Fourteenth Annual Report

1986

The International Centre of Insect Physiology and Ecology

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The International Centre of Insect Physiology and Ecology

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Foreword

On Thursday, 27 November 1986, a crucial event took place at the Kenyatta International Conference Centre, in Nairobi, Kenya, that of the signing of the Charter of the International Centre of Insect Physiology and Ecology (ICIPE) by three countries: Kenya (the host country), Zambia and Côte-d'Ivoire. A few weeks later, four other countries formally adhered to the Charter: the Philippines, Chile, Norway and Sweden. Other countries may subscribe to the Charter in the future. The signing of the Charter ended one era and initiated another in the development of the ICIPE.

The ICIPE was established in April 1970 as an institute of advanced research and training in insect science and its application to the development of integrated pest management strategies. The principal impetus for its establishment was the concern of eminent scientists throughout the world that conventional insect control strategies, by relying heavily on insecticides, were becoming ineffective and unsuitable because of a growing resistance in crops and livestock to insecticides, a growing sensitivity in people to environmental pollution due to the harmful chemicals in pesticides, and the high cost and capital-intensive nature of these methodologies. The main target of the ICIPE—the resource-poor rural communities in the tropical regions of the world—required a radically different approach, which would be the principal mandate of the ICIPE.

The headquarters of the ICIPE are located in Nairobi. In its first 16 years of existence, the Centre was registered under Kenya Law as a non-profit-making company limited by guarantee and having no share capital. At the signing of the Charter on 27 November 1986, the provisions of the Charter became immediately effective. These required the abolition of the ICIPE Company and all its organs—the Annual General Meeting of the Company, which was the final authority of the organization; the Governing Board, which was the principal policy organ of the Centre; and the Governing Board's associated organs, especially the Executive Committee (on management and financial policy matters) and the Programme Committee (on science policy issues). The Company was abolished and its place taken by (a) a Governing Council, which is now the final authority of the organization, and (b) its associated organs, especially the Executive Board and the Programme Committee. The major changes, however, are not these structural ones, but rather those outlined in the Charter's Declaration, which reads as follows:

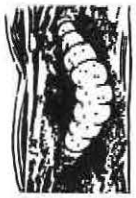
- The ICIPE shall be constituted as an international research centre established with a world headquarters in Nairobi, in the Republic of Kenya, with full international legal status and personality as an autonomous, non-profit-making research and training institute;
- The government of the host country and other subscribers to the Charter shall, subject to negotiation and agreement with individual governments, accord to the ICIPE rights, powers, privileges and other conditions necessary to enable it to operate effectively and efficiently in carrying out its mandate and objectives;
- This Declaration shall constitute a Charter of the ICIPE and make it a body corporate with perpetual succession and a Common Seal. The ICIPE shall have under the laws of the host country and other states subscribing to this Charter power to contract, to acquire and to dispose of immovable and movable property and to institute and defend legal proceedings in that name.

We believe that the signing of this Charter has indeed transformed the degrees of freedom of ICIPE's functionality, especially in terms of outreach activities and interactive collaborative scientific work with national programmes.

The transformation of the ICIPE through the negotiations that led to the signing of the Charter ran parallel with the development of the ICIPE Strategic Plan for the three-year period 1987–1989. The Charter signing itself was preceded by the Second Triennial Review of the Centre's programme and management, which was carried out from April to October 1986. The Centre is therefore now armed with a medium-term development plan for its core activities, and can look to its future with vision.

THOMAS R. ODHIAMBO
Nairobi
11 October 1987

Crop Pests



Crop Pests Research Programme

The main goal of the Crop Pests Research Programme (CPRP) is to develop strategies for managing key insect pests of ICIPE's target crops for resource-poor small-scale farmers in African and other developing countries. These farmers have neither the means to buy nor the skills to handle pesticides that harm the environment. The pest management strategies being developed in CPRP are environmentally safe and technically as well as economically feasible for resource-poor farmers in developing countries. In order to achieve its objectives, CPRP is conducting research in four areas: (1) Bionomics and Applied Ecology (BAE), (2) Plant Resistance to Insect Pests (PRIP), (3) Biological Control (BC) and (4) Insect Mass-Rearing Technology (IMRT). These sections contribute to the development of integrated pest management (IPM) of crop pests by providing information in the following areas: plant resistance to pests, intercropping, traditional farming practices (planting time, crop residue disposal, etc.) and biological control using parasitoids and pathogens.

*The target crops CPRP has studied for the past few years are maize, sorghum, cowpea and rice. The pests of maize, sorghum and cowpea, being studied at ICIPE's Mbita Point Field Station, on Lake Victoria, include the stem borers of maize and sorghum (*Chilo partellus, Busseola fusca, Sesamia calamistis *and* Eldana saccharina*), the sorghum shootfly (*Atherigona soccata*), the cowpea pod borer (*Maruca testulalis*) and aphids (*Aphis craccivora*). Besides these, special projects have concentrated on the biological control of the cassava green spider mite (*Mononychellus *spp.*) and vectors of citrus greening disease. For the past nine years the pests of rice, particularly the brown planthopper,* Nilaparvata lugens, *have been investigated by an ICIPE team at the International Rice Research Institute (IRRI), the Philippines, in an ICIPE-IRRI collaborative research project. The insect pests of cowpea-based farming systems are being studied by an ICIPE team at the International Institute of Tropical Agriculture (IITA), Nigeria, in an ICIPE-IITA collaborative project.*

The following reports from the four sections of CPRP present the work done by this programme in 1986.

BIONOMICS AND APPLIED ECOLOGY

The Bionomics and Applied Ecology section conducts research on the incidence and population dynamics of ICIPE's target crop borers in relation to crop losses caused by the borers, reproduction and behaviour of the borers and the role of intercropping and other traditional farming practices as components of pest management in subsistence agriculture.

INCIDENCE OF SORGHUM/MAIZE STEM BORERS AND CROP LOSSES

K.V. Seshu Reddy

Incidence of Stem Borers in Relation to Crop Phenology

The population patterns and fluctuations for the target stem borers on sorghum and maize crops at Mbita Point Field Station have been reported in the *1983 ICIPE*

Annual Report. During 1986 a similar study was undertaken at the newly acquired field site at Ungoye, on the shores of Lake Victoria, where large-scale experiments are planned for the future. The results of the study show that on sorghum (cv. Serena) the initial infestation by the two most important stem borers, *Busseola fusca* and *Chilo partellus*, started from the fourth week after emergence (WAE). A peak density of 21.6 larvae of *B. fusca* per 10 plants was observed at 7 WAE and 2.4 larvae of *C. partellus* per 10 plants at 5 WAE. At harvest almost all the plants in the field were damaged by the stem borers, but the population densities of *B. fusca* and *C. partellus* declined to 10.6 and 0.4 larvae/pupae per 10 plants, respectively.

On maize (cv. Katumani) the incidence of *C. partellus* started 3 WAE, with a peak density of 3.2 larvae per 10 plants at 4 WAE. *B. fusca* started infesting the crop late at 6 WAE and reached a peak density of 1.4 larvae/pupae per 10 plants at 11 WAE. At harvest only 4% of the plants were damaged by these two stem borers, with a negligible density of pest population. Thus incidence of stem borers at the Ungoye field site was higher on sorghum than on maize.

