, and 71% with a simple aqueous suspension. The fungus became less effective at lower humidities, higher temperatures and increased exposure to UV light.

The above two pathogens have an additive effect. Applying both the fungus and the protozoan together brought about a significant decline in the LT_{50} compared to the pathogenic effects of the individual pathogens. Work on improving the efficacy of biocontrol agents is continuing, and a broad-range biocide of protozoan origin is being tested against both *L. migratoria* and *S. gregaria.*



The life stages of the desert locust: five instar hoppers and the adult, all shown 50% of true size.

It is a biophysical attraction

Locusts respond to differences in shapes and colours, and this information can be used in designing monitoring devices, or traps. Locusts show a maximum response to a combination of blue and UV light (see *1992 ICIPE Annual Report*), and prefer vertical or pointed objects in wind tunnel tests. Studies on the effect of light intensity on the orientation of the locusts to radiation indicate that solitarious males are more active at light intensities of less than 100 lux, whereas gregarious males tolerate brighter conditions, and remain active up to 400 lux.

Collaboration and networking

Currently the LRP 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 Ministry of Agriculture, Forestry and Fisheries, Tsukuba, Ibaraki, Japan. The Programme is 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.

Five PhD scholars (two from Egypt, two from Sudan and one from Senegal) are being supported by the Programme, under the ARRPIS training scheme, as part of the networking arrangements between the ICIPE and the locust-affected countries. In addition, there are five other PhD scholars (one from Burkina Faso, two from Kenya and two from Sudan) who are conducting their thesis research on desert locust at ICIPE but are not fully funded by the Programme.

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

See also the BCERU, MBRU and IABU sections of this Report.

The following donors sponsored locust research in 1993: IFAD, SAREC, AFESD and UNDP.

LPRP

Livestock Pests

Livestock play a crucial role in virtually all agricultural systems. Other than producing milk and meat, they provide traction, fuel, hides and manure for crops. They contribute to regional development through their multiple roles as a basis for food security, a means of storing wealth, and an item of trade and barter.

The two major diseases affecting livestock production in Africa are the trypanosomiases (nagana) and the tick-borne diseases (TBDs). These diseases and their arthropod vectors were the targets of ICIPE's Livestock Pests Research Programme (LPRP) once again in 1993.

TSETSE

Masai herdsmen and ICIPE scientists (top left) exchange views about tsetse management strategies in the community-based tsetse control project at Nguruman in south-west Kenya.

The tsetse fly (*Glossina* spp.) is the vector of a disease complex, the trypansomiases, which is unique to Africa. Nagana (animal sleeping sickness) and the human form of the disease are caused by parasites of the *Trypanosoma* genus, which are transmitted by the fly when it bites its host for a blood meal.

The tsetse infests over 10 million km^2 spanning 37 African countries; expansion of the tsetse belt is occurring in some regions, especially those left fallow due to war or civil strife. Tsetse-infested land constitutes about one third of the total area of eastern and southern Africa, with Rwanda and Burundi almost entirely under tsetse threat, and Tanzania and Mozambique over three quarters infested. The disease is most prevalent in the subhumid zone, which has the greatest potential for agricultural development.

The three major intervention methods currently used in the fight against African trypansomiases all have serious disadvantages. For example, the use of drugs against the trypanosome parasites in livestock, either as prophylactics or as therapeutics, is beset by the problems of drug resistance, the high recurrent cost of the drugs and the logistics of delivery. Many of the methods aimed at controlling the population of the *Glossina* vector, e.g., aerial or ground spraying, are too expensive for the poor countries of the South. The introduction of trypanotolerant cattle such as the N'dama of west and central Africa into tsetse-infested areas has not been very successful, due to the severity of the tsetse challenge and to the high pathogenicity of the trypanosomes.

ICIPE's thrust on tsetse research is vector management, through control strategies that are environmentally safe, socially acceptable and within the reach of the resource-poor local community.

A disease as complex as trypanosomiasis is most effectively tackled through an integrated approach, including the combination of environmentally sound land-use, cost-effective vector management, strategic use of trypanocidal drugs and introduction of trypanotolerant breeds where appropriate. The main objective of ICIPE's thrust on tsetse research is vector management, through control strategies that are environmentally safe, socially acceptable and within the reach of the resource-poor local community. In pursuit of this objective, the LPRP has concentrated its efforts this year on studies of the ecology and behaviour of tsetse, on the epidemiology of trypanosomiasis, and on adaptive research which stresses community participation in tsetse control.

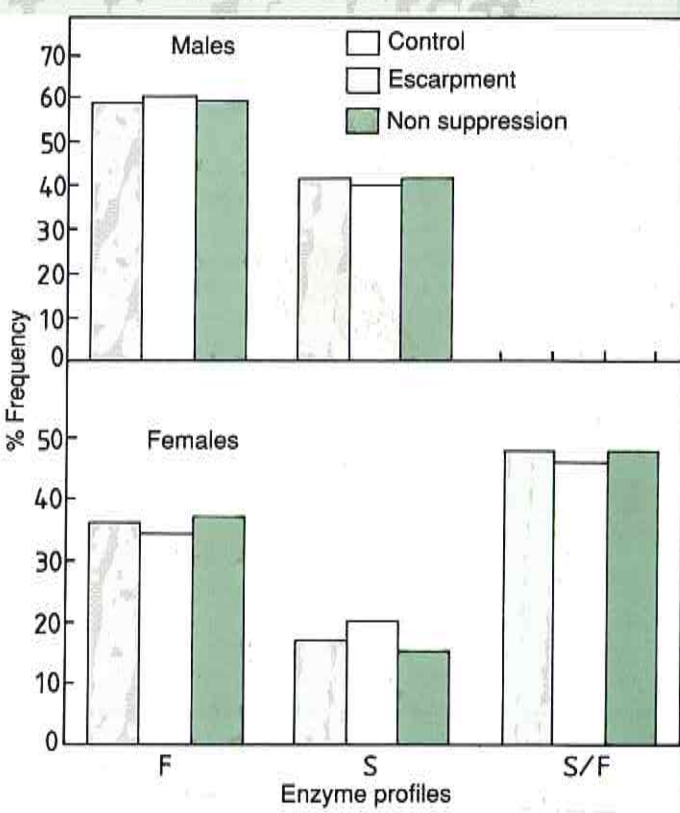
RESEARCH HIGHLIGHTS

1. A method was developed for estimating the daily natural mortality of tsetse. The method is based on the prevailing population of old flies.
2. *Glossina austeni*, a species which has so far not responded well to the existing trap-types, was found to be successfully attracted to a modified version of the pyramidal trap.
3. Host blood from goats, pigs and rats were shown to enhance trypanosome (*T. congolense*) infection, but blood from cattle and other wild bovids suppressed infections in tsetse.
4. Analysis of alleles of the tsetse population showed that although severe drought during the year in Nguruman affected the survival of *G. pallidipes* and consequent populations, there was no evidence that one segment of the population was more vulnerable to the prevailing dry conditions than others.
5. Feeding ticks on cattle immunised with solubilised tick midgut antigens followed by treatment using low doses of ivermectin produced a profound reduction in tick engorgement.
6. The tick parasitoid, *Ixodiphagous hookeri* was successfully introduced into new areas where the parasitoid has not been previously reported.
7. Aqueous suspensions of two entomopathogenic fungi, *Beauveria bassiana* and *Metarhizium anisopliae*, induced heavy tick mortalities under natural field conditions.

Monitoring the link between disease and vector in Nguruman

In 1990, ICIPE began a pilot programme of tsetse suppression in Nguruman in southwestern Kenya. The project employed ICIPE-designed NG2B traps in an area of about 100 km² of the Nguruman escarpment, at a trap density of 2–3 traps/km². Within only 10 months, the population of *Glossina pallidipes* was reduced by 98–99% relative to the area outside the suppression zone. In 1993, the study area was enlarged to cover about 1000 km². The enlarged area offers a bigger challenge in studying tsetse suppression by use of traps, particularly with regard to fly movement. Studies on tsetse movement showed that although flies move widely, they prefer to move from the open woodlands towards the more densely wooded escarpment.

The severe drought in 1993 drastically reduced fly survival and consequently the population densities of *Glossina pallidipes* and *G. longipennis*. In spite of the very high fly mortality observed, there was no evidence that one age group of the population was more vulnerable than another to the dry conditions experienced during the year. However, other climatic factors, especially temperature and humidity, played an



Phenotype frequencies of phosphoglucomutase (PGM) during July–December 1993 among the Glossina pallidipes population in Nguruman suppression zone. Three PGM phenotypes were observed: fast (F), slow (S), and double band (SF). This genetic fingerprinting can be used to help explain the origin of the tsetse in the study area.

Testing of family goats for the presence of trypanosomes at Ole Karamatian and Shompole Group Ranch in Nguruman. Goat blood is an ideal medium for culturing these agents of animal sleeping sickness.

important role in regulating genotype frequencies of the wild fly population. Rare PGI alleles disappeared during suboptimal conditions and reappeared when conditions became more favourable.

Trypanosomiasis was monitored in a sentinel herd kept in the study area. Whereas no parasitologically positive cattle or goats were identified in the latter half of the year when the work was done, immunodiagnosis using antigen ELISA suggested that many animals had trypanosomiasis. There were very few infected flies detected; an average of 1.5% *G. pallidipes* and 2.5% *G. longipennis* were diagnosed to have a trypanosome infection. This would explain why trypanosomes were virtually absent from the herd.

A method was developed for estimating the daily natural mortality of tsetse. The method is based on the prevailing proportion of old flies and is similar to the mean parous method used for mosquitoes. Using this method, the daily mortality rate was found to vary between 2–5% for both male and female flies. Estimation of tsetse mortality due to natural causes and removal by trapping is an important tool in evaluating the feasibility of managing tsetse populations using recently developed trapping technologies.

Designing tsetse traps

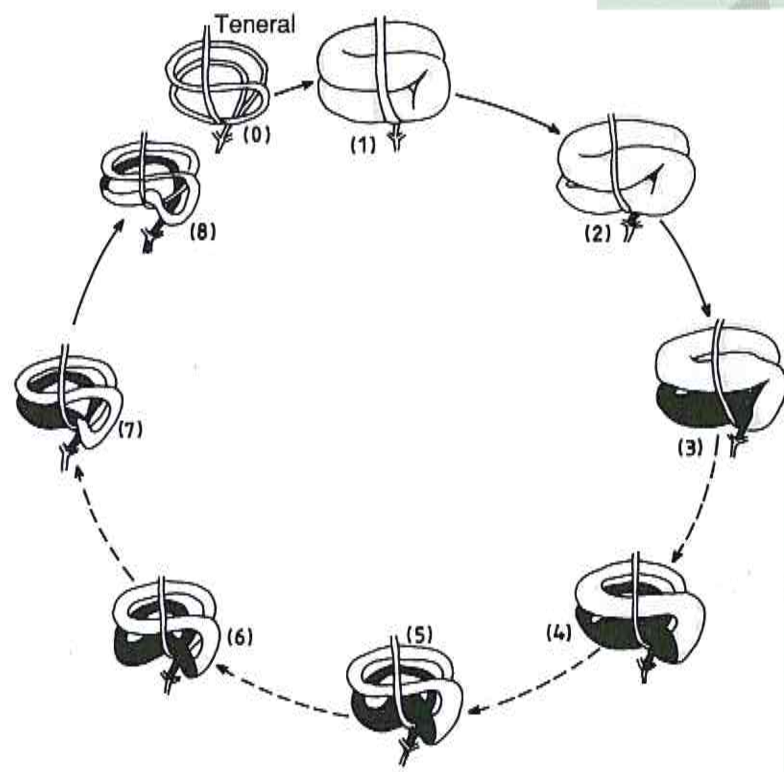
Trapping is an environmentally benign way of reducing tsetse numbers to levels where they no longer pose a serious threat to man or livestock. Tsetse use both visual and olfactory stimuli when locating their hosts. Knowledge of the fly's ecology and behaviour in the vicinity of a potential host can provide clues to effective trap design and to rational placement of traps in the field. Tsetse traps now come in a variety of designs, most of them derived from the shape of a vertebrate host. A given trap design is somewhat species- and sex-specific, exerting its fatal attraction on one species of fly more than others, and luring one sex and hunger state more than another.

Investigations on tsetse behavioural ecology were carried out in order to determine whether the number of entrances can influence the effectiveness of a trap. Three trap types, each with a different number of entrances were compared. Each design caught three species of tsetse, *G. pallidipes*, *G. brevipalpis* and *G. austeni* in descending order of the number of flies caught per

Installing and inspecting the ICIPE NG2B trap in Nguruman. These traps when placed at a density of 2–3 traps/km^2 have effectively lowered the tsetse population in the area to 98–99% of pre-trapping levels. The tin can on the right holds the odour bait of cow urine and another container the acetone bait.

trap. It was noted that the trap with one entrance (the NG2G) caught significantly more tsetse than others of basically the same shape, but with either two (the Siamese) or three (the Oge) entrances. Increasing the number of trap entrances is therefore not a factor in increasing the efficiency of this trap.

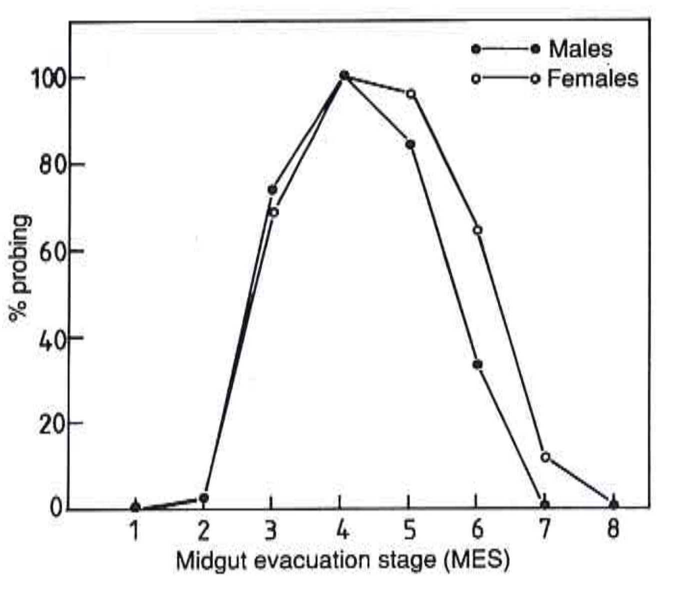
Since each species of tsetse has its preferred hosts, the addition of an odour 'bait' to the trap also acts to discriminate among the particular species attracted to the trap. In recent years, odour attractants (cow urine, acetone, octenol, buffalo urine, etc.) have been used to increase *G. pallidipes* catches with significant success in lowering the incidence of nagana in the trapping zones. *Glossina austeni*, however, is one species which has so far not responded well to existing trap-types and host odours. Studies carried out in 1993 show that the fly responds well to a modified version of the pyramidal trap, and that the fly responds better to host odours if these are carried in dry rather than in humid air. *Glossina austeni* flourishes well in the humid coastal climate of eastern Africa.



Stages in the evacuation of one bloodmeal from the midgut of a tsetse fly. The hunger state of the fly helps determine how actively it searches for food and how easily it can be trapped.

Glossina fuscipes fuscipes is an efficient transmitter of human trypanosomiasis (sleeping sickness). Recent studies have shown that this fly feeds almost exclusively on monitor lizards. Could it be that the presence of monitor lizards dampens the otherwise explosive situation during epidemic outbreaks of sleeping sickness in areas infested by *G.f. fuscipes?* Investigations are in progress to isolate and identify effective host odours from the lizard which can be used in suitable traps to control this species.

The hunger status of flies has an influence on the probing (feeding) behaviour and trappability of *Glossina* spp. Using a model previously devised for *G. pallidipes*, LPRP scientists have demonstrated that *G. longipennis* visiting traps are usually in midgut evacuation stage (MES) 6 to 8, whereas over half the tsetse biting a host animal are in MES 3–5 and the other half in MES 6 and 7. This information suggests that improving the efficiency of a trap to attract



Probing responsiveness of tsetse at various stages of midgut evacuation (shown above). Flies in stages 1 and 2 are evidently not yet hungry enough to search for food. Flies in stages 7 and 8 may be too weak to feed.

flies in the widest range of hunger stages could best be done by exploitation of cues arising from the live host — including olfactory stimuli and visual cues (over 75% of all fly landings occurred on the forelegs alone).

Interrupting the disease cycle

The acquisition of trypanosomes by tsetse is not a straight-forward phenomenon. Tsetse exposed to trypanosome-infected blood do not all acquire infection with the parasite. Infection rates of 2–5% are typical, as ICIPE frequently reports from Nguruman and in the Lambwe Valley, although unusually high rates of 6–16% for *G. pallidipes* and up to 20% for *G. brevipalpis*, mainly from *Trypanosoma congolense* (75%) and *T. vivax* (25%), have recently been observed in the Coast Province of Kenya. *Glossina austeni* was shown to be the most susceptible species in this region (see table).

Monthly trypanosome infection rates in the three species of tsetse (*Glossina pallidipes* spp.) in Shimba Hills, Coast Province Kenya. Although *G. austeni* is the rarest fly, it is particularly susceptible to infection with trypanosomes

	G. pallidipes			*G. brevipalpis*			*G. austeni*		
	N	Inf	% Inf	N	Inf	% inf	N	Inf	% Inf
Mar.	166	11	7	25	2	8	5	4	80
Apr.	102	16	16	29	3	10	13	3	23
May	233	35	15	30	6	20	3	2	67
June	174	19	11	18	1	5	3	0	0
July	142	19	13	11	1	9	4	1	25
Aug.	115	10	9	6	1	16	3	1	33
Sept.	83	9	11	3	0	0	0	0	0
Oct.	133	8	6	1	0	0	3	0	0

N = number of flies dissected; Inf = infected flies

A complex of factors control establishment of the trypanosomes in the fly. Some of these arise from the tsetse itself, some from the host on which the fly has fed, and some from the environment (see *ICIPE 1992 Annual Report*). Identification of these factors may help in disrupting disease transmission. Studies on the role of host blood factors have shown that blood ingested from goats, pigs and rats enhances *T. congolense* infection in most tsetse, but blood from cattle and wild bovids suppresses infection. (In fact, some of these bovids are poor reservoirs of trypanosomes). Addition of both 0.01M cholesterol and 0.06M *N*-acetylglucosamine to goat blood facilitates infection, but can also cause fly mortality. Work on transmission dynamics is continuing and studies on host effects of wildlife species are being planned.

The ecology of biting flies such as *Stomoxys* spp., *Tabanus taeniola* and *Atylotus agrestis*, for their potential role in the mechanical transmission of trypanosomes is under investigation. *Stomoxys* were found to be vectors of some microfilaria, and their role in transmission of livestock parasites such as *Onchocerca* will be assessed. The Vavoua trap baited with octenol has proven effective in catching Stomoxyinae.

In keeping with ICIPE's philosophy of environmental conservation, the main objective of (our) control strategy is presented as reducing tsetse numbers to levels where they no longer pose a serious economic or public health risk, rather than completely eliminating them from the environment.

Community-based tsetse management

Communities that live side-by-side with tsetse experience first-hand the effect of limited agricultural land, sick and underweight livestock, and occasionally risk to themselves of contracting human trypanosomiasis. One such community lives in Nyaboro, on the periphery of Ruma National Park in the Lambwe Valley in the Lake Victoria Basin of Western Kenya. This area (Gwasi location) is a well-known endemic focus of Rhodesian sleeping sickness and the cattle disease nagana. Since the time when *Glossina pallidipes* first invaded the valley 100 years ago, the region has been the site of several tsetse control programmes mounted by external agencies, usually totally divorced from the community of farmers. Not surprisingly, these previous efforts have been unsuccessful in permanently removing the threat of trypanosomiasis.

ICIPE's approach in Gwasi location is to intimately involve an informed community in the control operation. Working together with the Social Science Interface Research Unit (SSIRU) of the Centre, the LPRP is first arming farmers with basic knowledge on the biology and ecology of the fly and the complex cycle of disease transmission. Through training courses and in practical workshops and field demonstrations, the farmers learn about trapping theory and techniques, and construction and placement of traps for both control and tsetse population monitoring purposes. The ICIPE trap is the control technology of choice, due to its relatively low cost and simplicity in operation. In keeping with ICIPE's philosophy of environmental conservation, the main objective of the control strategy is presented as preventing the flies from biting man and domestic animals and reducing tsetse numbers to levels where they no longer pose a serious economic or public health risk, rather than completely eliminating them from the environment.

In order to demonstrate how effective trapping can be, active surveillance of the incidence of trypanosomiasis in man and livestock is being conducted simultaneously with trapping operations in the control area. Baseline data on the pre-trapping density of tsetse and its population characteristics were collected between April–December, 1993. Tests showed that the trypanosomiasis challenge over this period varied from 8–400, and most cattle infections resulted from *T. vivax*. Some parameters investigated, such as male/female ratio, age-grading of males by the wing fray method, and packed cell volme (PCV) of cattle, appear at this point to be less useful data. The lessons learned in this project will be used to devise methods and materials for future use in community-based tsetse control operations elsewhere in Africa.

In a socio-economic survey of the impact of tsetse control operations on crop and animal production in the Lambwe Valley, the following were found to be key indicators ($P = 0.01$) of the impact of tsetse control on land use systems: human settlement; bush clearance; proportion of fallow land and tsetse-infested area; improved animal health and survival; time when animals are brought home to the homestead; increased amount of cropping land; soil erosion.

TICKS

Two species of ticks, the brown ear tick *Rhipicephalus appendiculatus* and the spotted tick, *Amblyomma variegatum* are vectors of protozoan and rickettsial parasites that cause two devastating diseases, East Coast fever (ECF), a form of theileriosis and heartwater. ECF is responsible for the death of over 1.1 million cattle annually in east, central and southern Africa, valued at US$ 168 million. Heartwater occurs in most of the sub-Saharan region, and is the most important tick-borne disease in southern Africa. Ticks inhabit the most favourable agricultural land and probably infest about 90% of Africa's 200 million cattle, causing livestock losses worth billions of dollars.

Tick-borne diseases have conventionally been controlled by acaricides, but these imported chemicals are generally too expensive for poorer countries. Other disadvantages in the chemical approach to livestock ticks management include the environmental debts rung up by acaricides, such as pollution of groundwater sources and contamination of farm personnel, as well as of meat and milk products. In a classic example of the 'pesticide treadmill', underuse or misuse of the chemicals leads ticks to develop a resistance to the acaricides. What is worse, reliance on acaricides makes even naturally resistant breeds of cattle completely susceptible to tick infestation; in case of breakdown of dipping regime for whatever reason, losses in cattle by both tick infestation and disease transmission can be exceedingly high. These constraints to the use of chemicals for controlling livestock ticks have prompted LPRP scientists to look for alternative, environmentally sound technologies to suppress the tick population in pastures below the economic injury level. ICIPE's emphasis this year was again on development of an anti-tick vaccine, supplemented with other components of integrated vector management such as biocontrol agents.

Reliance on acaricides makes even naturally resistant breeds of cattle completely susceptible to tick infestation.

Tick basic biology

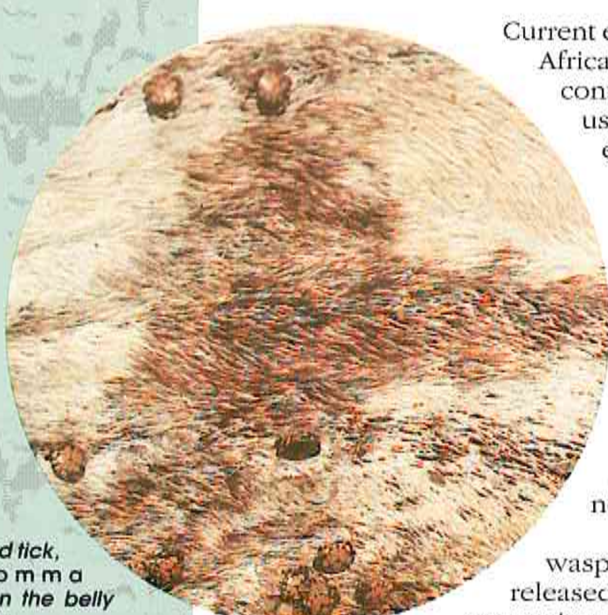
Non-chemical tick control strategies need to be based on firm knowledge of tick behaviour and ecology. Ticks interact with their hosts, their environment and with each other via air-borne chemical signals. Studies of the pheromones emitted in the body volatiles and breath of host animals by ICIPE's Behavioural and Chemical Ecology

Research Unit (BCERU) have demonstrated that ticks are directed to zero in on their favoured target feeding areas (ears for *R. appendiculatus*, anal region for *A. variegatum*) by specific chemical attractants present in the volatiles. Such compounds might be employed as odour baits in custom-designed tick traps. Other possibilities for odour-baited traps could be based on the pheromones that control aggregation, mate location and copulation.


Removing ticks from the king of beasts. Wildlife form an important reservoir for vector-borne livestock diseases, and can themselves succumb to parasitic infections.

One study this year on the population dynamics of ticks looked at the drop-off patterns of the three instars (immature forms) of *R. appendiculatus* and *A. variegatum*. The drop-off of engorged ticks from their hosts is not a random process, but follows a regular pattern that tends to ensure that the tick drops off in an area favourable for its continued development and where it is likely to encounter a new host. Preliminary results indicate that the engorged ticks tend to drop off in the afternoon hours while the animals are still grazing. Work is continuing to assess any seasonal variations in this pattern.

Biological control of ticks


The spotted tick, *Amblyomma gemma* on the belly of a giraffe.

Current estimates put the cost of chemical acaricides consumed in Africa at about US$ 720 million annually. One alternative control strategy to these expensive, imported products is the use of locally produced biological control agents. Two entomopathogenic fungi, *Beauveria bassiana* and *Metarhizium anisopliae* are being tested for their efficacy on ticks. In both laboratory and field tests of ticks feeding on zebu cattle, spray application of aqueous suspensions of the fungi at 10^8 spores/ml drastically reduced egg hatchability to 0–4 %, prevented egg laying in 5–11% of ticks, and reduced fecundity by 80–99% in two experiments. Heavy mortalities of up to 78% followed 1–2 weeks after application of the fungal agents, after the ticks had engorged and dropped off the animals. These approaches offer encouraging possibilities for new alternative tick management strategies in the near future.

Amblyomma variegatum is the host for a tiny parasite wasp, *Ixodiphagus hookeri*. This year, ICIPE acarologists released 30,000 of the parasitoids in each of two regions of Kenya over a six-month period, in an attempt to determine if the wasp could establish itself in a tick-infested region far from its site of origin. Within two months of the final release, 24% of the *A. variegatum* collected at the coast (one site) were found to be parasitised, and 34% in the site in western Kenya. However, there were no recoveries of parasitoids in four of the six months of parasitoid release. Laboratory studies have shown that another tick, *A. spursum*, is a suitable host for the wasp, with a parasitisation rate of 80%. Three other tick species (*A. voaberens, A. gemma, R. appendiculatus*) were not accepted for parasitism.

Effects of the biocontrol fungi *Metarhizium anisopliae* and *Beauveria bassiana* on the brown ear tick, *Rhipicephalus appendiculatus* engorging on zebu cattle

Treatment	Mean mortality %	Mean engorgement (g)	Mean eggs per tick	Decrease in fecundity (%)
Control	21	0.1738	3937	0
M. anisopliae	88	0.1509	774	80
M. bassiana	99	0.1204	106	97

Means from 5 cattle are presented.

Developing a tick vaccine

The high cost of acaricide treatment (ranging anywhere from US$ 2–20 per animal per annum) and the even more expensive curative treatment (US$ 10–20 per animal per treatment for East Coast fever), coupled with generally poor veterinary services, means that the majority of smallholder farmers in Africa have little or no access to treatment of tick-borne diseases. Immunisation of livestock offers a cheaper, safer and more sustainable tick control strategy, and ICIPE over the past decade has been actively participating in the search for an effective tick vaccine. ICIPE's approach in this endeavour is to develop a protein molecule that can be injected as an antigen into cattle; the cattle in turn will produce antibodies to the tick antigen, such that when another tick draws blood from the immunised cow, it will ingest the antibodies which then cause a fatal reaction within the feeding tick.

Previous work at ICIPE has shown that one of the immune effects of solubilised tick gut antigens (SGAs) is the increase in permeability of the host gut wall of the host; this enhances the crossing-over of molecules from the gut lumen into the haemocoel. This characteristic has been exploited to enhance the anti-tick effects of a systemically administered anti-tick compound. In all cases where ticks were first exposed to an immune response in the host animal (induced by immunisation with the SGAs) and then to the anti-tick compound, feeding performance and fecundity were drastically reduced and mortality increased. Two proteins integral to the synergistic immunogens have been purified.

In another study, a purified polypeptide antigen ('antigen B') recognising antibodies from extracts of *R. appendiculatus*, was administered to cattle in an adjuvant carrier system. Ticks fed on these cattle immunised with antigen B showed an increase in mortality, and a decrease in mating, oviposition, egg hatchability, etc. These effects were exacerbated with each successive feeding on immunised animals. A residual effect of the immune response produced by antigen B on the complete development and reproductive potential of ticks from one generation to another was also observed.

Naturally acquired host immunity is important in protecting certain indigenous breeds of cattle against tick-borne diseases. Since ticks and tsetse co-exist over much of Africa a study was mounted to determine what effects an underlying infection with *Trypanosoma congolense* has on host resistance. The results show that the immune response to tick infestation was unaffected, in spite of a high parasitaemia from the protozoan.

See also the BCERU, MBRU, IABU and SSIRU sections of this Report for more information on tsetse and tick research.

Research on livestock pests was funded in 1993 by UNDP (Global), UNDP (Africa Region), EEU, ODA/NRI, and DGIS.

MVRP

Medical Vectors

Insects serve as vectors of several of the world's most devastating diseases. One of ICIPE's original mandates is the promotion of better human health through the control of these medical vectors. Again in 1993, activities in the Medical Vectors Research Programme (MVRP) concentrated on two of the most important vectors and their associated diseases: mosquitoes and sandflies. Through understanding of the behaviour and ecology of these insects, more rational and efficient vector control strategies are being developed.