Grain Yield Losses in a Tolerant Sorghum Cultivar

Grain yield losses in sorghum due to the stem borer *C. partellus* have been studied for the last two years. The methodology developed and the information generated in 1985 on the yield losses in the tolerant sorghum cultivar (Serena) in relation to the plant age at the time of infestation and the number of larvae were presented in the *ICIPE 1985 Annual Report*. During 1986 similar studies were conducted on another cultivar, ICS 2, which has been developed at ICIPE. Also, a greater number of densities of the stem-borer larvae has been tested for possible effects on yields. The larval densities tested were 2, 4, 8, 16 and 32 per plant at three crop growth stages: 20, 40 and 60 days after emergence (DAE).

Larval infestation at 20 DAE caused yield losses that increased from 35% at 2 larvae per plant to 98-99% at 16 and 32 larvae per plant. Infestation of the plants at 40 DAE caused losses that, though increasing with larval density, were less than those obtained at 20 DAE. When larval infestation was postponed to 60 DAE, no significant differences occurred in the yield losses among the various levels of larval infestation. In view of the above, it is clear that the grain yield losses in sorghum increase with increased numbers of *C. partellus* larvae per plant up to a maximum of 16 larvae per plant at 20 DAE and that the grain yield reduction caused by the stem borer decreases with increased plant age at the time of larval infestation.

REPRODUCTIVE BIOLOGY AND BEHAVIOUR OF *CHILO PARTELLUS* AND *ATHERIGONA SOCCATA*

G. C. Unnithan, K. N. Saxena

Study of the reproductive biology and behaviour of the stem borer, *Chilo partellus*, continued during 1986.

Factors Governing Mating, Fecundity and Egg Fertility

The factors governing mating, fecundity and egg fertility investigated were the effect of the age of male and female moths on mating, the frequency of mating, the effect of successive matings by the male on the production of fertile eggs, and, in the female, the effects of delayed mating on fecundity and egg fertility.

The percentages of males and females mating declined with the advancing age of the moths. The females usually mated only once in their lifetime, but the males mated up to 9 times in their lifetime, the average number of matings for a male being 4.6 ± 0.4 within a period of about 5 days. Successive mating by the females did not significantly affect the fecundity and egg fertility of the females except that the fertility was reduced after the sixth mating by the male (Table 1). In the absence of mating, oviposition was inhibited or delayed considerably. A maximum number of eggs was laid within 24 hours after mating. A delay in mating for up to 5 days did not significantly affect the total number of eggs laid. On the other hand, a delay in mating affected egg fertility significantly: the percentages of fertile eggs laid by moths mated on day 0 and 4 days after eclosion were 94.8 ± 2.5 and 50 ± 8.8, respectively, and these percentages decreased further with a further delay in mating.

Table 1. Fecundity and egg fertility of *C. partellus* after successive mating by the male

Mating	Eggs/female	Eggs fertilized (%) (angles)
1st	312.18^{b}	73.70^{ab}
2nd	317.91^{b}	76.08^{ab}
3rd	474.73^{a}	81.03^{a}
4th	374.91^{ab}	84.52^{a}
5th	436.30^{a}	69.88^{ab}
6th	391.00^{ab}	59.02^{b}
LSD*	125.72	18.06

Mean values in a column bearing the same superscript letters are not significantly different.
* LSD: least significant difference.

Factors Influencing Pheromonal Trapping of *Chilo partellus*

Studies on the factors influencing the performance of pheromonal traps, initiated in 1985 (*ICIPE 1985 Annual Report*), were continued to improve and standardize trapping methods used to monitor adult populations of *Chilo partellus*. The factors investigated in 1986 were trap height, types of traps, source of pheromone, and interaction between pheromone traps and female populations in the field. In addition, studies were initiated to determine the range of pheromone traps and the relationship between trap catches and female populations.

Trap height

A comparison of pheromone traps set at different heights when the average maize/sorghum crop height was 1.45 ± 0.1 m showed that trap catches decreased with increasing trap height. The percentages of catches

in traps set at 0.5-, 1.0- and 1.5-m heights were 44.5 ± 16.2, 34.3 ± 12.6 and 21.2 ± 13.1, respectively.

Types of traps

The performance of different types of traps that lure males with virgin females was evaluated. The traps tested were the water trap; the sticky tray trap (whose surface area is the same as that of the water trap); and three of the commonly used sticky traps, namely, a Phercon IC trap, the Delta trap and the "Agrotis" sticky trap (supplied by Dr. J. Lofqvist, University of Lund, Sweden). The water trap was the most efficient of all the traps tested (Table 2). However, the sticky traps did catch males and, where water traps are inconvenient, particularly in farmers' fields, may be used effectively for monitoring the pest.

Table 2. Efficiency of water and different types of sticky traps baited with *Chilo partellus* virgin females for trapping males

Traps	Males trapped (%) (±SEM)†	Males trapped per night (no.) (± SEM)†
Water	61.4 ± 3.7**	3.90 ± 0.55
Sticky tray	38.6 ± 3.7	2.59 ± 0.43
Water	61.7 ± 5.3*	4.81 ± 0.70
Phercon IC	38.3 ± 5.3	3.12 ± 0.50
Water	65.6 ± 6.6*	2.74 ± 0.45
"Agrotis"	34.4 ± 6.6	1.50 ± 0.37
Water	71.9 ± 5.7**	4.57 ± 0.58
Delta	28.1 ± 5.7	1.69 ± 0.37

* Differences between the means significant at $P = .01$.
** Differences between the means significant at $P = .001$.
†SEM: standard error of the means.

Sources of pheromone

A synthetic pheromone of *C. partellus* received from the Tropical Development and Research Institute, U.K., was tested against virgin females to compare the ability of the two to attract males. The results showed that one virgin female was about five times more efficient than the synthetic pheromone in attracting males. The mean numbers of males trapped with 1 virgin female and 1 mg synthetic pheromone were 2.0 ± 0.5 and 0.4 ± 0.1, respectively. Even using as high a dose as 5 mg of the synthetic pheromone, the number of males caught per trap by the pheromone was only 0.6 ± 0.2 as against 2.6 ± 0.3 by a virgin female.

Interaction between pheromone traps and female populations in the field

To study the interaction between pheromone traps and female populations in the field, two series of experiments were carried out using virgin females in wire-mesh cages (5 × 8 cm).

In the first series of experiments, a single water trap bearing 2 virgin females was placed in a field plot and surrounded by 24 pairs of virgin females arranged on the circumferences of 3 concentric circles of 2-, 4- and 6-m radii, all circles having the same centre. The control trap was set in an adjacent field plot. The number of males caught by the trap surrounded by 24 pairs of females was significantly lower (0.5 ± 0.2) than that caught in the control trap (6.5 ± 1.0).

In the second series of experiments, 2 traps bearing 2 virgin females each and placed 40 m apart were surrounded by 42 pairs of virgin females placed 10 m apart, the females forming a grid on a 70- × 40-m sorghum plot. The control trap also consisted of two traps but had no female grid. The number of males caught within the female grid was significantly lower (1.0 ± 0.3/trap) than that caught in the control trap (8.2 ± 3.6/trap). These results demonstrate that the female population in the field interfered with the efficiency of the pheromone trap, suggesting that mass-trapping males with pheromone traps for pest management may be interfered with by a high population density of females.