MOSQUITOES

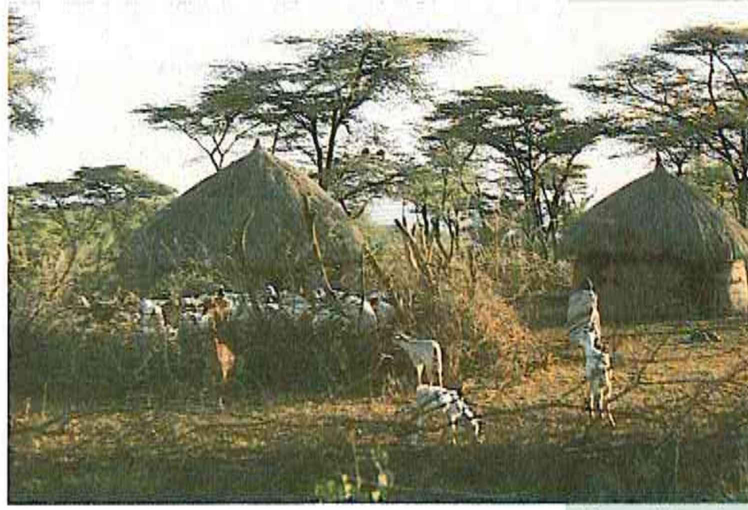
Mosquitoes are the vectors of malaria, the most important parasitic disease afflicting man in the tropics, and several other serious but less prevalent diseases, including yellow fever, dengue, filariasis (elephantiasis) and encephalitis. Over 80% of the population of Africa (about 400 million people) live in areas with little or no malaria control programmes. WHO estimates that about 100 million clinical cases of malaria occur in this region annually, resulting in over 1 million deaths, 90% of these in children. Worldwide, the incidence of malaria is increasing in the 102 affected countries, with global cases now reported anywhere between 200 to 400 million.

Malaria is caused by a protozoan parasite (*Plasmodium* spp.) transferred to man by an infected *Anopheles* mosquito when it obtains its blood meal. The perseverance of malaria, in spite of almost a century of research and control efforts, can be attributed in large part to the increasing resistance of mosquitoes to the larvicidal chemicals used in public health programmes, and to the parasites' resistance to the antimalarial drugs used in therapy. The high cost of chemical control of the vector, especially with the newer and environmentally less harmful pesticides, limits the applicability of this

RESEARCH HIGHLIGHTS

1. **Evaluation of the Mbu Cloth as a simple low-cost technology for control of mosquito and sandfly vectors is continuing. No resistance to the permethrin used has been noticed, and sustained malaria control in the irrigation scheme study site is being maintained.**
2. **Studies show that the Cloth remains effective in killing sandflies for up to 6 months at a permethrin concentration of 0.5 g/m^2.**
3. **Ecological studies of phlebotomine sandflies reveal some relationships between fly population densities and soil chemical and physical characteristics at their breeding sites.**
4. **A DNA probe developed for leishmanial parasite characterisation has proven to be a useful tool for identifying *Leishmania* field isolates.**
5. **The gonotrophic status of female sandflies collected by three different methods has been determined, and the three trap styles shown to give comparable catches.**
6. **The relationship between rice husbandry practices and mosquito population density have been monitored for the purpose of determining the optimum time for use of mosquito biocontrol agents.**

method. ICIPE's two-pronged approach to malaria control has for the past several years centered around (i) the development of a simple technology to control the vector when it lands inside houses, and (ii) the search for effective biological control agents.



Domestic animals frequently serve as reservoirs for parasites that also infect man. In situations where humans and animals live in close proximity, as on this farm in Baringo District in Kenya, control of the insect vectors is often the only feasible method of disease management.

The *Mbu Cloth* for vector control

In 1993 research activities concentrated on evaluation and improvement of the *Mbu Cloth*, developed by MVRP scientists several years ago. The cloth is active against mosquitoes (*mbu* in Kiswahili), sandflies and other insect pests such as cockroaches, fleas, bedbugs and lice. The cloth is hung on the inside walls of houses, and most effectively near sleeping areas, where the volatile substances emitted in human breath and sweat act as attractants to the biting insects. A mosquito landing on the cloth picks up a lethal dose of the insecticide. Indications are that the mosquito and sandfly species in the study area are not yet developing resistance to the permethrin. Experiments are underway to determine the most effective colour for the cloth.

The Mbu Cloth is installed in a rural home in Kenya. The 9-m long cloth gives significant protection to the entire household against mosquitoes and sandflies for up to 6 months before it requires re-treatment. The permethrin insecticide in the cloth is harmless to domestic animals and man.

The Mbu Cloth has been officially recommended for adoption by the Kenya Ministry of Health and by UNICEF for use in the eastern and southern Africa region. These endorsements, as well as by other governments and NGOs, will help ensure the widespread availability of this simple, low-cost technology.

Biological control of mosquitoes

Last year's *ICIPE Annual Report* described the isolation and identification of eight strains of the mosquito-toxic bacteria, *Bacillus thuringiensis israelensis*. In order to determine the optimum time for application of this and other biological control agents, ecological studies of mosquito breeding in the study site in a rice irrigation scheme were undertaken. Results show that the schedule of rice husbandry was more important than rainfall in influencing breeding. The most critical period in the cropping cycle was the flooding of the rice paddies. Another important period occurred when the young seedlings were transplanted into the main paddies; the numerous shallow and sunlit pools formed from the footprints of the workers created extensive habitats conducive to intensive breeding, especially of *Anopheles* species.

The perseverance of malaria, in spite of almost a century of research and control efforts, can be attributed in large part to the increasing resistance of mosquitoes to the larvicidal chemicals used in public health programmes, and to the parasites' resistance to the antimalarial drugs used in therapy.

SANDFLIES

The leishmaniases are a complex of fatal and/or disfiguring diseases caused by protozoa of the *Leishmania* genus. The parasite has only two stages in its life cycle. One stage is spent in the reticuloendothelial cells of a vertebrate host such as man or wild or domestic animals. The other stage must develop in the gut of tiny (3 mm) blood-sucking phlebotomine sandflies.

Once contracted, leishmaniasis is a pernicious and intractable disease. The visceral form, also called kala-azar, requires 30 daily injections of an expensive and toxic antimonial drug for effective therapy; if left untreated, kala-azar is fatal within 6–12 months. The cutaneous and muco-cutaneous forms affect the skin and often lead to permanent facial scaring and disfigurement. These diseases are widespread in the tropics, with over 400,000 new cases recorded each year from the 80 or so affected countries.

Control of the sandfly vectors has in the past met with only limited success because of their widespread and hidden breeding sites (termite mounds and animal burrows are preferred) and their resistance to common insecticides such as DDT and dieldrin. The presence of reservoir hosts that live in close proximity to man may be difficult to restrict and make control of the disease hardly feasible. Goats, dogs, pigs and wild animals such as rodents, lizards, mongoose, etc., all support the parasites that can be transferred to man by the bite of the sandfly.

ICIPE's thrusts in leishmaniasis control are based on the control of the vector using the Mbu Cloth, on studies of the causative parasites, and on understanding the ecology and biology of the flies. The Mbu Cloth (described above) has proven to be an effective technology for sandfly control. Studies have shown that the cloth remains efficacious for 6 months against the flies.

Hungry flies are more easily trapped

The physiological condition of female sandflies is relevant to their vector potential. Sandflies attracted to host animals and baited traps are nearly always in the unfed condition and are not gravid (pregnant). The results of a study comparing three types of traps developed by ICIPE for population monitoring of sandflies shows that the updraft trap, the sticky traps and the CDC trap caught comparable proportions of unfed, fed, semi-gravid and gravid female flies, regardless of where the flies were caught and what species of flies was trapped. Thus, the three trap types can be used interchangeably for assessing fly population characteristics.

Sandflies breed in the soil of earthern floors in traditional houses, in animal burrows and termite mounds, and along river banks. An ecological study to determine the relative abundance of adult phlebotomine sandflies in relation to soil characteristics, from favoured sandfly breeding sites was undertaken in Baringo District, a leishmaniasis-endemic focus in Kenya. The results show that *Sergentomyia* species were positively correlated with organic carbon, potassium and sand during the wet season; during the dry season, they were negatively correlated with pH and positively with magnesium.

Control of the sandfly vectors (of leishmaniasis) has in the past met with only limited success because of their widespread and hidden breeding sites and their resistance to common insecticides.

Characterising the parasites

Knowledge of the species of parasites present in a leishmaniasis focus is essential for effective disease control and treatment. A species-specific DNA probe that can be used to distinguish *Leishmania tropica* from the other species causing the cutaneous form of the disease in Kenya (*L. aethiopica* and *L. major*) has been developed. The DNA probe selected is specific for *L. tropica* and is sensitive to the level of 103 parasites in dot blot hybridisation. In addition, use of OFAGE and TAFE techniques have shown that the profiles of chromosome-dyed DNA molecules varies significantly among the species of *Leishmania*.

See also the MBRU, IABU and SSIRU sections of this Report.

Research on medical vectors was funded by donors to the Core Fund.

Specialist research support units

BCERU

Behavioural and Chemical Ecology

Behavioural and Chemical Ecology Research Unit (BCERU) scientists hold expertise in arthropod ethology, electrophysiology and chemistry. The mandate of the Unit is to undertake research in areas of chemical and behavioural ecology pertinent to ICIPE's target pests. In 1993, BCERU centred its activities on crop borers, the banana weevil, tsetse, the desert locust and ticks. In addition, several botanicals potentially useful for livestock and crop protection were investigated.

Crop borers research — learning to beat the borers

***Chilo partellus*.** During 1993, basic studies directed to the process of developing and optimising a controlled-release dispenser for more widespread use in *C. partellus* monitoring over long distances were undertaken. Last year, BCERU scientists demonstrated that both the major components (*Z*-11-hexadecenal and *Z*-11-hexadecen-1-ol) of the sex pheromone blend of the insect were involved in attracting males of this species in Africa. This year, studies on the periodicity of the female's calling behaviour and the corresponding rates at which she releases the pheromone blend, as well as the ratios of components emitted were initiated. In addition, the kinetics of synthetic pheromone release from different dispensers is being examined.

In areas where mixed populations of crop borers co-exist, results show that both *C. partellus* and *C. orichalcociliellus* are allured to our traps; this suggests a close similarity in the pheromone systems of the two. On the other hand, a pronounced antagonistic effect of *Busseola fusca* pheromone was found on the performance of the pheromone of *C. partellus*, indicating that where these two pests occur together and need to be

RESEARCH HIGHLIGHTS

1. The experimental pheromone dispenser developed for *Chilo partellus* is also an effective bait for *C. orichalocilliellus*. On the other hand, its performance is strongly affected by the pheromone of *Busseola fusca*.
2. A minor monoterpenoid constituent of banana plant varieties susceptible or tolerant to the banana weevil, *Cosmopolites sordidus* is also attractive to the adult stages of the insect. The component is absent in a resistant variety.
3. Plant odours from intact flowering cowpea plants were shown to activate and orientate *Maruca testulalis* moths to the odour source. Identification of active components in the plant is in hand.
4. Sensory responses of the tsetse *Glossina morsitans morsitans* to 13 synthetic analogues of previously identified phenolic kairomones showed high activities with respect to two synthetic compounds. Evaluation of these in the field has started.
5. Progress has been made in locating candidate attractants from tsetse larvae that are active toward gravid females of *G. m. morsitans* and *G. m. centralis*. The major components for each species have been identified and are being evaluated.
6. The locust pheromone complex modulating the cohesive behaviour of 2nd to 5th instar nymphs, young adults and older adults has been defined. The adult pheromone blend, now fully characterised, has also been shown to accelerate the maturation of young adults.
7. Haemolymph UV-absorption of the desert locust at 460 nm and 680 nm due to yellow and blue pigments, respectively, appears to be useful in characterising the phase of the insect. Further studies are in hand to validate this.
8. Detailed studies on the behaviour of two *Rhipicephalus* species of ticks have confirmed the mediation of host-derived semiochemicals in the location of feeding sites.

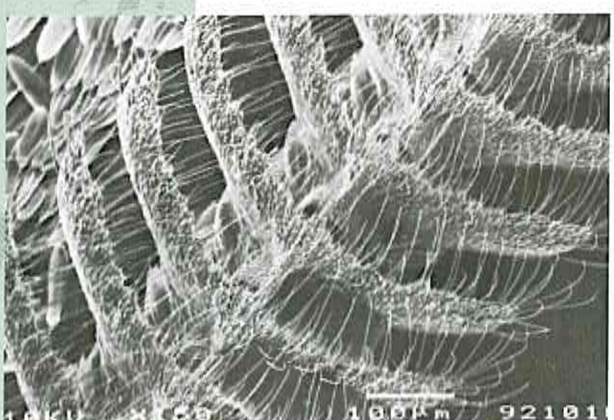
monitored concurrently, special consideration will need to be given on the way the two pheromone traps are deployed. An additional important observation is that in a mixed population of *B. fusca* and *C. partellus*, females of the former appear to avoid laying eggs on plants already infested with *C. partellus* larvae. This suggests an allomonal link between the two borers and an additive effect of their infestations on the final yield loss.

An oviposition deterrent has been isolated from the petroleum ether washings of whorls of 3-week-old sorghum plants of the resistant cultivar, IS 1044. The substance deterred oviposition by *C. partellus* in laboratory bioassays, and a bioassay-guided search for the active component pinpointed methyl-11,14,17-eicosatrienoate as the active factor deterring oviposition.

Banana weevil. Work on several groups of semiochemicals of *Cosmopolites sordidus* continued during the year. GC-EAD studies on the volatiles of eight local banana cultivars revealed the existence of 22 minor compounds showing biological activity. One electrophysiologically active monoterpenoid ether has been identified and shown to be attractive to both males and females of the pest. Interestingly, this component is present in all susceptible and tolerant banana plant varieties, but not in a resistant variety. The identification of other possible attractants is in progress.

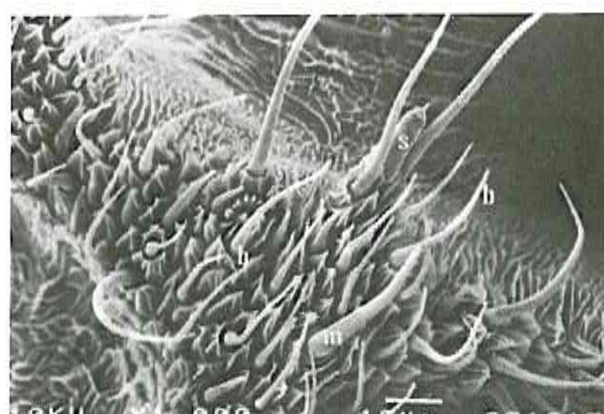
The search for feeding stimulants in the pseudostem was undertaken by a Tanzanian ARPPIS student. Polar extracts were found to be the most stimulatory; the complex blend of polar compounds have now been fractionated by micro-preparative HPLC into seven components. Feeding bioassays have shown that these compounds act together additively or synergistically; no single compound dominates in activity.

The aggregation behaviour of the adult weevil was shown to be associated with a male-produced pheromone. Gas chromatographic (GC) analysis has revealed seven components, of which four give strong electrophysiological responses. GC-MS analysis has suggested that the candidate pheromone components are a group of closely related bi-cyclic ethers.



Micrograph of the antennae of the male stemborer, Busseola fusca, *showing branched segments. x150.*

Busseola fusca. As part of the PhD project of a Nigerian ARPPIS scholar on the sensory perception of semiochemicals of *B. fusca*, the types and distribution of antennal sensilla of the male insects were studied. Five types of sensilla were evident, with some discernible structural differences within each type and a clear sex differentiation in some types. The role of these sensilla in the perception of host odours and pheromones is still unknown.



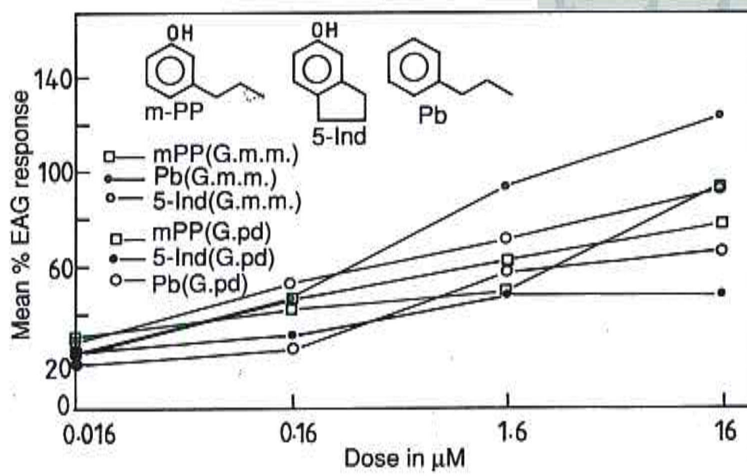
A closer look at the sensilla (sensory cells) on the antennae, which are responsible for picking up odours arising from the host plant and from other B. fusca *individuals. Shown here is the middle portion of a male antennal segment bearing a thermoreceptor or a styloconica sensilla (s), a chemo-mechanoreceptor (m) and several olfactory units of the basiconica (b) type.*

Maruca testulalis. A detailed analysis of the pod borer, *M. testulalis* responses to volatiles collected from intact flowering cowpea plants was undertaken in a wind tunnel by an ARPPIS scholar from Sierra Leone. Activation time of the moths was found to correlate negatively with the concentration of host odours. However, although the moths were strongly attracted to the odours over a wide range of concentrations, they invariably failed to land on the odour source. Thus, although the initial orientation of the insect is mediated by host odours, additional cues may be involved in landing and host plant recognition. GC-EAD of the volatiles revealed that of about 40 components, only 5 evoked strong electroantennal responses. Identification of these compounds is at hand.

Odour baits for tsetse

The Unit's focus on tsetse has been centred around the identification of a broad range of semiochemicals that are attractive to different tsetse species or are potentially useful in attracting specific physiological states of the flies. During the year, BCERU workers experimented with different techniques for trapping air-borne volatiles from the bodies of host animals. A packet containing different adsorbents placed between aluminium foil and fine wire gauzes was devised. These packets were found to be very effective and can be plastered on almost any part of the host body. A study is now underway to compare the relative attractancy of volatiles from host animals preferred by different species of tsetse and to locate and identify the electrophysiologically active components.

The olfactory sensitivity of *G. m. morsitans* to 13 analogues of previously identified phenolic kairomones was investigated. Although the pattern of results shows some resemblance to that of *G. pallidipes* obtained last year, a few significant departures were recorded. Most interesting were the high activities of 5-indanol and propylbenzene. These two constitute lead compounds for further optimisation studies. In the meantime, their effectiveness in the field is being investigated.



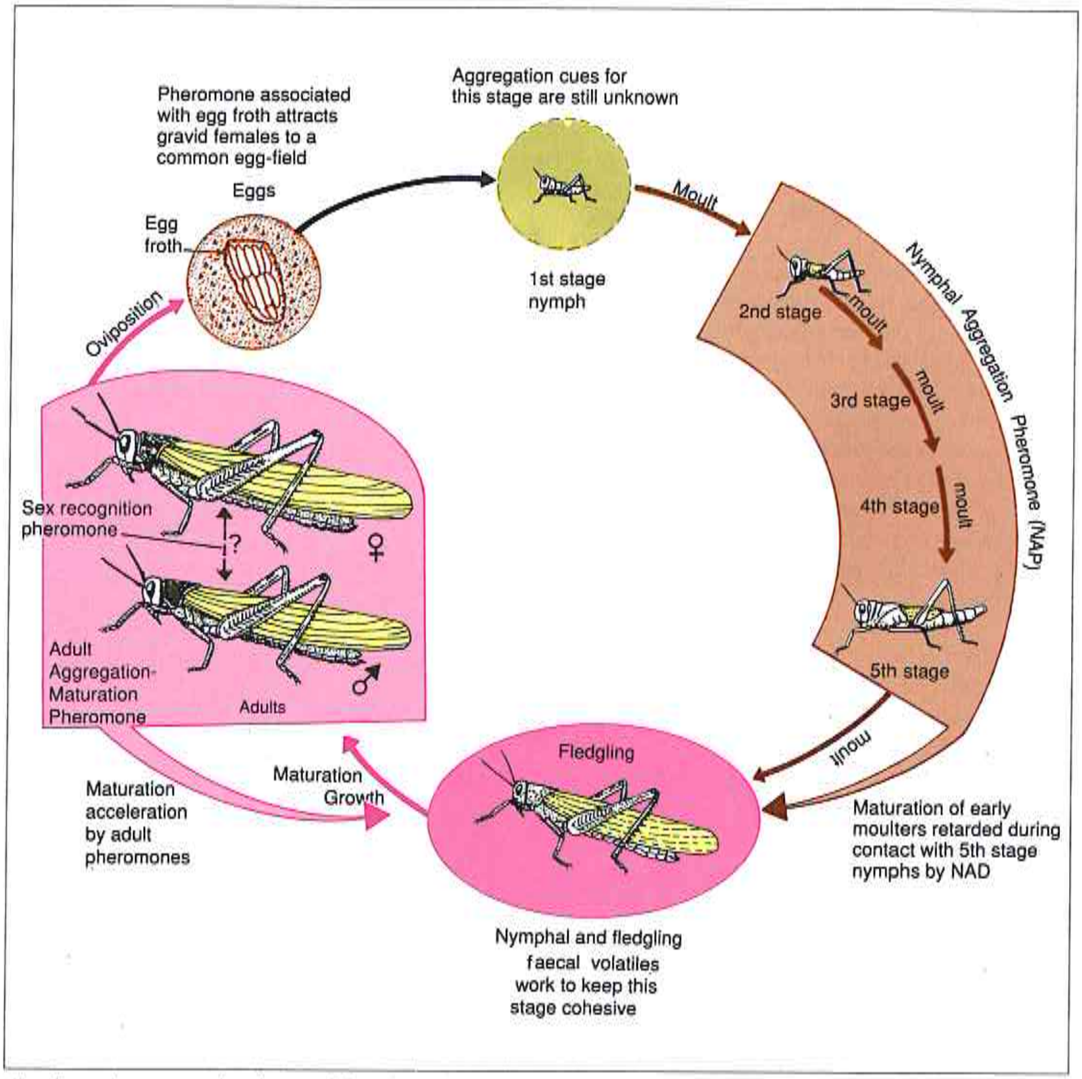
The graph shows the response of two species of tsetse, Glossina morsitans morsitans (G. m. m.) and G. pallidipes (G. p.) to the same three phenolic compounds which could have potential use as odour baits in a tsetse trap. The differential response of the two implies that the baits would be more attractive to one species than another.

Extensive GC-EAD studies of larval volatiles of *G. m. morsitans* and *G. m. centralis* showed, in both cases, one area associated with single prominent EAG-active peaks identified by GC-MS as being C15 and C12 hydrocarbons, respectively for the two insects. Behavioural studies of these putative pheromonal components are underway. Gravid females of *G. m. morsitans* respond to volatiles from the larvae, as well as to 4 -cresol and a number of kairomone analogues. Maximum receptor sensitivity in both species occurred during the time of actual larviposition and prior to ovulation.

Locust semiochemicals control key activities

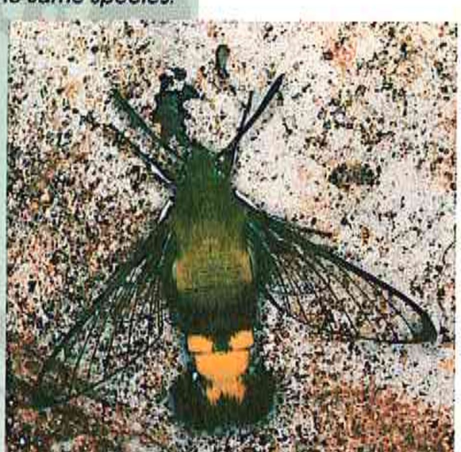
Progress was made in elucidating the identity and role of the pheromone systems involved in modulating key behavioural traits of the gregarious-phase desert locust, *Schistocerca gregaria*: aggregation, maturation and oviposition. Noteworthy insights into locust behaviour provided by BCERU research during the year include the following:

Young adults which do not emit any significant amount of aggregative volatiles of their own respond to volatiles from the faeces of both nymphs and adult insects, although they are indifferent to the volatile emissions of live nymphs. The faecal volatiles of nymphs and young adults are chemically identical, both containing guaiacol and phenol as the major components. The faecal volatiles may function not only to hold the young adults together, but also to do so in close association with the nymphs when these are in the process of fledging (undergoing the final moult into the fledgling stage). This would ensure the



The five pheromonal systems of the desert locust which control aggregation behaviour, necessary for swarm formation. The evidence for a separate system keeping the first instar nymphs together is at present circumstantial.

A moth exhibits her hair pencils, specialised projections protruding from the tail region, which hold sensory cells that collect volatile chemicals that guide the moth to its feeding site and to other moths of the same species.



cohesiveness of the whole fledgling generation that emerges, which would continue to rely on its faecal volatiles until its members start to produce the adult aggregation pheromone. Thus, the aggregation behaviour of the insect is modulated by a pheromone complex made up of not only the nymphal and adult volatiles, but also volatiles emitted by the faeces of nymphs and young adults.

- The volatiles of older adults are composed of phenylacetonitrile, guaiacol, phenol, benzaldehyde, veratrole and anisole as the major electrophysiologically active components. Only the first four, however, are behaviourally active. Phenylacetonitrile comprises about 75–80% of the volatiles and is the most potent aggregant of the adult stages.
- Maturation of young adults is accelerated by essentially the same pheromone blend produced by mature adult males. Thus, the volatile emission of the gregarious adult males plays a parsimonious role, acting as both an aggregant and as a maturation accelerant.

- Nymphal volatiles *inhibit* the maturation of young adults, thus contributing to maturation synchrony by retarding the process in the early fledgers.
- Egg-laying (oviposition) in gregarious-phase locusts is mediated by a volatile signal emitted from the egg froth and probably a close-range or contact polar signal also present in the froth. Two electroantennally active components have been identified in the froth volatiles and are being evaluated in behavioural assays.

As part of BCERU's efforts in identifying phase markers, it was demonstrated this year that a pair of blue and yellow pigments in the insect haemolymph can provide a convenient basis for quick characterisation of the phase of the insect. The ratio of absorptions at 460 and 680 nm has been shown thus far to be very effective in differentiating the phases of laboratory insects. Further observations are underway to validate these findings with insects originating from different populations and fed on different diets.

Tick-related research

Feeding site location. Last year we speculated on the possible mediation of semiochemicals in host location and recognition, and feeding site location by adult *Rhipicephalus appendiculatus*. An ARPPIS PhD scholar from Zaire has recently undertaken a detailed observational study of ticks released on different parts of the host body. Although initially ticks exhibit random searching movements, as they get closer to the feeding site a straight path movement is observed, until the tick is finally arrested at the feeding site. Olfactometric assays have confirmed the mediation of volatile and non-volatile kairomones emitted by the host in this behaviour.

Tick-repelling plants. Last year, BCERU scientists reported on the tick-repellent properties and constituents of *Cleome monophylla* (Capparidaceae). During the year, we examined a related shrub, *Gynandropsis gynandra,* which is traditionally used as a vegetable and in folk medicine. This plant was recently reported to be allomonal to ticks (*ICIPE Annual Report*, 1990, 1991). Twenty-eight (28) constituents of the essential oil of the shrub have been identified by GC-MS. Several of these have shown some degree of repellent action against adult ticks. *Gynandropsis gynandra* has been proposed as a possible anti-tick pasture plant (*ICIPE Annual Report*, 1991).

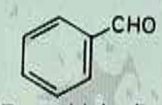
In vitro feeding optimisation. The apparatus for *in vitro* feeding of *R. appendiculatus* was further improved this year by placing the blood chamber above the tick chamber which allows the ticks to attach on the undersurface of the artificial blood-containing membrane. The system allows effective transmission of the parasite *Theileria parva* in both females and males.

Botanicals — building on traditional knowledge

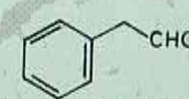
ARPPIS scholars from Tanzania and Ethiopia based in the Unit have been investigating botanicals known from folklore as agents for livestock and crop protection. Three *Ocimum* species (*O. suave, O. kenyenze* and *O. kilimandscharicum*) have been assessed against three storage pests (*Sitophilus zeamais, Rhizopertha dominica* and *Sitotroga cerealella*). Ground *O. kilimandscharicum* and its essential oil were the most toxic, however, *O. suave* oil was the most persistent; its effect could be observed up to 70 days after application. More than 90% of the constituents of the three *Ocimum* plants have been identified and assays are in progress to identify the active components.

See also the CPRP, LRP, LPRP and MBRU sections of this Report.

Research by BCERU scientists was funded in 1993 by EEU and UNDP (tsetse); IFAD, UNDP, SAREC and AFESD (locust); Norwegian Government (banana weevil); and SAREC (Chilo pheromone).

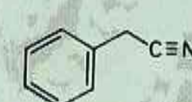


Benzaldehyde

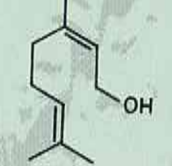


Phenylacetaldehyde

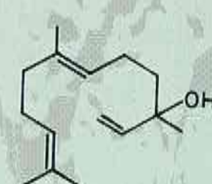

m-cymene



Phenylacetonitrile



Nerol



Nerolidol

A few of the 15 compounds identified from *Gynandropis gynandra* oil which show a repellent action to the tick, *Rhipicephalus appendiculatus* comparable to DEET, a commercial arthropod repellant.