Diversion of Sorghum Shootfly Oviposition to Non-host Plants in the Field

The role of sorghum seedling extract in eliciting sorghum shootfly (*Atherigona soccata*) oviposition on non-host plants was reported in the *1985 ICIPE Annual Report*. Studies conducted in 1986 in cages as well as in fields explored the possibility of using the sorghum extract to divert sorghum shootfly oviposition upon sorghum to oviposition upon maize, the non-host plant. Tests on 3- × 2.5-m caged field plots revealed that shootfly egg-laying was diverted to maize that was planted around sorghum and sprayed with CSH 1 extract: the percentage of treated maize oviposited upon was greater (97%) than the percentage of untreated maize oviposited upon (16%). Furthermore, the percentage of sorghum oviposited upon in the treated plot (79%) was less than that oviposited upon in the untreated plot (93%).

In field trials on 10- × 10-m plots, 2 rows of maize planted around 10 rows of sorghum (Serena) were sprayed with acetone extract of CSH 1. Shootflies laid significantly more eggs on maize in the treated plots than on maize in the control plots. The ratio between maize and sorghum oviposited upon in control plots was 25:75, while in treated plots the ratio was 63:27. In control plots, 23% of the eggs were laid on maize and 77% were laid on sorghum; in the treated plots, 61% of the eggs were laid on maize and 39% were laid on sorghum. In a field trial where 25- × 6-m treated plots comprised strips of maize sprayed with CSH 1 extract alternating with strips of sorghum, about 69% of the maize plants in the treated plots were oviposited upon compared with only about 12% of the maize plants in the untreated plots. Moreover, in the treated plots the percentage of eggs laid on the sorghum strips was significantly lower (by about one-half) than that laid on the sorghum in the untreated plots. These observations suggest that growing maize around sorghum or in strips alternating with sorghum and spraying the maize with an ovipositional stimulant (e.g., host plant extract) can divert significant amounts of shootfly oviposition from sorghum to maize and thus may be useful in shootfly management.

INTERCROPPING FOR CULTURAL MANAGEMENT OF PESTS

E. O. Omolo

Investigations on intercropping during the past few years have shown that certain host/non-host combinations, such as sorghum/cowpea and maize/cowpea, reduce crop-borer attacks, whereas other combinations, such as sorghum/maize, boost pest attack (*ICIPE Annual Report*, 1984 and 1985). The mechanisms of such effects have also been elucidated with reference to crop physiology and have been reported in the *ICIPE 1985 Annual Report*. To refine intercropping as a component of pest management, further investigations have been carried out, as reported below.

Multi-line Intercropping

Although intercropping different plant species has been found to influence pest attack and yields, little information exists on the effects of intercropping different cultivars of one species with one another and with those of other species. A study of this was initiated in 1985. The results of intercropping certain resistant cultivars of sorghum (ICS 1, ICS 2) with those of cowpea (ICV 2) were presented in the *ICIPE 1985 Annual Report*. During 1986 a study was initiated to find out how intercropping different cultivars of the same crop species—sorghum—would affect the crop's pests and yield. The reasons for mixing varieties or lines of the same crop species vary. In this study, the resistant sorghum cultivar IS 4660 was mixed with the tolerant cultivar Serena for protection against *C. partellus* attack. The number of larvae/pupae per plant was monitored 28, 70 and 84 days after germination (DAG). The results (Table 3) indicate that at 28 DAG the number of larvae/pupae on Serena/IS 4660 intercrop was lower (5.0 per 10 plants) than the number on Serena planted alone (6.0). Similarly, at 70 and 80 DAG the number of larvae/pupae per plant on Serena/IS 4660 intercrop was significantly lower than that on Serena pure stand. There were no significant differences in the number of larvae/pupae per plant between Serena/IS 4660 intercrop (6.0 and 4.0) and IS 4660 planted alone (5.4 and 5.9). These observations suggest that Serena was significantly protected by the presence of the resistant line IS 4660.

The resistant line IS 4660 appears to be unadapted (1397 kg/ha) and Serena agronomically adapted (1780 kg/ha) (Table 3). When Serena was intercropped with IS 4660, the yield of Serena, which comprised half of the plot, was 1112.8 kg/ha while the yield of half the plot of Serena that was planted with Serena alone was 890.0 kg/ha. These results support the argument for mixing resistant lines with susceptible lines for protection against insect pest attack. The best proportion for this combination of lines will be investigated next.

Factors Affecting Production Under the Intercropping System

Previous work at the ICIPE Mbita Point Field Station (MPFS) and different ecological zones indicates that the following agronomic factors may influence production in intercropping systems: cultivars, time of planting, plant population/spacing, soil fertility and weeds. The role of these factors in monocultural systems is known, but little is known about the effect of these factors on yield in intercropping systems. In view of this, investigations on the effects and interaction of these factors on yield in selected intercropping systems were initiated during 1986 using a multifactorial experimental design, which included ICIPE's recommended practice and the sub-optimum practice adopted by subsistence farmers.

The results obtained during the year show that crop yield was determined by planting time, cultivars, plant populations and soil fertility, in that order. That soil fertility had the least impact on crop yield in these experiments may be due to the fact that soil fertility at MPFS is relatively good because the soil is regularly fertilized. Further experiments and the processing of the data are in progress and will give more detailed information on the role of these factors, including the second and third order interactions.

Seconded in April 1986 to work with ICIPE's Social Science Interface Research Project.

PLANT RESISTANCE TO INSECT PESTS

The work of the Plant Resistance to Insect Pests (PRIP) section of CPRP is aimed at developing strategies for using plant resistance to insect pests as a component of a pest management system. To accomplish this, PRIP concentrates on three main activities: (1) the evaluation

Table 3. *C. partellus* infestation in resistant/susceptible sorghum varieties intercropped at Mbita Point Field Station, Kenya, during the short rains (1985/86)

	Number of larvae/pupae per 10 plants at different plant stages*				Yield (kg/ha)	
	28 DAG	70 DAG	84 DAG	Mean†	Serena	IS 4660
Serena	6.0	8.1	8.2	7.5[a]	1780.0 (890.03 §)	—
Serena/IS 5660	5.0	6.0	4.0	5.0[b]	1112.8	577.0
IS 4660	3.6	5.4	5.9	4.9[b]	—	1397.8

* DAG: days after germination.
† Mean values bearing the same superscript letters are not significantly different at $P = 0.05$.
§ Figure in parenthesis is yield from half of the Serena plot.

of sorghum, maize and cowpea cultivars from different sources for resistance or susceptibility to the target crop borers, (2) the elucidation of mechanisms of resistance or of susceptibility in these cultivars to pests and (3) the study of the genetics of these plants' resistance to the insects concerned. As reported below, in 1986 PRIP carried out more detailed studies and studies on more cultivars of the target crops than it had in the past.

SORGHUM RESISTANCE/SUSCEPTIBILITY TO STEM BORERS

K. N. Saxena

Work during previous years has shown that the sorghum cultivars originally obtained from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the U.S.A. have varying degrees of resistance to the target stem borers. Furthermore, while a few resistant cultivars, such as IS 4405 and IS 1044, are agronomically useful, many other resistant cultivars have poor agronomic qualities. Other cultivars that are agronomically useful have a high susceptibility to the pests. In order to develop cultivars that will combine pest resistance with other desirable characters and that will suit diverse ecological zones, additional sorghum cultivars from various sources, including local ones, were studied in 1986.

Evaluation for Resistance/Susceptibility

The approach and methods used are the same as those standardized and reported in the *1985 ICIPE Annual Report*. The first-stage evaluation involved planting selected cultivars in single-row plots, the second-stage evaluation, planting in multiple-row plots. The parameters used for comparing the cultivars included infestation and damage levels, on the basis of which the overall resistance/susceptibility indices (ORSI) were calculated (see *ICIPE 1985 Annual Report*). The tolerant cultivar IS 18520 (Serena) has been used as the standard reference, its ORSI value being 1.0.

Of the cultivars subjected to the first-stage evaluation during 1986, all those listed in Table 4 were obtained from ICRISAT except Serena, which is local. The cultivars listed in Table 5 were obtained from the farmers in the neighbourhood of Mbita Point Field Station. Among the cultivars from ICRISAT, IS 12308 had the lowest ORSI and, hence, the highest resistance, followed by IS nos. 1044, 4776, 5585, 13100, 18573 and 18577; PB 8104-1; PS 14413 and PS 19349, which had a low susceptibility relative to the tolerant check IS 18520.

Only one local cultivar, *Nyar Kodipo*, had as low a susceptibility to the stem borers as did IS 1044 (Table 5). The remaining cultivars showed a much greater susceptibility than those listed in Table 5.

On the basis of single-row tests on the above-mentioned cultivars as well as on cultivars tested during pre-

Table 4. Relative differences in the levels of infestation and damage by stem borers in single-row plots of certain sorghum lines from ICRISAT (India) at Mbita (South Nyanza, Kenya) and the overall resistance/susceptibility index of these sorghum lines

	Relative infestation levels*		Relative damage levels*			
Sorghum lines	Eggs	Larvae + pupae	Foliar	Dead-heart	Stem tunnelling	ORSI†
IS 1044	0.2	0.8	1.0	0.5	0.6	0.6 (L)
IS 2123	1.0	1.5	1.2	0.5	0.3	0.9 (M)
IS 2205	1.1	1.9	1.0	1.0	0.4	1.1 (M)
IS 2309	0.6	1.3	1.5	0.5	0.6	0.9 (M)
IS 4776	0.6	1.3	1.0	0	0.5	0.7 (L)
IS 5469	0.6	1.5	1.4	0	0.6	0.8 (L)
IS 5538	0.3	1.4	1.2	0.5	0.4	0.8 (L)
IS 5585	0.9	1.3	1.1	0	0.4	0.7 (L)
IS 12308	0.4	0.2	0.8	0	0.5	0.4 (VL)
IS 13100	0.6	0.6	1.3	0.5	0.4	0.7 (L)
IS 13674	0.5	1.5	1.2	2.5	0.8	1.3 (H)
IS 18333	0.9	1.7	1.2	0.5	0.5	1.0 (M)
IS 18551	0.3	2.0	1.2	0.5	0.6	0.9 (M)
IS 18573	0.6	1.9	1.0	0	0.6	0.8 (L)
IS 18577	1.2	1.7	0.9	0	0.4	0.8 (L)
IS 18579	0.3	1.6	0.9	2.0	0.5	1.1 (M)
IS 18580	0.9	1.6	1.2	0.5	0.5	0.9 (M)
PB 8104-1	0.6	1.2	1.0	1.0	0.4	0.8 (L)
PS 14413	0.4	1.4	1.0	1.0	0.3	0.8 (L)
PS 19349	0.2	1.2	0.9	1.0	0.8	0.8 (L)
PS 19522-1	0.8	1.5	1.1	2.0	0.9	1.3 (H)
PS 1988-1	0.5	1.3	0.8	2.5	0.6	1.1 (M)
PS 28157-1	0.7	1.7	1.2	1.5	0.8	1.2 (M)
ICSV 1	0.2	1.7	1.2	4.0	1.0	1.6 (H)
IS 18520	1.0	1.0	1.0	1.0	1.0	1.0 (M)

* Ratio of each parameter's value for a test line to that for the reference check (IS 19520).

† ORSI: overall resistance/susceptibility index; the lower the index, the greater the resistance and the lesser the susceptibility of the line. VL, L, M and H represent very low, low, medium and high susceptibility levels, respectively.

Table 5. Relative levels of infestation and damage by stem borers in single-row plots of certain local sorghum lines from Mbita (South Nyanza, Kenya) and the overall resistance/susceptibility index of these sorghum lines

	Relative infestation levels*		Relative damage levels*			
Sorghum lines	Eggs	Larvae + pupae	Foliar	Deadheart	Stem tunnelling	ORSI †
Gopari	0.57	1.72	0.79	4.0	0.98	1.6 (H)
Andiwo III	0.76	1.70	0.87	5.5	0.45	1.9 (VH)
Nyar Kambuya	0.68	1.35	1.08	5.5	1.02	1.9 (VH)
Andip Rateng'	0.60	1.63	0.95	5.0	0.69	1.7 (VH)
Andiwo Marachar II	0.51	1.50	0.88	4.5	0.73	1.6 (H)
Nyar Kodipo	0.43	1.30	1.04	0	0.74	0.7 (L)
Nyar Konyango	0.42	1.75	0.87	0.87	3.5	1.4 (H)
Andiwo I	0.42	0.28	0.95	4.5	0.74	1.5 (H)
Nyar Majita	0.92	1.49	0.83	4.0	0.73	1.6 (H)
Ochuti Rabuor I	0.44	1.46	0.96	3.0	0.65	1.3 (H)
Adip Rachar	0.52	1.54	0.96	3.5	0.74	1.4 (H)
IS 18520	1.0	1.0	1.0	1.0	1.0	1.0 (M)

* Ratio of each parameter's value for a test line to that for the reference check (IS 19520) as given in Table 4.
† ORSI: overall resistance/susceptibility index; the lower the index, the greater the resistance and the lesser the susceptibility of the line. L, M, H and VH represent low, medium, high and very high susceptibility levels, respectively

vious years, the eight most promising cultivars were selected for multiple-row tests (Table 6). Of these, IS 1044 continued to show a low susceptibility—that is—a high resistance, to the stem borers, whereas P 967083 showed a high susceptibility to the pests. The remaining cultivars were similar to the tolerant check IS 18520.

Mechanisms of Resistance/Susceptibility of Sorghum Cultivars

In the study of target crop mechanisms of resistance to stem borers *(ICIPE Annual Report,* 1984, 1985), the first phase of the study involves the elucidation of the role of various colonizing responses of the pests determining differences in their populations and, hence, damage on resistant and susceptible cultivars. The second phase elucidates the role of different plant characters determining these responses to resistant and susceptible cultivars.