MBRU

Molecular Biology

In its second year of operation, the Molecular Biology Research Unit (MBRU) continues to undertake research in biochemistry and molecular biology pertinent to the broader goals of ICIPE's programmes. The work of the Unit has been streamlined to be directly relevant and supportive to selected research objectives of the programmes, which during the past year, involved collaboration on crop pests research in the area of *Bt* research; on livestock pests (tsetse-trypanosome relationships and development of microsatellite markers); on medical vectors (development of DNA probes for *Leishmania*); and, on locust research (identification of biochemical markers for solitarious and gregarious locusts). In addition, the Unit continues to provide centre-wide services in light microscopy, and scanning and transmission electron microscopy. Additional services are provided in photography and photofinishing.

Tsetse-trypanosome relationships

Transformation of bloodstream trypanosomes into procyclic (midgut) forms is a crucial step in the establishment of a mature infection within the tsetse fly. Consequently, a great deal of effort has been devoted in trying to understand the fly midgut factor(s) that mediate this process. Work carried out in the biochemistry laboratory has resulted in the isolation of a chimeric molecule (trypsin-lectin complex) involved in transformation of bloodstream trypanosomes.

Consumption of a bloodmeal induces the release of several molecules within the tsetse fly midgut, including a group of agglutinins (lectins) and trypsin or trypsin-like enzymes. As reported previously (*ICIPE 1992 Annual Report*), the lectin and trypsin share several similarities, suggesting the occurrence of both activities on the same or on a closely related protein. The protein was isolated from midgut extracts of previously

RESEARCH HIGHLIGHTS

1. A bloodmeal-induced chimeric molecule (trypsin-lectin) important in differentiation of bloodstream trypanosomes into procyclic (midgut) forms has been isolated and partially characterised. Polyclonal antibodies have been used to show the presence of a similar molecule which is found only in several members of *Glossina* species. The possibility that this might explain why tsetse are the only known vectors of trypanosomes is being explored.
2. A method for introducing the DNA virus into tsetse populations in the field is being developed. The method will be used in conjunction with tsetse trapping technology as part of the sterile insect technique (SIT) method of control.
3. Molecular karyotyping has revealed a striking polymorphism among *Leishmania* species. This karyotyping approach should provide useful information for studies on the taxonomy and epidemiology of leishmaniasis.
4. A genomic library of *Glossina pallidipes* is under construction, and screening for simple sequence repeats done, with the ultimate aim of identifying the genes responsible for important biological traits in tsetse relative to their trappability and capacity as disease vectors.
5. A haemolysin from the midgut of tsetse has been isolated and partially characterised. Its assessment as an anti-tick vaccine component is underway.

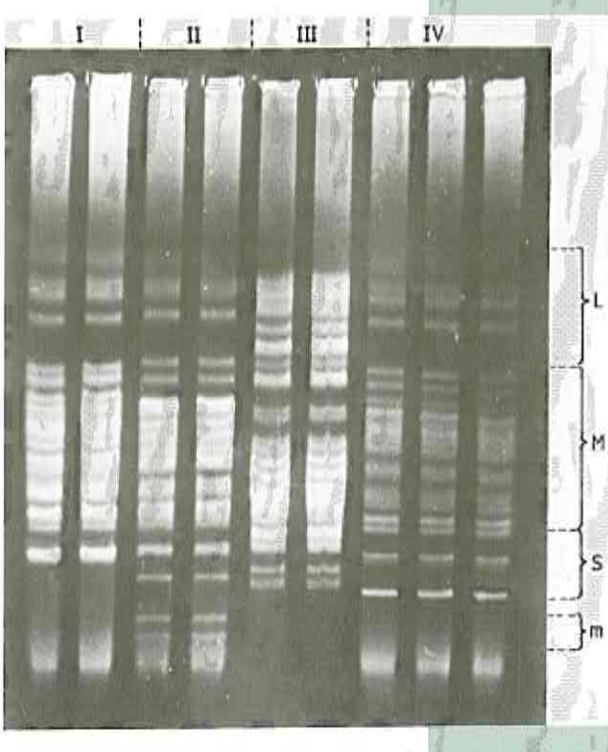
fed *Glossina longipennis* by anion-exchange (Mono Q) and fast protein liquid chromatography (FPLC). Trypsin activity was detected in both the unbound and bound fractions while agglutination activity was found only in the bound fractions, where it is co-eluted with trypsin activity. When the bound fractions with agglutinating activities were rechromatographed on the same column, a single protein peak resulted with molecular weight (M_r) of about 61,000. This band gave two closely migrating non-covalently linked subunits, the larger of which ($M_r \sim 33{,}000$) showed trypsin activity.

The results show that the molecule involved in trypanosome differentiation is a lectin-trypsin complex. Consequently, inhibitors of lectin activity (glucosamine) or trypsin activity (soybean trypsin inhibitor) can interfere with parasite differentiation. Work to define the precise structure of this molecule is currently in progress.

Leishmania chromosomes vary in size and number

Research on the development of DNA probes for the identification of *Leishmania* parasites, the causative agents of leishmaniasis, continued in 1993. In addition, pulsed field gradient electrophoresis was used to study relationships between different *Leishmania* species and between isolates of the same species from widely separated geographical areas. Applying transverse alternating field electrophoresis (TAFE) and orthogonal field alternation gel electrophoresis (OFAGE) to the reference strains of *Leishmania donovani* IC-245, NLB-065, NLB-061 and NLB-325, we found that the four *L. donovani* reference strains exhibited a striking polymorphism. Differences were noticeable in terms of variation in sizes and intensity of chromosomal bands and in the number of chromosomes. Studies have also shown that *Leishmania* species have a distinctive molecular karyotype when their chromosomes are size-fractionated by pulsed field gradient electrophoresis methods. This karyotyping approach should provide useful additional information for studies on the taxonomy and epidemiology of leishmaniasis.

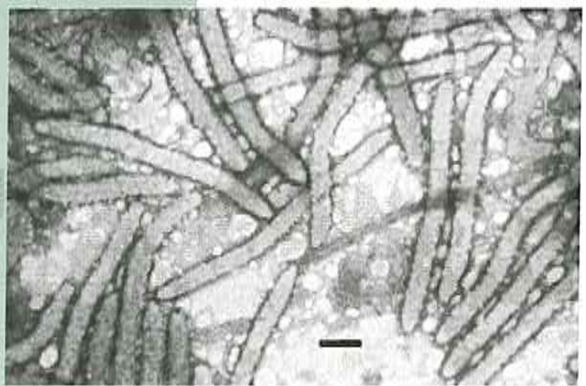
Pulsed field gel electrophoresis reveals differences in the chromosomes (karyotypes) of four* Leishmania donovani *reference strains. Photograph of an ethidium bromide-stained gel. (I) strain NLB-061; (II) NLB-065; (III) IC-245; (IV) NLB-325. L = large-size chromosome; M = medium size chromosome; S = small size chromosome and m = minichromosome. Such differences help in identifying the origin of the parasite infection.



A virus to control tsetse

Previous studies have shown that *Glossina pallidipes* infected with the tsetse DNA virus become sterile and that the testes of such flies manifest severe necrotic lesions and absence of spermatozoa. This virus might therefore be useful as a biological control agent in tsetse control operations as a form of the SIT (sterile insect technique).

Studies on the effects of infection of tsetse with the DNA virus on feeding, longevity, duration of pregnancy cycle, mean pupal weights and male accessory reproductive gland function have revealed that these physiological parameters are severely affected. Infected tsetse probe many more times than normal flies before settling to feed; they are not able to digest the bloodmeal and live for a significantly shorter time than their normal counterparts. Female pregnancy cycles become much longer and pupae from infected females are significantly lighter in weight. Infected males of *G. morsitans centralis* generally fail to form spermatophores, hence the severe reduction in their inseminating potential. Only 1.6% of infected males were able to inseminate their mates, compared to 98% of the uninfected controls. Further studies will confirm how the virus affects the cells of the accessory reproductive glands, although first suggestions are



Transmission electronmicrograph of semi-purified, negatively stained rods of the male sterilising tsetse DNA virus recovered from salivary gland material. (x112,500)

that the virus interferes with the formation of gland secretions necessary for the formation of the spermatophore (the sperm sac transferred into the female fly during copulation).

Field-oriented research is currently concentrating on developing a method, appropriate for use with the tsetse trap technology, for introducing the DNA virus directly into wild populations of the flies. Such methods would be ideal because they would circumvent the need to rear large numbers of different sterile *Glossina* species, some of which are extremely difficult to rear in the laboratory. Field infection would also significantly reduce the costs of the application.

Mapping the tsetse genome

While a complete genetic map exists for *Drosophila* spp. (fruit flies) and *Anopheles gambiae*, an important vector of malaria, very little is known about the genome of other medically important disease vectors, including *Glossina* species. Knowledge about the linkages of genes that render tsetse fly populations vulnerable to control strategies, and those that interrupt the transmission of the trypanosome parasites from the fly to its vertebrate host is prerequisite to manipulating the genetic makeup of the flies. For instance, mapping genes that mediate olfaction would contribute to understanding why fly populations in the wild respond differently to odour-baited traps. Other important genes to investigate are those controlling insecticide resistance, vectorial capacity, and genes that produce a trypanocidal effect.

One current project in MBRU is to develop genetic molecular markers (DNA markers) that pinpoint variations in the DNA of different fly species and among individual flies. Microsatellite markers will be isolated, using RAPD and primers (see *1992 ICIPE Annual Report*). In 1993, work has been done on the construction of a *Glossina pallidipes* genomic library and screening for simple sequence repeats, using $(GT)_{15}$ and $(TAAA)_6$ probes. Sequencing of the positives clones and preparation of polymorphic markers is currently in progress. This will supplement the plasmid genomic library of *G. morsitans morsitans* constructed last year.

Causing indigestion in ticks

Bloodmeal digestion plays a central role in the life of a tick, since important processes such as moulting, mating and vitellogenesis are preceded by a bloodmeal. Red cell breakdown (haemolysis) is a prerequisite for digestion, because the process releases haemoglobin, the major blood protein, thus facilitating its attack by proteolytic digestive systems. Consequently, it may be possible to interfere with tick digestion and related physiological processes by the vaccination of animals with purified midgut haemolysin.

In line with this hypothesis, the isolation and characterisation of the midgut haemolysin of the brown ear tick, *Rhipicephalus appendiculatis* has been initiated. Once purified, the haemolysin will be assessed for its potential as an anti-tick vaccine component. Our results to date show that the *R. appendiculatis* midgut haemolysin is a $M_r \sim 500{,}000$ glycoprotein, showing endpoint inhibition, and that its activity is positively modulated by EDTA. Furthermore, the haemolysin shows sigmoidal kinetics, indicating that there may be several other components involved in haemolysis. As in many other haematophagus arthropods, the midgut haemolysin is not detectable in unfed ticks, but its activity is stimulated by a bloodmeal, and increases during the growth phase of tick digestion.

See also the LPRP, MVRP and BCERU sections of this report.

MBRU research this year was supported by the EEU, UNDP (Africa region), USAID, OPEC Fund and donors to the Core Fund.

BTRU

Biotechnology Research

The primary task of the Biotechnology Research Unit (BTRU) is to perform insect-related biotechnology research in collaboration with relevant programmes and units in the Centre. During 1993, the Unit concentrated on optimising fermentation conditions for production of *Bacillus thuringiensis* (*Bt*)-based pesticides and on the massive field application of *Bt* serotype H1 ('Dudustop') for control of houseflies in refugee camps in Kenya.

Bt-based biopesticides

Bt is one of a group of bacteria that are toxic to insects. The bacterium produces toxins which cause disruption of the insect midgut, eventually leading to death. In the area of research and development of *Bt*-based biopesticides, the following activities are being undertaken:

- isolation and identification of insecticidal *Bt* strains and evaluation of their pathogenicity to target pest insects
- evaluation of biosafety aspects
- quality control of strains and toxins
- study of persistence in the field
- production of optimal formulations of the bioinsecticides, including incorporation of UV screens
- development of modes of application

***Tsetse-specific* Bt.** The Unit continues to evaluate the potential of the *Bt* tsetse-specific bacteria as a biological control agent in collaboration with the Livestock Pests Research Programme (LPRP). Some promising persistent formulations have been developed. The BTRU is undertaking the serotyping and characterisation of the *Bt* in collaboration with the Forest Research and Development Foundation (FRDF) of Quebec, Canada.

Optimising fermentation conditions. Production of *Bt*-based pesticides continues in the Biostat R^E 15-litre fermentor, both for in-house work and for the Crop Pests Research Programme (CPRP) of ICIPE. A research project aimed at determining the conditions for producing optimal yields of *Bt* H1 as a biological pest control agent is being conducted in collaboration with the Department of Applied Chemistry and Microbiology of the University of Helsinki, Finland. Conditions for production of 10^9 cells/ml or 10^9 spores/ml within 20 h have been established. The bacteria are grown on a medium of low-cost, locally available materials, including soybean, molasses and phosphates.

Developing effective formulations. Since *Bt* is sensitive to ultraviolet light, there is need for incorporation of simple and cheap broad-spectrum ultraviolet protectants in *Bt* formulations if the pathogen is to retain its activity for long periods of time. An active dry yeast matrix system can be used successfully to encapsulate *Bt* var *kurstaki* to maintain its biological activity.

OPTIMAL PRODUCTION OF *BT* SEROTYPE H1

In 1993, the Unit established the conditions for production of *Bt* serotype H1 (fly factor). The parameters identified are pH, temperature, aeration and agitation. The established conditions can be used to produce maximal quantities of spores in a fermentor within 20 hours. This improvement in process development is being considered for registration as a Utility Model by the Kenya Industrial Properties Office (KIPO).

Formulations of *Bt* spores and crystals, encapsulated together within a yeast extract containing either Orzan (lignosulphonate) ultraviolet screen or Coax (a feeding stimulant) showed moderate spore viability and retained at least 50% of their toxicity

ICIPE scientists test the run-off from garbage in the densely populated community of Kibera in Nairobi for the presence of fly larvae. Bt is being tested as a microbial biocontrol agent for control of disease-spreading filthflies in this village.

30 and 14 h, respectively, after exposure to an ultraviolet source.

In most developing countries, long-term storability at room temperature will be an important property of *Bt* formulations. The fermentation broth produced by BTRU has been treated with a number of preservatives, of which sodium chloride and propionic acid appear to be the most promising. The shelf-life studies are continuing.

Field testing of *Bt* for control of filthflies

Bt serotype H1 is effective in controlling filthflies that breed in toilets, garbage and effluents. In 1992, a project to treat toilets of the deep pit latrine type was initiated in refugee camps in Kenya and in a low-income, high-density residential area in Nairobi. This was done in collaboration with the University of Helsinki, the United Nations High Commissioner for Refugees (UNHCR), CARE International, Lutheran World Federation (LWF), the International Committee of the Red Cross (ICRC) and ApproTECH, a local non-governmental organisation, among others. By the end of 1993, over 3200 toilets in Ifo Camp, Dadaab in northeastern Kenya had been treated with the ICIPE formulation of *Bt*, 'Dudustop'.

Previous studies have shown that *Bt* has a long-lasting control effect on fly larvae, due to the growth of the bacterium in the excreta or filth and production of the toxin, thuringiensin. However, for cost-effective fly control, more specific data about the duration of the toxic effects of the treatments and the initial concentration of the bacterium required are needed. Accordingly, tests were initiated in July, 1993 to assess the foregoing. A centrifuged paste of *Bt* was used, produced at the Technical Research Centre of Finland in a 2 m^3 (working volume 1200 litres) fermentor. The paste preparation was diluted with water to 1:10, 1:20, 1:50 and 1:100 concentrations. Five months after the start of the trials, all the concentrations used remained effective in controlling flies. The initial concentration of the bacterial preparation is therefore not significant for the concentrations tested.