The role of the colonizing responses of *C. partellus* in determining the resistance or susceptibility of selected sorghum cultivars has been studied for the past three years. The responses that are involved in an insect's colonization of a plant (*ICIPE Annual Report*, 1984, 1985) belong to the following categories: (1) behavioural responses determining the initial selection or rejection of a plant by an insect: orientation (attraction/arrest, repulsion), feeding and oviposition; (2) physiological responses involving the utilization of ingested food by the insect and its nutrition; (3) larval development; and (4) egg-production (fecundity). Of these, the contribution of oviposition, larval attraction, arrest, feeding and development to resistance or susceptibility of 7 sorghum cultivars has been reported in the *ICIPE Annual Reports*, 1984, 1985. During 1986 the role of physiological responses was investigated by comparing the utilization of food by *C. partellus* larvae (fourth instar) from the same seven cultivars and their nutritional effects.

Two series of experiments were carried out. In one, the nutritional effects of the plant leaves were compared by giving to the first-instar larvae different diets incorporating freshly blended or powdered dry leaves of the test cultivars. The development of the larvae on these

Table 6. Relative levels of infestation and damage by stem borers in multiple-row plots of certain sorghum cultivars from various sources and the overall resistance/susceptibility index of those cultivars

	Relative infestation levels*		Relative damage levels*			
Cultivars	Total eggs	Larvae + pupae	Foliar	Dead-heart	Stem tunnelling	ORSI†
IS 4405	0.7	0.9	1.0	1.2	0.8	0.9 (M)
IS 1044	0.5	0.8	1.0	0.3	0.8	0.7 (L)
PS 14413	0.9	0.9	1.6	1.5	0.5	1.1 (M)
83 SR KAT/419	0.8	1.2	1.2	1.0	1.0	1.0 (M)
IS 4881	1.0	0.7	1.4	1.8	0.6	1.1 (H)
P 967083	1.0	1.4	1.3	2.2	1.1	1.4 (H)
Nyar Kambuya	0.9	1.2	1.1	1.7	1.1	1.2 (M)
IS 18520	1.0	1.0	1.0	1.0	1.0	1.0 (M)

* Ratio of each parameter's value for a test cultivar to that for the reference check (IS 18520) as given in Tables 4 and 5.
† ORSI: overall resistance/susceptibility index; the lower the index, the greater the resistance and the lesser the susceptibility of the cultivar. L, M and H represent low, medium and high susceptibility levels, respectively.

diets was compared with that on the normal artificial diet on which they are grown in the culture. The results (Table 7) show that on the diet without any sorghum leaf powder (SLPDD), the percentage of larvae developing to pupal stage was very low (22%) compared with that on the normal diet (ND) (82%). Even the incorporation of cellulose powder in the diet (SLPDD + CP) did not improve larval development. However, the incorporation in the diet of freshly blended leaves of the susceptible cultivars IS 18363 and IS 2146 and the resistant IS 4660 supported as much larval development as the normal diet. Incorporation of freshly blended leaves of the resistant cultivars IS 2205 and IS 1044 reduced the larval development to pupal stage to 44% and 26%, respectively. Incorporation of powdered dry, instead of freshly blended, leaves of IS nos. 18363, 2146 and 4660 was less efficient in supporting larval development (56–66% of the larvae developed to pupal stage). However, the dry leaf powders of the resistant IS 2205 and IS 1044 supported more larval development than the freshly blended leaves. These observations clearly suggest that certain constituents in sorghum leaves are important as nutrients for larval development and that certain constituents present in fresh—but lost in dry—leaves of IS 2205 and IS 1044 serve to interfere with metabolic processes or nutrition in the insect, thereby interrupting larval development.

Table 7. Role of nutritional factors from different sorghum cultivars in determining development of *C. partellus* larvae

Diet*	Insects pupating (%) (mean ±SE) †
ND	82.0 ± 3.7
SLPDD	22.0 ± 5.8
SLPDD + CP	32.0 ± 10.2
SLPDD + IS 18520 L	84.0 ± 6.8
SLPDD + IS 18520 LP	78.0 ± 3.7
SLPDD + IS 18363 L	74.0 ± 5.1
SLPDD + IS 18363 LP	56.0 ± 5.1
SLPDD + IS 2146 L	68.0 ± 11.6
SLPDD + IS 2146 LP	56.0 ± 4.0
SLPDD + IS 4660 L	78.0 ± 5.8
SLPDD + IS 4660 LP	66.0 ± 10.8
SLPDD + IS 2205 L	44.0 ± 5.1
SLPDD + IS 2205 LP	76.0 ± 9.2
SLPDD + IS 1044 L	26.0 ± 6.8
SLPDD + IS 1044 LP	62.0 ± 14.6

* ND: normal diet (Ochieng et al., 1985); SLPDD: sorghum leaf powder deficient diet; CP: cellulose powder; L: freshly excised, blended leaves; LP: dry leaf powder.

† SE: standard error.

In another series of experiments, the consumption, absorption, assimilation and overall nutritive value of the stems of the susceptible IS 18363, the tolerant IS 18520 (Serena) and the resistant IS 1044 were compared. The methods used were modifications of those described earlier by Saxena (Patterns of insect-plant relationships determining susceptibility of resistance of different plants to an insect, *Ent. exp. & Applic.*, 12: 751–766, 1969). The results (Table 8) show that absorption of food ingested by *C. partellus* larvae was almost equally high for all three cultivars. However, assimilation of the absorbed food, that is, its conversion into body tissues, as well as its overall nutritive value, was highest for the susceptible IS 18363, slightly less for the tolerant IS 18520 (Serena) and very low for the resistant IS 1044. Thus, poor assimilation of the food from IS 1044 contributes greatly to that cultivar's resistance.

Strategies using the above information are being formed to develop improved sorghum cultivars.

MAIZE RESISTANCE/SUSCEPTIBILITY TO *CHILO PARTELLUS*

J. K. O. Ampofo

Resistance/Susceptibility of Certain Maize Cultivars in Relation to Plant Age at Infestation

Previous studies have indicated that the maize cultivars ICZ2-CM and MP 704 have high levels of resistance to—and Inbred A high susceptibility to—*Chilo partellus* when the plants are young at the time of larval infestation. During 1986 studies were undertaken to determine

Table 8. Utilization of food ingested by *C. partellus* from the stem of certain sorghum cultivars

Sorghum cultivar	Stem segment	Absorbability* (mean % SE) §	Assimilability † (mean % SE) §	Overall nutritive value # (mean % SE) §
IS 18363	Top	73.6 ± 8.0	10.5 ± 5.8	4.3 ± 1.7
	Middle	77.5 ± 11.4	7.0 ± 2.4	3.3 ± 0.8
	Bottom	78.0 ± 5.0	3.0 ± 0.5	2.2 ± 0.4
IS 18520	Top	81.9 ± 9.0	3.9 ± 2.0	1.5 ± 0.5
	Middle	80.7 ± 6.8	3.9 ± 1.6	2.2 ± 1.6
	Bottom	75.4 ± 7.5	9.0 ± 2.7	5.3 ± 1.5
IS 1044	Top	90.4 ± 2.3	0.2 ± 0.4	1.2 ± 0.4
	Middle	95.0 ± 8.0	1.2 ± 0.3	1.8 ± 0.7
	Bottom	95.2 ± 7.0	0.9 ± 0.2	0.8 ± 0.1

* Absorbability: dry-wt. food absorbed/dry-wt. food ingested.

† Assimilability: dry-wt. gain/dry-wt. food absorbed.

§ SE: standard error.

Nutritive value: dry-wt. gain/dry-wt. food ingested.

the resistance or susceptibility levels of these cultivars at different phenological stages. The cultivars tested were enclosed in cages to reduce contamination. The treatments consisted of infestation at 4, 8 and 12 weeks after plant emergence (WAE) and included a control (no infestation).

The results showed that after 3 weeks of infestation foliar lesions were the main form of damage when plants were infested 4 WAE. Nearly all plants showed this form of damage. Stem tunnelling also occurred but its intensity and extent were low. Infestations at 8 and 12 WAE resulted in stem tunnelling but caused no foliar lesions. Damage (both foliar lesions and stem tunnels) was more severe on Inbred A than on MP 704. Both Inbred A and MP 704, however, suffered more stem tunnelling from infestation at 8 and 12 WAE than did ICZ2-CM. Previous studies have shown MP 704 to be highly resistant to whorl stage (first brood) infestation of *C. partellus*. The present study confirms this resistance but shows MP 704 to be susceptible at flowering stage to the second brood of this pest.

Mechanisms of Maize Resistance/Susceptibility

To investigate the colonizing responses *C. partellus* and the plant factors controlling such responses, seven maize cultivars with varying levels of resistance were grown in a screenhouse for tests on larval feeding (first and third instars), larval growth and development and larval penetration of stems. The results are presented in Table 9.

Larval feeding. The neonate larval feeding was very low. Third-instar feeding was 10–20 times more than the first-instar feeding. Among the cultivars, third-instar feeding was about 4 times as much on ICZ2-CM as on MP 704. Feeding on Inbred A, Inbred G and OH 43 was also high and similar to that on ICZ2-CM.

Larval growth and development. Despite the high level of feeding on ICZ2-CM, larval weight gain during the first 10 days of development was about a third of the weight gained by the larvae on Inbred A. Larval weight gain on ICZ1-CM, MP 702 and MP 704 was the lowest, about a sixth of the weight gained by larvae on Inbred A. None of the larvae collected from MP 704 was beyond the third instar, compared to 30% and 33% of the larvae collected from Inbred A and ICZ2-CM, respectively. Also, at day 20 only 44% and 38% of the larvae from MP 702 and MP 704, respectively, were in the fifth instar, compared with 72% and 62% of the larvae from ICZ1-CM and OH 43, respectively.

Larval penetration of stems. The results suggest that the larvae were able to penetrate equally well at both nodes and internodes. However, there was a difference in the extent of penetration in Inbred A, Inbred G, OH 43 and ICZ1-CM on the one hand (high), and in MP 702 on the other (low). The penetration in ICZ2-CM was intermediate.

Table 9 shows a variability in *C. partellus* larval responses among the parameters measured. Apart from MP 702 and MP 704, which scored low in all the parameters, no other cultivar scored the same level consistently.

OVIPOSITIONAL RESPONSES OF *CHILO PARTELLUS* TO SOME MAIZE CULTIVARS IN RELATION TO THE CULTIVAR'S RESISTANCE/SUSCEPTIBILITY

S. K. Firempong

The incidence of *Chilo partellus* oviposition on five maize cultivars—MP 704, MP 702, MP 701, CMT 178 and Inbred A—was monitored over 13 weeks in a field experiment. Each of the cultivars was planted both as a monovarietal stand and as a multivarietal stand in 10 plots so that there was an equal number of plants of each variety in each stand. The preference for oviposition, in a descending order and irrespective of the stand, was Inbred A, CMT 178, MP 701, MP 702 and MP 704.

A series of screenhouse tests was conducted based on distance- and contact-perceivable characters to find the causes for the above differential oviposition in the cultivars. The methodology followed that reported in the *ICIPE 1984 Annual Report.*

Table 9. A profile of *C. partellus* responses to resistant and susceptible maize cultivars

		Leaf area eaten (cm^2)		Development			Stem penetration	
Cultiva	Oviposition (%)	1st instar	3rd instar	Larval wt. (mg) 10 days	L3* in 10 days (%)	L5 † in 20 days (%)	Penetrating (%)	Tunnel length
Inbred A	19.4	0.07	1.49	37.1	29.5	51.4	83.3	3.3
Inbred G	—	0.08	1.43	12.0	5.4	48.8	100.0	2.7
OH 43	19.7	0.08	1.38	13.2	15.5	61.8	83.3	3.1
ICZ1-CM	11.3	0.06	1.27	5.7	9.0	72.4	83.3	2.9
ICZ2-CM	30.2	0.06	1.60	10.6	32.5	50.2	66.7	2.4
MP 702	12.0	0.02	0.58	5.5	0.0	43.5	66.7	1.8
MP 704	7.4	0.03	0.37	5.7	0.0	37.7	66.7	1.3

* L3: larvae in 3rd instar.

† L5: larvae in 5th instar.

Distance-perceivable characters

No significant differences in oviposition were observed when each of the cultivars was presented as a choice against Inbred A (the susceptible check). But significantly more eggs were recorded for each variety when that variety was matched against a "blank side" of the cage, that is, a side in which there were no plants. To eliminate the role of chemical stimuli, on one side of the cage a sheet of glass was placed between the test plants and the cage; the other side of the cage had neither plants nor glass. Oviposition on the two sides of the cage differed insignificantly, suggesting that visual stimulus is not important in attracting the moths to the plants.

Contact-Perceivable Characters

The basal, middle and apical areas of maize leaves, as well as the upper and lower surfaces of the leaves, were tested. Consistent significant differences were obtained when MP 704 was tested against Inbred A, with the former receiving less oviposition. Even though the other cultivars also received less oviposition than Inbred A, certain parts of the leaves of the other cultivars were as attractive as Inbred A. In tests between each of the cultivars and wax paper (blank), the maize cultivars were significantly preferred. These results indicate that contact-perceivable characters are more important than distance-perceivable characters for *C. partellus* oviposition. The role of surface chemicals in determining such ovipositional preferences is currently under study.

PRINCIPLES DETERMINING CERTAIN COWPEA CULTIVARS' RESISTANCE TO *MARUCA TESTULALIS*

S. H. O. Okech

Previous studies on principles determining the resistance to *Maruca testulalis* by three cowpea cultivars—VITA 1 (susceptible), VITA 5 (resistant) and TVu 946 (resistant)—showed that VITA 5 and TVu 946 elicited a lower level of attraction and arrest/stay of the larvae than VITA 1 (*ICIPE 1985 Annual Report*) and that the architecture of TVu 946 cultivar influenced the rate of infestation of its pods.

Further studies using the above three cultivars were conducted on the role of plant volatiles, humidity and visual stimuli on the larval attraction to/arrest on cowpea plants. Feeding responses to sugars, raw plant juice and methanol extract were also studied.

The volatiles, serving as olfactory stimuli, from the susceptible VITA 1 leaves and flowers were more attractive to *M. testulalis* larvae than the volatiles from TVu 946 and VITA 5.