The ICIPE Pathogen Bank

The Unit continues to carry out quality control of all the micro-organisms in the ICIPE Pathogen Bank, which is in the custody of BTRU. To date, there are over 200 isolates in the Bank. Most of the organisms are stored in glycerol at 4°C. The organisms are still viable after 2–3 years of storage. The Unit hopes to acquire a lyophiliser to freeze-dry the samples for longer storage periods. Work on isolating and screening more potent isolates from the local environment continues in collaboration with the Molecular Biology Research Unit (MBRU) of ICIPE.

See also the CPRP, LPRP and MBRU sections of this Report.

Work in BTRU was funded in 1993 by the following donors: Academy of Finland, EEU and donors to the Core Fund.

Application of the Bt formulation to a pit latrine toilet in Kibera, Nairobi. The preparation remains active for up to 6 months, after which re-treatment is necessary.

BMRU

Biomathematics Research

The increasing awareness among scientists and graduate students at ICIPE of the need for biomathematical input into all scientific work has considerably increased the workload and scope of activities of the Biomathematics Research Unit (BMRU). The Unit assists the Centre by providing consultancies through modelling and Geographic Information Systems (GIS), biostatistics, computing and training. In addition, the Unit undertakes original research in modelling, and in biostatistics.

Specialist services offered by BMRU

Biostatistics. Biostatistical services in the design of experiments, analysis of data and assistance with interpretation of results is an important function of the Unit. ARPPIS PhD scholars continue to take up an increasing proportion of time spent on data management and analysis. The Unit actively collaborates with national institutions in biostatistical work.

Geographical Information Systems (GIS). GIS services were in higher demand during the year due to increasing awareness of the usefulness of GIS models. Most new projects now include some measure of GIS activities. In the ISERIPM project (Interactive Socio-Economic Research for Biointensive Pest Management), these concentrated on the acquisition and mapping of socio-economic data necessary for characterisation of villages in the Kwale and Kilifi districts of Coast Province, Kenya. This will aid in the selection of study sites, in combination with climatic and soil data for the two districts. Through this project, the Unit acquired a Global Positioning Systems (GPS) receiver which is expected to play a key role in future GIS activities.

For the community-based tsetse control project in the Livestock Pests Research Programme (LPRP), a map of Nguruman was prepared showing vegetation cover, roads, rivers and tsetse trap locations. The project area has been extended to the border with Tanzania, and this new area will be incorporated into the GIS database early in 1994.

Contact and collaboration with the Regional Centre for Services in Surveying, Mapping and Remote Sensing (RCSSMRS), United Nations Environment Programme (UNEP), International Livestock Research on Animal Diseases (ILRAD), Kenya Agricultural Research Institute (KARI) and Kenya Meteorological Department (KMD) were maintained during the year for the acquisition of information and use of needed equipment which were not available at the Centre. Collaboration with Purdue University in the USA on the use of GIS has also been initiated.

Computing. The acquisition of eight new computers and three laserjet printers in 1993 further strengthened the computing power of the Centre. In addition, four automatic remote weather stations were installed or re-installed at various field stations of ICIPE during the year, enhancing the collection of weather data essential for the research work at ICIPE. Slide and graphic production, as well as other software services have been on the increase during the year.

Training. Staff training in the use of statistical, word processing, data management and graphics softwares were conducted during the year, both at the headquarters (Duduville) and at the Coast Station (Mombasa). ARPPIS teaching in biostatistics and computing were also undertaken by the Unit.

Project staff of the Kwale/Kilifi Adaptive Research Project at a training course on the use of software for data management and graphics. Participants are drawn mainly from the KARI, who collaborate with ICIPE on this project.

Evaluating non-precision in field scores

Several methods have been developed for quantifying the non-precision in field scores this year. Visual assessments are usually carried out on experimental plots of crops with different treatments in order to determine the level of some factor, such as disease or pest infestation and damage, which are scored for incidence or severity using a pre-determined range of scores. Non-precision in the scores arises as a result of human judgmental error and inconsistency and from the inter-dependency of the scores, when the scorer will naturally compare the scores of the previous plots, before determining the score of the present plot. Small differences in the 'true' scores are hence concealed, especially when the scores' range is narrow. It is necessary to quantitiatively describe the non-precision before statistical inferences are made on such data. Given a set of n scores in the order of observation, s_i,s_1, s_2 ...., s_n, different methods for quantifying the non-precision in score s_i were proposed.

Measuring intercropping advantage

The Land Equivalent Ratio (LER) is probably the most frequently used index for expressing intercropping yield advantage. The LER is defined as the relative area required by a sole crop to produce the same yield as in intercropping. However, component crops in an intercrop sometimes differ greatly in their maturity periods. A common example is the usual practice of intercropping cassava and maize by farmers in the tropics. While maize is usually planted twice annually, one crop of cassava usually requires a whole year in the field. An essential point, which has hitherto been ignored in the literature, is that the sole crop must be grown for the same length of time as the intercrop to evaluate the intercropping advantage. Results of modifications proposed by BMRU researchers indicate that the LER and its various forms over-estimate intercropping advantage in relation to optimum land use when the intercrops differ in maturity periods.

Modelling tsetse populations

Continuous assessment of population level is an integral part of any pest management campaign. Population estimates of tsetse are most often determined on the basis of the mark-release-recapture method. This method is particularly time-consuming and does not permit a clear definition of the area covered in the estimates. However, population estimates based on trap catches can be relatively defined in space and time. The availability of tsetse for trapping appears to be closely linked with the hunger status of the flies.

An approach to estimating tsetse population size based on proportional representation of trap-caught flies in the various hunger stages was developed by BMRU staff. Likely field situations regarding the distribution of flies in the various hunger stages were considered. Preliminary simulation studies have shown encouraging results, with the extincting population situation giving highest estimates. This result was also confirmed using field data. Further development of the model is continuing.

How far does a tick travel?

A study to determine the expected path and distance a tick moves from the time it is picked up by its host until the point when it reaches its feeding site is underway. A preliminary experiment showed that a model developed in BMRU could be used to monitor tick movement.

Classifying crop varieties

Crop varieties are usually classified as resistant or susceptible to pests based on some infestation and/or damage level. A univariate statistical procedure for classifying crop varieties into resistance groups, developed by a Ugandan ARPPIS student in the Unit, gives results which can be applied to single-parameter based classification problems.

See also the CPRP, LPRP and SSIRU sections of this Report.

Biomathematics research and facilities were sponsored by EEU, UNEP and Core Fund donors in 1993.

IABU

Insect and Animal Breeding

The Insect and Animal Breeding Unit (IABU) is concerned with effective production and distribution of the high-quality insects and small mammals required by the core research programmes/units for use in their research for the control of target pests of major food crops and vectors of important livestock and human diseases. The unit is organised into three sections: phytophagous arthropod rearing (stemborers, podborers and locusts); haematophagous arthropod rearing (tsetse and mosquitoes); small mammals breeding (rabbits, rats, mice and hamsters).

IABU is also active in training scientific and technical personnel from national and international institutions in insect rearing and animal breeding technology, and offers consultative services in insectary management and design.

Research in insect breeding

The R & D projects undertaken by IABU are aimed at improving techniques for efficient and cost-effective production. Lepidopteran stemborers require a moisture content of about 80% in their diets, and this is usually achieved by incorporating agar as a gelling agent. This year, IABU staff have discovered that about 50% of the agar — the most expensive ingredient, accounting for two-thirds of the cost of the diet — can be substituted with locally available and inexpensive maize meal, with no deleterious effects on larval production.

The tedious task of manually counting out individual eggs and neonate larvae has been superseded by using a system of estimating the numbers of *B. fusca* eggs by weight. This year, the Unit collaborated with the Crop Pests Research Programme (CPRP) and Behavioural and Chemical Ecology Research Unit (BCERU) in developing bioassay techniques for determining sorghum antibiosis and the efficacy of neem seed derivatives to *Chilo partellus* by incorporating the relevant plant extracts in the artificial diet.

See also CPRP and LRP sections of this Report.

1993 IABU Production and Supply

Chilo partellus. *At the Mbita Point Field Station (MPFS) 49.5 million egg equivalents (MEQ) of this stemborer were produced and 11.1 MEQ distributed. It was decided this year to replace the laboratory colony, now in 83rd generation, with a nucleus of feral collections. To this end, 245 adult pairs were collected for eventual substitution once the wild population progeny are numerous enough.*

Busseola fusca. *A total of 3.3 and 0.8 MEQ were produced and distributed, respectively at MPFS for work on this stemborer.*

Maruca testulalis. *This podborer is being reared at Duduville exclusively for use by some ARPPIS scholars. This year, 0.4 MEQ were produced and supplied.*

Glossina morsitans morsitans and G. m. centralis. *These tsetse species are reared in the IABU laboratories at Duduville. The level of production of each of the two species was maintained at between 10,000 to 14,000 flies throughout the year. The level was sufficient to meet user demand.*

Mosquitoes. *Two species were reared this year,* **Aedes aegypti** *and* **Culex quinquefasciatus**, *with production of 131,000 and 119,000, respectively. These colonies are due for infusion of wild genes next year.*

Locusts. *The gregarious colony reached the 27th generation since its inception while the solitary colony is now in its 17th generation. A total of 54,102 gregarious and 3393 solitary locusts were produced and supplied to users this year.*

Small mammals. *The number of rabbits, rats, Swiss mice, balb/c mice, and hamsters produced and supplied were 1813, 1757, 766, 1901 and 69, respectively. One hundred (100) extra rabbit holding cages were acquired during the year, and this substantially increased the rate of rabbit production as compared to the previous year.*

IABU work was sponsored this year by the Netherlands Government, UNDP, EEC and Core Fund donors.

SSIRU

Social Science Interface Research

The Social Science Interface Research Unit (SSIRU) aims at promoting interactive research involving multidisciplinary scientists, collaborating agencies and farming communities, in order to assist the Centre in fulfilling its basic mandate of developing appropriate pest and vector management technologies. SSIRU research in 1993 consisted of a variety of field activities involving socio-economic surveys, community training and mobilisation, and monitoring and assessment of technology development and the adoption processes.

Research activities and collaborative projects

Interactive Socio-economic Research for Bio-Intensive Pest Management Technology Development (ISERIPM) in Coast and Western Provinces (in collaboration with CPRP and LPRP)

Adaptive Research on Community-based Management of Tsetse and Trypanosomiasis in Lambwe Valley (ARCMTT) (in collaboration with LPRP).

Kwale and Kilifi Adaptive Research Project (KKAR) (in collaboration with CPRP and LPRP).

Socio-economic Aspects of the Tsetse Research Project in Coast Province (with LPRP).

Socio-Economic Aspects of the Problems of Ticks in Kuja River, Western Kenya (with LPRP).

Socio-Economic Research on the Application of the Mbu-Cloth Technology in Baringo District (with MVRP)

In 1993 the Interactive Socio-Economic Research for Bio-Intensive Pest Management (ISERIPM) Project set out on-station crop trials at six sites at the Kenyan Coast. The farming communities were mobilised to visit the on-station trials and to participate in their evaluation. In the ARCMTT project on the community-based management of tsetse, the major field activities carried out included the promotion of community participation in the management of the tsetse trapping technology, and monitoring and technology impact assessments.

A socio-economic survey of Lambwe Valley

An economic survey of 30 homesteads in Lambwe valley, specifically in the area where ICIPE is currently carrying out an adaptive research project (ARCMTT) to assess the sustainability of its tsetse trap under the management of the local community, was aimed at determining current crop yields and livestock productivity as well as current homestead levels of incomes, consumption and expenditures. Preliminary results show that crop yields are very low in this region, probably the result of the low application of inputs. Most of the production was consumed within the homestead. Livestock population projections showed dwindling holding herd sizes for cattle, donkeys, sheep and goats.

Livestock accounts for about a third of farm income. Most of the livestock farmers perceive trypanosomiasis as the most important constraint to livestock improvement and production. Control of the disease is crucial if the problem of lack of draught power, which is perceived as the second most important constraint in crop production, is to be alleviated.

Data were collected on 546 head of cattle kept by 60 homesteads. The entire herd was of the Zebu breed. The sex-age structure showed that female cattle are maintained for relatively longer periods. The proportion of calves was quite small, an indicator of low herd fertility. The herd showed prolonged age at first calving (4.7 years), long calving intervals (2.4 years) and low calving rate (0.41 calves/female/year). Another study showed that there is need for strengthening local capacity for organisation and management.

Assessing community capacity for IPVM

A study carried out as part of the activities of the socio-economic component of the Kwale and Kilifi Adaptive Research Project aimed to assess the contribution made by the various components of the farmers' production system to household food security, in relation to the farmer's resource base, and patterns of production and consumption, bearing in mind that these factors can determine a farmer's capacity to adopt and sustain IPVM technologies. More than two-thirds of the respondents had more than 4 hectares, with about 38% owning more than 8 hectares. Estimated annual cash incomes for households were low, with a significant number declaring incomes of less than Kshs 12,000 (about $184) per year.

Another study carried out in the context of the ISERIPM Project sought to analyse the availability and use of household and other labour resources for agricultural production and the implications of labour resources constraints upon the adoption of IPVM technologies. Although many male family members were not resident on the farms for the greater part of the year, more than half of the households reported regular involvement of adult males in farming activities.

The primacy of housekeeping roles for female members appeared to relegate agricultural work to the secondary, though critical, place. Hired labour was used to a limited extent, with land preparation and weeding using most of this resource. About 43% of the households used hired labour for land preparation, 27% for weeding and 17% for planting.

Livestock production systems

Three closely related studies were carried out on the livestock sector to provide benchmark information for assessing the impact of integrated tick management technologies being developed at ICIPE and expected to be tested at Kuja River in western Kenya. Out of 272 homesteads, it was found that 14.7% farmers were in the G1 category (no livestock), 35% had less than 10 SSU, 26% had between 10–20 SSU, and 23% had 20 or more SSU.

A study in progress to assess farmers' indigenous knowledge and control of ticks and tick-borne diseases (TBDs) indicates that although TBDs are endemic, farmers do not know the vectorial role of ticks in the transmission of disease and associated economic losses. For example, only 14% of respondents ranked disease as the most important harm caused by ticks. By contrast, 42% and 26% ranked loss of blood and milk respectively as the most important economic losses caused by ticks. No methods of tick control are used regularly by the farmers, but hand deticking, spraying and dipping are sporadically used. There is therefore a great need for farmer education on ticks and tick-borne diseases in this region.