Chloroform and n-hexane extracts from the cowpea leaves, flowers and pods were attractive to *M. testulalis* larvae when impregnated on a piece of muslin cloth. However, the degree of attraction of the extracts from VITA 1 was higher than that from the resistant TVu 946 and VITA 5.

In tests on the role of humidity (muslin cloth soaked in water) and green colour (cowpea leaf kept behind a glass barrier) in larval orientation, the larvae were attracted to the humidity source but showed no response to the colour green.

Sugars such as glucose, fructose and sucrose were phagostimulatory to *M. testulalis* larvae but not as phagostimulatory as raw juice and methanol extracts from the leaves, flowers and pods of the cowpea. The phagostimulatory responses of the larvae to the extracts were similar for all the three cultivars.

GENETICS OF PLANT RESISTANCE TO INSECTS

R. S. Pathak

Studies were conducted to determine the nature of gene action in resistance to the stem borer, *Chilo partellus*, in maize crosses between susceptible Inbred A and resistant cultivars ICZ1-CM and ICZ2-CM. Six generations (P_1, P_2, F_1, F_2, B_1 and B_2) of three crosses (Inbred A × ICZ1-CM, Inbred A × ICZ2-CM and ICZ1-CM × ICZ2-CM) were evaluated under artificial infestation (20 *Chilo* eggs/plants at 28 days after crop emergence) in a randomized complete block design with four replications. For each plant, observations were recorded on leaf-feeding (1–9 scale), dead-heart, stem-tunnel length, days to 50% tasselling, ear height and grain yield. Data on the percentages of dead-heart and stem-tunnel length were subjected to arc sine transformation for statistical analysis; gene effects were estimated using the generation mean analysis of Hayman (1958).

The frequency distribution of the percentage of dead-heart, the percentage of stem-tunnel length, and leaf-feeding in the parents, F_1s and F_2s, suggested polygenic control of resistance by dominant genes. The segregation of the F_2 population for the percentage of dead-heart and the percentage of stem-tunnel length showed a skewness towards the resistance class, which suggests the dominance of resistance over susceptibility.

Estimates of gene effects on leaf-feeding indicate that both additive and non-additive gene effects were important (Table 10). Similarly, the magnitude of negative dominance gene effects was greater than that of additive gene effects for dead-heart in all crosses. Among gene interactions, dominance × dominance was highly significant in all crosses; however, the magnitude of additive × additive was greater than that of additive × dominance. For stem-tunnel length, additive gene action was more important than dominance gene action.

Gene effects on days to 50% tasselling indicate the importance of additive, dominance and epistatic gene interactions. For each height, the most important gene actions were additive, dominance and additive × additive gene interaction. Highly significant dominance gene effect was found for grain yield among interactions, additive × additive was highly significant in all crosses. The positive additive × additive gene interaction indicates the enhancing effect on grain yield.

Negative F_1 heterosis over mid-parent observed for all three damage parameters—leaf-feeding, dead-heart and stem-tunnel length—suggests dominance of resis-

Table 10. Gene effects for maize resistance to stem borer *C. partellus* in three crosses: (1) Inbred A × ICZ1-CM, (2) Inbred A × ICZ2-CM and (3) ICZ1-CM × ICZ2-CM

Genetic parameter		Leaf-feeding (1–9)	Dead-heart (%)	Stem-tunnel length(%)	Days to 50% tasselling	Ear height (cm)	Grain yield (%/plant)
M (F_2 mean)	(1)	4.4**	17.8**	27.4**	−53.2**	68.9**	81.5**
	(2)	4.6**	15.3**	26.5**	57.7**	83.7**	92.6**
	(3)	4.2**	6.4*	22.4**	51.4**	89.6**	112.3**
Additive (d)	(1)	1.0**	14.3*	5.5**	6.5**	−15.4**	−30.2
	(2)	0.5	5.0	3.6	3.8**	−6.8	−15.8
	(3)	−0.1	−2.9	−1.7	− 3.0**	−13.1*	22.9
Dominance (h)	(1)	−0.9	−61.2**	−2.0	−12.0**	117.6**	582.1**
	(2)	−2.1	−63.4**	−5.9	−17.2**	108.7**	309.6**
	(3)	−9.4**	−16.6**	−0.7	7.9**	26.9	195.8**
Add. × Add. (i)	(1)	−0.4	−30.6	−10.8**	−5.4*	87.8**	260.0**
	(2)	−1.0*	−39.0**	8.6	−15.2**	254.2**	201.0**
	(3)	−0.6	−14.4	4.2	− 4.8**	−4.2	115.4*
Add. × Dom. (j)	(1)	0.8*	−12.0	− 3.4**	0.7	−13.0	−15.8
	(2)	0.5	−23.5*	−5.5	−1.2	5.8	36.5
	(3)	−2.2	−5.1	−1.9	−2.2	4.6	87.6**
Dom. × Dom. (l)	(1)	3.5*	192.6**	154.5**	345.5**	−112.6**	−331.1**
	(2)	−0.6	86.7**	147.1**	233.5**	−79.3	−162.4
	(3)	−0.1	28.6	134.3**	311.9**	−3.3	−48.9

* Significant at 5% level.
** Significant at 1 % level.

tance over susceptibility. Regarding grain yield, highly significant positive F_1 heterosis was found in all crosses and the performance of hybrids between Inbred A × ICZ1-CM (194.9%) and Inbred A × ICZ2-CM (105.2%) was highly encouraging. The dominance of resistance and the high magnitude of positive heterosis for grain yield in all crosses may make commercial exploitation of stem-borer resistant F_1 hybrids possible.

Association analysis between resistance and agronomic characters indicates significant positive correlations between leaf-feeding, dead-heart and stem-tunnel length. All three damage parameters showed strong negative correlations with grain yield, suggesting that these stem-borer damages reduce grain yield significantly. Thus the transfer of resistance genes into agronomically acceptable commercial cultivars/hybrids may increase and stabilize grain yields considerably.

Information from the above studies indicates the viability of the following breeding procedures.

(1) *Back-crossing to transfer resistance genes into an agronomically acceptable cultivar.* If the F_1 hybrid is involved and all parents are susceptible, it may be necessary to transfer the desired resistance into each parent. However, if the resistance is due to dominant genes, it will then be necessary to transfer the resistance into only one parent, as indicated above.

(2) *Recurrent selection for combining good agronomic lines with good sources of resistance.* Reciprocal recurrent selection may be useful in a hybrid breeding programme; it may then be desirable to use two untreated sources of resistance in the two populations.

INHERITANCE OF COWPEA RESISTANCE TO APHID, *APHIS CRACCIVORA*

R. S. Pathak

Previous studies on inheritance of cowpea resistance to *Aphis craccivora* indicated that the resistance was governed by a single dominant gene (*ICIPE 1985 Annual Report*). Further studies were undertaken to confirm the monogenic inheritance of resistance in back-crosses and to determine whether the genes of different resistant cultivars were the same or different.