Sustainability of Mbu cloth technology

In 1989, the Medical Vectors' Research Programme provided 2000 permethrin-impregnated Mbu cloths to residents in the Perkerra Irrigation Scheme area of Baringo District in Kenya. Between 1991–93, more cloths were sold to the tenants of the scheme. A SSIRU study to provide an understanding of the perceptions of the users of the cloth, and their capability and that of the larger community to afford, handle and sustain the technology was done in the study area. Malaria was the most common disease in the area, and whereas the users of the Mbu cloth had used other methods of controlling mosquitoes, 68% preferred Mbu cloths, 28.9% preferred bednets and 1.2% preferred traditional methods. Reasons for the preference of Mbu cloths included their effectiveness in controlling mosquitoes and their relatively low price. However, 85% of the users had not re-impregnated the cloths after 6 months as recommended. Two-thirds of the users had a high enough income so that they could afford to purchase the cloths, mainly from money earned from sale of their crop produce and livestock.

See also CPRP, LPRP and MVRP sections of this Report.

Research in SSIRU was funded by Rockefeller, UNDP, EEU and donors to the Core Fund.

IBIRI

Institutional building, interactive research and information

Education and Training

Two decades of capacity building in insect science and pest management

Although insect pests pose tremendous constraints to food security and health in Africa, the human resource base necessary for the development and utilisation of insect pest and vector management technology is limited. More specifically, African countries lack the necessary cadre of scientists at postgraduate level as well as the institutional capacities to undertake purpose-oriented research for development. Even at the consumer level, there is need to educate IPVM (insect pest and vector management) practitioners and farmers to ensure the diffusion, internalisation and usage of such technology.

Soon after its establishment in the early 1970s, the ICIPE realised the need for enhanced training in insect science and for international as well as regional cooperation in capacity building for sustainable IPVM. Consequently, the ICIPE has adopted a networking approach in developing Africa-wide programmes. ICIPE's capacity-building strategies are being implemented through two major networks:

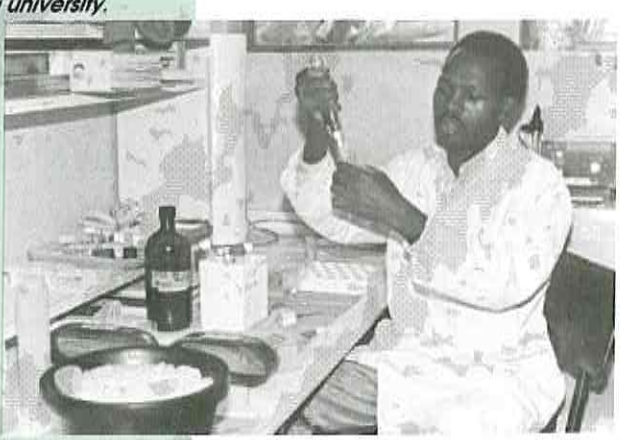
- The African Regional Postgraduate Programme in Insect Science (ARPPIS), and
- The Pest Management Research and Development Network (PESTNET).

The ARPPIS PhD Programme

In 1983, in collaboration with several institutions of higher learning in Africa, and with the financial backing of several donors, ICIPE initiated a unique training programme: the African Regional Postgraduate Programme in Insect Science (ARPPIS). The programme was designed to bring together African universities into partnership with ICIPE in offering young African scientists the opportunity to pursue higher training on the management of African insect pests and disease vectors within the ecological and socio-cultural context of the Continent. The universities register students for their PhD degrees, while the training is offered at the ICIPE using a curriculum of coursework and research developed jointly by the ICIPE and the universities, and approved by their graduate schools.

Today, with 26 participating universities in 22 countries and 115 scholars enrolled, the ARPPIS programme has become a model in co-operative high-level manpower development in Africa. The programme has to date produced 40 PhD graduates. Thirty-three (33) scholars are still on the programme, while the rest are awaiting graduation or thesis examination. After 13 years of implementation, ARPPIS has developed into a reputable collaborative training facility that continues to attract the interest of increasing numbers of African universities and scholars. 1993 saw the graduation of 13 members of the 1990 class. Ten scholars from eight African countries, including for the first time Egypt and Malagasy, enrolled on 22 February for the 1993 class.

ARPPIS PhD students undertake their research projects in ICIPE's well-equipped laboratories. Students are supervised by an ICIPE staff member and by one from their registering university.



The ARPPIS MSc Programme

Following the continued success of the foregoing ARPPIS model, and the need to accelerate post-graduate education in insect science, leading educationists, policy makers and donors have endorsed the establishment of a wider ARPPIS network with four Sub-Regional Centres offering the Masters Degree in Insect Science. This Programme is already being implemented in a step-wise manner, beginning with the Sub-Regional Centre for Southern Africa based at the University of Zimbabwe, Harare, where the first intake of seven Zimbabwean and Namibian students graduated in October 1993 with an MSc in Tropical Entomology. Other Sub-Regional Centres are to be located as follows: Eastern and North-Eastern Africa (University of Addis Ababa, Ethiopia); Anglophone West Africa (University of Ghana, Legon). The Centre for French-speaking Africa is yet to be selected. More recently, several universities in North Africa (Egypt, Libya, Algeria, Morocco, and Western Sahara) have shown interest in participating in ARPPIS, and a Sub-Regional Centre for Northern Africa might soon be necessary.

African countries lack the necessary cadre of scientists at postgraduate level as well as the institutional capacities to undertake purpose-oriented research for development.

Professional development training

IBIRI coordinates other non-degree training programmes for postdoctoral scientists, pest and vector management research scholars and research associates from the national agricultural research and extension systems (NARES). A total of 11 postdoctoral research fellows, including four in the senior category, worked at ICIPE in 1993. The scientists originated from Kenya (6), Chad (1), Sierra Leone (1), Sudan (2), and Ghana (1).

The Research Training Internship Scheme is now well established at ICIPE and is offered to individuals at modest fees. Participants are normally sponsored by a donor agency. During the year, trainees from Sri Lanka and Tanzania participated on this programme. Under the Industrial Attachment Programme, a total of 18 students on industrial attachment were trained during the year.

The Visiting Scientist Programme enabled several scientists to participate in collaborative research at ICIPE under various schemes. Under the Research Associateship Scheme, two research associates from the Netherlands worked on projects on which the ICIPE is collaborating with Wageningen Agricultural University (WAU): tsetse and biological control of stemborers. A third Tanzanian scientist worked with the Banana Project. Two scientists worked at the ICIPE on appointment under the more senior Visiting Scientist Scheme this year.

Due to financial constraints, ICIPE staff development training was severely curtailed in 1993. However, three members of staff were sponsored for skills-development training abroad, with the assistance of collaborating institutions and donor agencies. The Association of African Universities (AAU) continued its collaboration with the ICIPE through ARPPIS, which is an Associate Member. The AAU awarded grants to support visits to the ICIPE by two professors on the AAU Staff Exchange Programme. The Royal Society, in a long-standing collaboration with the ICIPE on the John Pringle Staff Exchange Scheme, awarded an exchange fellowship to an ICIPE scientist tenable at the Department of Veterinary Parasitology. Cooperation with the Third World Academy of Sciences (TWAS) was maintained. The TWAS selected 6 nominees to benefit from the ICIPE/TWAS Fellowship Scheme in 1994.

Specialist courses for technology adoption

In-country training courses for national staff and farmers were conducted as a part of ICIPE's capacity building and technology transfer through the PESTNET collaborative activities. In collaboration with the Kenya Government's Department of Livestock Development, and with financial support from the World Bank, the ICIPE conducted a project to disseminate tsetse trapping technology in the Lake Victoria region of Kenya. The practical development, application and maintenance of the ICIPE NGU tsetse trap and methodologies for assessing the impact of the tsetse control programme were covered. By the end of the project, which was implemented over a 6-week period, 12 senior and mid-level officers, 9 extension personnel, 15 community leaders and over 1000 farmers had been trained.

An International Group Training Course on methods and techniques used for biological control in the tropics was held at the ICIPE for three weeks and covered the most recent developments and advances in field techniques used in biological control. Special emphasis was placed on training in practical applications of pathogens as IPM components. The course was attended by 14 scientists from 11 African countries and included three women participants.

Networking and Collaboration

IPVM technology is tested, validated and adapted interactively with national agricultural research and extension systems (NARES) through the instrument of the Pest Management Research and Development Network (PESTNET), established through ICIPE's initiative in 1986. Since its inception, the network has spearheaded productive collaboration with NARES in Kenya, Zambia, Somalia, Ethiopia, Tanzania, Rwanda, Sudan and the Philippines.

Several features distinguish PESTNET from other networks in the region. The emphasis on interaction with the national research and extension systems at policy and operational levels means that pest and vector management efforts are fully coordinated. Recognising the value of equal partnership, PESTNET has given new meaning to the concept of 'resident scientific team' (RST). PESTNET's RSTs are fully integrated into the national systems, and are responsible to the national Directors of Research through the Station Directors. In 1993, due to reduced funding, RSTs operated in only three countries: Ethiopia, Kenya and Zambia; teams in Somalia and Rwanda were withdrawn for security reasons.

Objectives of PESTNET

- **Generation of scientific information and pest management methodologies**
- **Development of these methodologies into eco-specific packages of IPM technologies**
- **Strengthening of national scientific leadership capabilities**

Main Activities of PESTNET

- **Collaborative scientific research and technology development adaptation**
- **Institutional building activities, including human resources and research facilities development**
- **Facilitating information exchange and integrating activities of national and international institutions**

PESTNET recognises that technology development, adaptation and utilisation are part of a mutually reinforcing continuum in which inputs and outputs at every step of the way contribute towards the ultimate success of that particular technology. The farmer, who is the intended beneficiary of the technology, is an important source of information for technology development. Through its social science interface research work, ICIPE ensures that the technologies that PESTNET and its partners disseminate are not only farmer-driven but are also firmly grounded in indigenous knowledge. This is in sharp contrast to the conventional approach,where technology is first developed by researchers and then transferred through an extension agent to the end-users.

PESTNET recognises that technology development, adaptation and utilisation are part of a mutually reinforcing continuum in which inputs and outputs at every step of the way contribute towards the ultimate success of that particular technology.

PESTNET activities in Zambia

During the year, PESTNET (in collaboration with the NARES) continued to carry out investigations on key insect pests of maize and sorghum in Zambia. The following activities were carried out:

- Investigations on effective concentration of the natural plant product from *Tephrosia vogelii*
- Studies on the effects of intercropping maize and its infestation and damage by stemborers
- Determining the incidence of *Cotesia sesamiae* parasitism among stemborer species in relation to their host plants
- Screening several maize genotypes to determine tolerant and resistant cultivars
- Training activities

In efforts to strengthen scientific interaction and cooperation within the southern African region, PESTNET held a 3-week regional workshop on 'Statistics in Plant Protection' attended by participants from Tanzania, Zambia and Zimbabwe. The workshop was funded by the Plant Protection and Improvement Programme (PPIP) for Zambia, Botswana and Tanzania. The workshop reviewed the most widely used statistical concepts for technically accurate but proficient design and data analysis in plant protection experiments.

PESTNET activities in Kenya

The Kwale-Kilifi Adaptive Research Project, is a joint project between the ICIPE and the Kenya Agricultural Research Institute (KARI). The objectives of this project are to increase food production and cash incomes of resource-poor farmers on the Kenyan

Farmers in the Kenya PESTNET project discuss the good harvest following the use of improved maize varieties.

coast through increased knowledge and use of improved IPVM practices of selected crops and livestock.

To this end, volunteer farmers in the Shimba Hills (Kwale district) were trained in tsetse trap making and are deploying and servicing them in their own farms as a model effort. Similarly, farmers are simultaneously testing introduced crop technologies (new varieties) side-by-side with livestock technology (traps) to assess their relative adoption potential. Women's groups are already collaborating in selecting and refining the crop technologies for maize, cowpea and sorghum as they relate to the domestic/ consumption needs and dietary preferences of the farm families.

The refined design of the tsetse trap, modified to attract the two locally dominant species, was employed for assessing the tsetse population density for a 12 month continuum at five sites around the game reserve in Shimba Hills (Kwale district). Data on monthly incidence of trypanosomiasis was also assembled on over 200 head of cattle per site. These will constitute the benchmark data prior to mass deployment of traps in the next year to assess the impact of tsetse trapping technology.

Group training courses were organised for NARES personnel and farmers in on-farm/ farming systems approaches and on pest/vector management technologies, including a study tour to ICIPE's Mbita Point Field Station. One more KARI scientist was sponsored for advanced (PhD) training under ARPPIS at ICIPE. Construction and equipping of an insectary facility at Mtwapa and field facility at Muhaka have been completed as long-term physical support for adaptive research in the region.

Through its social science interface research work, ICIPE ensures that the technologies that PESTNET and its partners disseminate are not only farmer-driven but are also firmly grounded in indigenous knowledge.

PESTNET activities in Ethiopia

Some of the major problems of food production in rural Ethiopia are strongly related to insect pest and disease vectors. As a result of infestations by tsetse and ticks, the large livestock population in Ethiopia (approximately 77 million) does not fully contribute to the economic and social well being of the people. In addition, about 30–40% of crop production is lost every year through insect degradation. PESTNET scientists and technicians, led by a former ARPPIS graduate, are designing a tsetse control strategy that is sustainable and manageable by the rural people within their limited resources. The project activities include:

- Demonstration of a package for tsetse control under Ethiopian refugee resettlement conditions. The activity is focusing on the Omo River Basin, Ketto, Angertutin and later Gambella, which are the major sites for refugee resettlements.
- Evaluation of different tsetse control techniques including traps, targets and insecticide-treated cattle in the study area.
- Analysis of cost-effectiveness of tsetse control methodologies under the unique resettlement conditions of the displaced persons.

Field days constitute one of the linkages between farmers and researchers in identifying locally adapted pest-resistant sorghum varieties developed by ICIPE under the Kwale-Kilifi Adaptive Research Project in coastal zones.

- Assessment of natural resources in the area and agricultural potential of the tsetse-reclaimed land for subsequent intense livestock and crop production.
- Training of mid-level staff (extension workers) involved in day-to-day operation of the tsetse and trypanosomiasis control programme.
- Involvement and training of the community for effective participation in tsetse pest management.

In order to facilitate smooth operation of the PESTNET ICIPE/Ethiopia activities, the Ethiopian Government, represented by H.E. Mr. Ato Seyoum Mesfin, Minister for Agriculture, and the ICIPE, represented by its Director, Professor Thomas R. Odhiambo, signed a Country Agreement on 9 January, 1993 for innovation of new pest management technologies to address these pest and disease vector problems.

Training ensures skilled IPVM operators

At the practitioner level, technology may only have meaningful impact if applied by skilled operators. It is for this reason that the ICIPE puts a premium on the training of field technicians, extension agents and farmers, especially women's groups. Through group training courses, field days and demonstrations, and informal interactions during field testing, validation and adaptation of IPVM technologies is done.

The contents of the training courses are developed from farmer-validated technologies and information generated by ICIPE scientists. From 1977 to 1993, a total of 523 participants from 50 countries in Africa, the Middle East and Asia have attended 35 specialised short courses and field demonstrations at the ICIPE.

One such farmer-oriented training course took place in Kenya, for farmers in the Kwale-Kilifi Adaptive Research Project. The farmers were trained in tsetse trap making and in the installation and maintenance of the traps. Seventeen out of a total of 26 who participated in group training courses as well as in a computer training course held in Zambia were drawn from PESTNET collaborating countries. PESTNET collaborating countries continue to benefit from education and training offered at the ICIPE as well as within individual countries. A Rwandese who was sponsored through PESTNET completed his PhD studies and is now working with the NARES in Rwanda. Attachment training for one Somalia staff member was continued for three months of 1993.

International consumer-based training courses held at the ICIPE from 1977–1992

Area of training	No. of courses
Integrated pest and vector management techniques	16
Methodologies in host plant resistance (mechanisms, screening, loss assessment, etc.)	5
Insect mass rearing technology	2
Biological control of pests and vectors	1
Implementation of tsetse trap technology	1
Use of computers in pest management research	3
Pest management documentation and information systems	1

PMDISS information exchange includes the grey literature

Because of the relative isolation of many African scientists, they depend to a great extent on obtaining information from outside the continent. This information may not offer appropriate solutions to the problems at hand. In Africa, the 'grey literature', as found in national annual research reports, theses, conference proceedings, consultancy reports, etc., provides a valuable source of information for pest management.

The Pest Management Documentation and Information System and Service (PMDISS) is a network that incorporates all types of information. PMDISS is an information network for national research and educational organisations, and is already active in six countries in Africa — Kenya, Uganda, Zambia, Mozambique, Rwanda and Senegal. The database and secretariat are based at ICIPE Headquarters in Nairobi.

The **Information Resource Services** provides backstopping to ICIPE's research and training activities through a state-of-the-art information resources facility and the exchange and dissemination of insect pest and vector management information within the PESTNET region. Notwithstanding the shortage of funds this year, the Information Resource Centre (IRC) received about 800 books, and maintained its subscription to 150 journals as well as receiving about 50 new titles through donations and exchange. The growth of book acquisitions by a factor of about 30% was possible because of the continued arrival of books from the previous year's book grant from the Swiss Government and two major donations. The donations included one by the International Institute for Environmental Development (IIED) of all its publications and another of the personal library collections of Dr. Pritam Singh, the renowned expert in insect rearing. Dr. Singh donated his library to ICIPE on his retirement from the New Zealand Department of Industrial Research.

ICIPE started subscribing to FIDONET whose link, like that of CGNET, is hosted in the IRC. The IRC is a Fido "point" (5:731/10.4) linked to the host node at the African Regional Organisation for Standardisation (ARSO). The Fido communication system has not only electronically linked ICIPE to other local subscribers but also to other networks such as APC and INTERNET which have Fido gateways.

Service offered by the IRC centred on the facilitation of current awareness based on subscriptions to indexing and abstracting services in both printed and electronic formats. The IRC produced its in-house *Library and Documentation Bulletin* regularly, while PMDISS provided its quarterly bibliography as well. Over 1500 records were incorporated in the PMDISS data base this year. The enquiries desk recorded 80955 user visits. Computer bibliographic searches (92) were done and unlike in the past they were all done on locally held databases on hard disk and CD-ROMs.

The **Communication section** of IBIRI is responsible for organising major events at the ICIPE, which this year included the 23rd Annual Research Conference (ARC), and two mobile seminars. The first mobile seminar to be held in Africa, and the fourth in the series, was held in Ethiopia. The fifth seminar was held in Japan. The Communications section were also busy this year with organising the lively ICIPE Tuesday seminar programme, and other information and exchange activities.

The authors' editor in the office of the **Science Editor** this year processed over 44 scientific manuscripts destined for publication in international journals, as well as research and project reports, proceedings, and rapporteur's reports. Another major task of this office was the compilation and editing of the *1992 ICIPE Annual Report*, which for the first time included a general interest section for the non-scientist reader.

In publishing activities, the ICIPE editors are assisted by the **ICIPE Science Press (ISP).** This year the Press has undertaken the whole gamut of production procedures including the conceptualisation, design, typesetting and printing of prime documents for the Centre as well as for other international bodies. An important contribution to the region's document production capability has been the publishing of registers and survey material for a number of organisations in Kenya, Tanzania, Uganda and Ethiopia.

As a service to the scientific community, ICIPE serves as the headquarters and secretariat of the international journal, ***Insect Science and its Application (ISA).*** Volume 13, Nos. 5 & 6 were published in 1993, and Volume 14, Nos. 1 to 4. About 62% of the papers in volume 13 originated in Africa, with ICIPE contributing about 18% of the total. The journal is published by ICIPE Science Press (ISP).

With effect from January 1993, a new Editorial Advisory Board of 17 members and an Editorial Team were constituted to implement new journal policies. Professor K.N. Saxena, who has been Associate Editor of the journal for some time, became the Editor-in-Chief in 1993. Three new associate editors have been appointed: Professor R.W. Mwangi of the University of Nairobi, Dr. J.A. Odera, Director of Kenya Forestry Research Institute and Dr. R.K. Saini of ICIPE.

See also CPRP, LPRP, MVRP and SSIRU sections of this report.

Donors to IBIRI activities include UNDP, EEU, DAAD and donors to the Core Fund.

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Reprints of articles with a call-number at the end of the citation can be ordered from the Documentalist, ICIPE.

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UNDP Kwale/Kilifi Special Project

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TANZANIA: Bukoba-Based

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ICIPE/WAU Collaborative Project

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Mr. M. Kawaka, *Accountant*
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Mr. P. Nyongesa, *Farm Supervisor*
Miss D. Achieng, *Librarian*

Ungoye Field Station

Mr. E. G. Kabiru, *Farm Foreman*

Financial Report

Income and expenditure for the year ended 31 December 1993	Amount (KSh millions) Financial Year 1993	Financial Year 1992
INCOME		
Grants	403.4	*261.9*
Premium on foreign exchange bearer certificates	5.3	*41.7*
Miscellaneous	36.3	*26.0*
	445.0	***329.6***
EXPENDITURE		
Core research	286.1	*115.7*
Research support services	18.9	*30.7*
Training and international cooperation	40.0	*52.8*
Information	7.9	*18.3*
Management and general operations	51.6	*59.0*
Provision for doubtful grants	0.0	*13.4*
	404.5	***289.9***
Land and buildings	0.4	*4.6*
Scientific equipment	10.7	*12.7*
Office equipment and furniture	2.5	*0.6*
Vehicles	11.0	*9.8*
Generators	1.3	*0.0*
	430.4	***317.6***
SURPLUS FOR THE YEAR	**14.6**	***12.0***

Balance sheet as at 31 December 1993	Financial Year 1993	Financial Year 1992
FIXED ASSETS		
Nominally valued at Shs.20	–	–
ICIPE Riverside House	**18.5**	***19.0***
CURRENT ASSETS		
Premium receivable on foreign exchange bearer certificates	–	*2.6*
Stock	0.4	*0.0*
Grants receivable	32.9	*59.9*
Debtors and prepayments	31.1	*9.4*
Deposits — building maintenance fund	12.0	*6.8*
— Others	92.1	*1.9*
Bank balances and cash	54.6	*10.0*
	223.1	***90.6***
CURRENT LIABILITIES		
Bank overdraft	25.9	*19.9*
Loan repayable within one year	0.9	*0.3*
Creditors and accruals	94.2	*53.0*
Unexpected operating funds	82.0	*16.5*
	203.0	***89.7***
NET CURRENT ASSETS	**20.1**	***0.9***
TOTAL NET ASSETS	**38.6**	***19.9***
Financed by:		
Reserve funds	10.4	*(4.6)*
Buildings maintenance fund	12.0	*6.8*
	22.4	**2.2**
Deferred financing	5.9	*6.5*
Long term loan (secured)	10.3	*11.2*
	38.6	***19.9***

Donors for 1993

Grants received and receivable	Amount Received (KSh millions) 1993	1992
African Development Bank (ADB)	21.2	*0.0*
Arab Fund for Economic and Social Development (AFESD)	8.0	*2.9*
Canadian International Development Agency (CIDA)	0.0	*0.1*
Danish International Development Agency (DANIDA) — Danish Government	29.5	*17.9*
European Economic Union (EEU)	54.4	*18.0*
Finnish Government	1.3	*6.0*
French Government	0.0	*2.6*
Gatsby Charitable Foundation	0.3	*0.0*
German Academic Exchange Service (DAAD)	14.0	*5.4*
German Federal Ministry of Economic Cooperation (BMZ)	14.2	*9.2*
Institute of Molecular Biology and Biotechnology — Greece	2.3	*0.2*
International Bank for Reconstruction and Development (World Bank)	43.2	*20.6*
International Development Research Centre (IDRC)	0.9	*1.9*
International Fund for Agricultural Development (IFAD)	25.1	*5.9*
Japan Society for the Promotion of Science (JSPS)	0.3	*0.2*
Kenya Government	2.0	*2.0*
Natural Resources Institute (NRI) — U.K.	7.8	*3.0*
Netherlands Government	25.7	*28.9*
Norwegian Government	28.9	*17.0*
OPEC Fund for Economic Development	0.0	*2.1*
PEW Trust (through World Wildlife Foundation)	0.2	*0.0*
Rockefeller Foundation	22.0	*8.6*
Swedish Agency for Research Cooperation with Developing Countries (SAREC)	46.4	*32.9*
United Nations Children's Fund (UNICEF)	0.6	*0.4*
United Nations Development Programme (UNDP)	112.2	*62.7*
United Nations Environmental Programme (UNEP)	5.5	*1.2*
United States Agency for International Development (USAID)	0.4	*1.9*
Wellcome Trust	0.5	*0.0*
TOTAL GRANTS RECEIVED AND RECEIVABLE	**466.9**	***251.6***
Add:Unexpected grants — brought forward	16.5	*26.8*
	483.4	***278.4***
Less:Unexpected grants — carried forward	(80.0)	*(16.5)*
GRANTS TAKEN INTO INCOME	**403.4**	***261.9***

The rate of exchange used at 31 December, 1993 was KShs 65 = US$ 1.0 and KShs 35 = US$ 1.0 at 31 December, 1992.

"The creation and nurturing of an enabling environment for scientific discovery and technological innovation . . . enables the full potential of the brainpower of the scientist and technologist to be realised — to wonder, to explore, to tinker, and to find fulfillment".

Thomas R. Odhiambo
African scientist and visionary

1993 ICIPE Annual Report Highlights
ISBN: 92 9064 070 7

Compiled and edited by *A. N. Mengech*
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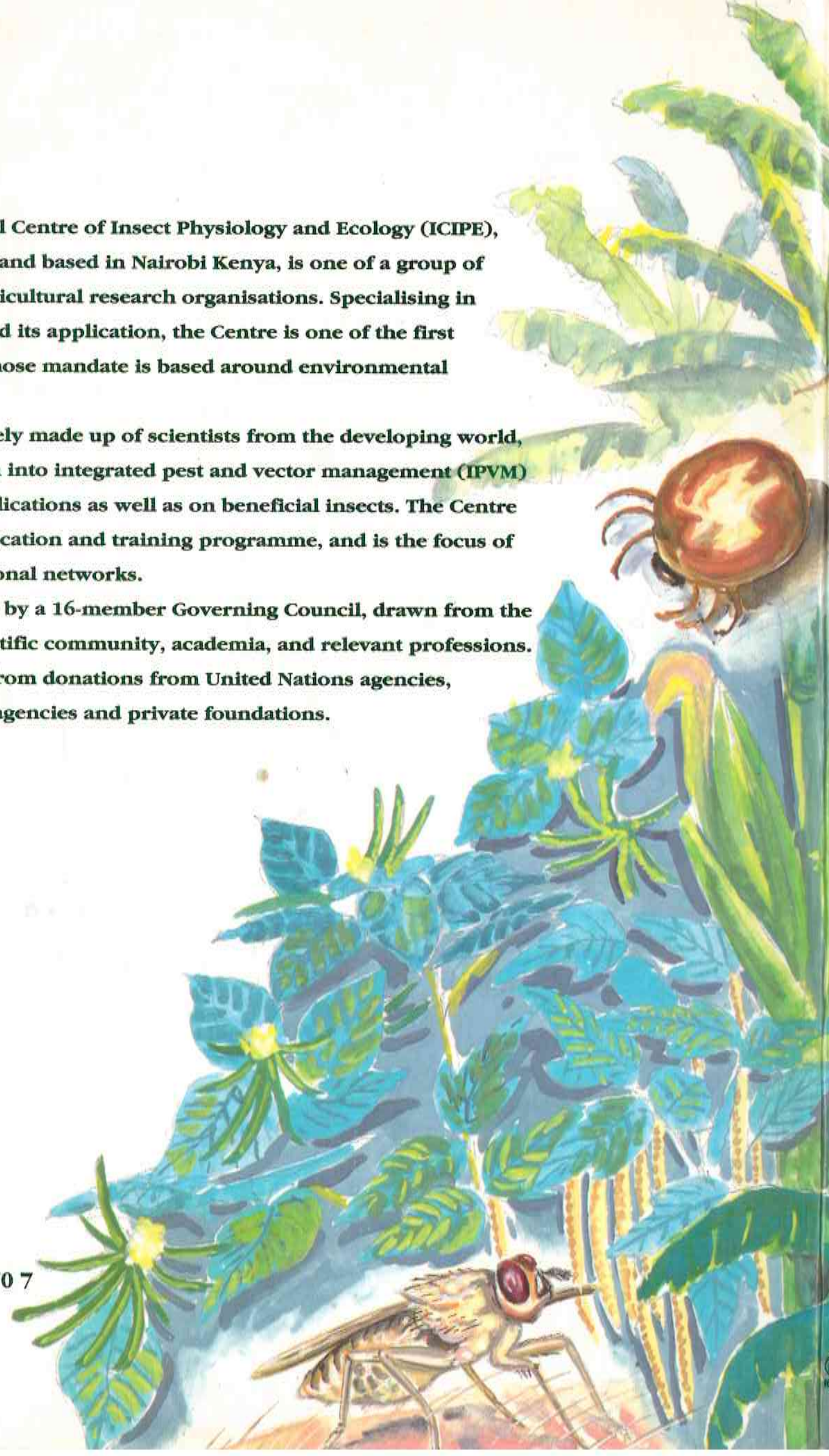
Cover illustration: *M. Njenga*
Proofreading: *D. O. Odhiambo*
Photographs: All photos by P. Lisamulla except for the following: W. A. Overholt (p. 9 top, 10, 13), S. K. Raina (p. 19), R. O. Olubayo (p. 26), S. Mihok (p. 38), S. Sithanantham (p. 53).

Cover illustration: A collage of some of ICIPE's target pests attacking man, his livestock and his crops.

The International Centre of Insect Physiology and Ecology (ICIPE), founded in 1970 and based in Nairobi Kenya, is one of a group of international agricultural research organisations. Specialising in insect science and its application, the Centre is one of the first organisations whose mandate is based around environmental conservation.

The staff, largely made up of scientists from the developing world, conduct research into integrated pest and vector management (IPVM) practice and applications as well as on beneficial insects. The Centre has an active education and training programme, and is the focus of several international networks.

Governance is by a 16-member Governing Council, drawn from the world-wide scientific community, academia, and relevant professions. Funding comes from donations from United Nations agencies, government aid agencies and private foundations.



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1993 ICIPE ANNUAL REPORT HIGHLIGHTS