Three resistant cultivars—ICV 10, ICV 11 and TVu 310—were crossed with the susceptible cultivar ICV 1. The F_1 of ICV 1 × ICV 11 was back-crossed to the susceptible parent ICV 1. The resistant cultivars were also crossed to each other. The parents, F_1s and F_2s, and back-cross progenies were grown in a screenhouse, and seedlings at three days after emergence were infested with 10 apterous adult aphids. Reaction on seedlings was recorded 10 days after infestation by counting susceptible (dead) and resistant (survived) seedlings in each population. All the F_1 seedlings were resistant. F_2 plants of the crosses between susceptible ICV 1 and resistant cultivars ICV 10, ICV 11 and TVu 310 segregated into resistant and susceptible lines in the ratio of 3:1, suggesting that the resistance was governed by a single dominant gene. Further, the segregation of back-cross progenies of the cross ICV 1 × ICV 11 into 1 resistant:1 susceptible confirmed the monogenetic inheritance of resistance.

Analysis of the allelic relationship of genes for resistance in crosses between these resistant cultivars showed

that the resistance genes in ICV 10 and TVu 310 are the same (no segregation in F_2) and are non-allelic to and independent of the resistance gene in ICV 11 (15 resistant:1 susceptible segregation in F_2). Thus, the dominant gene of ICV 10 and TVu 310 was designated as *Ac* 1 while the dominant gene of ICV 11 (mutant) was designated as *Ac* 2.

MULTILOCATIONAL TRIALS OF PROMISING CROP CULTIVARS IN DIFFERENT ECOLOGICAL ZONES

R. S. Pathak, J. K. O. Ampofo

The main objectives of the multilocational trials were (1) to evaluate the selected cowpea and maize cultivars for their reaction to insect pests and (2) to assess yield and adaptability of these cultivars in different ecological zones. The trials were conducted during the long rainy season of 1986 at the following locations.

- Mbita Point Field Station (altitude 1170 m, latitude 0°25′ S, annual rainfall 950 mm [locational at the shores of Lake Victoria], supplemental irrigation available)
- Rusinga Island (3 km west of Mbita and having the same altitude and latitude, erratic low rainfall similar to Mbita, no irrigation)
- National Dryland Farming Research Station, Katumani (altitude 1601 m, latitude 1°30′ S, annual rainfall 726 mm, no irrigation)
- Coast Agricultural Research Station, Mtwapa (altitude 21 m, latitude 3°56′S, annual rainfall 1267 mm)
- Alupe Agricultural Research Sub-Station, Busia (altitude 1220 m, latitude 0°28′ N, annual rainfall 1775 mm)
- National Maize Research Station, Kitale (altitude 1890 m, latitude 1°1′ N, annual rainfall 1191 mm)

Cowpea

Nine promising cowpea cultivars—ICV 1 (ICIPE), ICV 2 (ICIPE), ICV 4 (ICIPE), ICV 5 (ICIPE), ICV 6 (ICIPE), IT820D-889 (IITA), IT83D-442 (IITA), HB48/E10 (Katumani) and HB 419 (Katumani)—were planted in replicated trials at Mbita, Rusinga Island, Alupe, Katumani and Mtwapa. The crops at Mtwapa failed because of poor germination, water logging and weeds. The results of the trials at the other locations showed the following.

(1) The major yield-reducing pests of cowpea at Mbita, Rusinga Island and Alupe were aphids, thrips and *Maruca testulalis*, in that order. All cultivars were susceptible to aphids. Some cultivars were completely destroyed by aphids before flowering. Similarly, all cultivars were susceptible to thrips, though their tolerance levels varied. No aphid infestation was recorded at Katumani, and the leafhopper infestation was generally mild at all locations.

(2) Among diseases, bacterial blight, cowpea mosaic virus, *Ascochyta* leaf blight, *Cercospora* leaf blight and powdery mildew occurred at all locations. Scale disease was serious at Alupe, while *Septoria* leaf blight was serious at Katumani.

(3) The yield of local cultivars ICV 1, ICV 2, ICV 5 and HB 149 was better than that of both cultivars of IITA at all locations, suggesting the better adaptability of local cultivars. The cultivar ICV 4 did better at Rusinga Island than at the other locations.

We propose to include the recently developed aphid-resistant cultivar ICV 12 in future evaluations.

Maize

Four resistant cultivars (MP 701, MP 704, ICZ1-CM and ICZ2-CM) and two susceptible checks (Inbred A and CMT 178) were planted at Mbita, Rusinga Island, Katumani, Kitale and Mtwapa. In addition, one or two local checks were included in each location. At Mbita, Rusinga Island and Katumani all the plants in one-half of each plot were artificially infested by placing an egg mass (20–25 blackheads) in the whorl of 3- to 4-week-old plants. Plants in the other half were exposed to natural infestation. The plots at Mtwapa and Kitale were not infested artificially but were exposed to the natural populations of the prevailing stem borers. Plants in each location were assessed for foliar damage at 7–8 weeks after emergence and samples were split and examined for stem infestation and tunnelling. Larvae recovered during this exercise were identified and recorded.

The trial is still in progress, but data collected so far indicate that materials had a good adaptability at Katumani. The performance of most of the entries in this location was similar to that at Mbita. The cultivars were generally poorly adapted to the conditions at Mtwapa and Kitale; several of the entries showed susceptibility to diseases, particularly leaf rust. Stalk-borer infestations were, however, very low at Kitale.

We propose that future multilocational evaluations include several entries for selection of suitable materials to fit the different agro-ecological zones within Kenya and elsewhere.

BIOLOGICAL CONTROL

The natural enemies of target pests that have been identified as promising agents of biological control include parasitoids such as *Pediobius furvus, Dentichasmias busseolae* and *Trichogramma* sp. and pathogens such as *Nosema* sp., *Panagrolaimus* sp. and *Beauveria* sp. Previous work on the biology of these natural pest enemies was reported in the *ICIPE 1985 Annual Report*. The work done during 1986 is reported below.

PARASITOIDS FOR BIO-CONTROL OF STEM BORERS

G. W. Oloo

Techniques for Mass Culture of Parasitoids

Parasitoids used to control insect pests must be produced on a large scale and therefore must have a food source

that will support maximum fecundity and fast development. Thus, work was initiated in 1986 to develop suitable rearing techniques for *Trichogramma* sp. and *Pediobius furvus*.

With respect to *Trichogramma* sp. (collected initially from *Chilo partellus* eggs in Kenya), *C. partellus* eggs and eggs of the stored grain moth, *Sitotroga cerealella*, were compared for their suitability to support development of the parasitoid. Eggs of *C. partellus* and *S. cerealella* were kept in separate glass vials, each vial containing one mated *Trichogramma* female within a day of its emergence. The female parasitoids were left in the vials without food until they died. The period of development of the parasitoid, the progeny produced per female, the sex ratio of the progeny and the percentage of host eggs parasitized were compared for the two host insect species. The developmental periods for the parasitoids on the eggs of *C. partellus* and *S. cerealella* were the same: 9 days (Table 11). Similarly, the male:female ratio was the same—1:3—for the progeny developing on the eggs of both the hosts. However, progeny production on *C. partellus* eggs was slightly higher than that on *S. cerealella*, and the percentage of the host eggs parasitized was much higher for *C. partellus* (97.5%) than that for *S. cerealella*. Thus, *C. partellus* eggs appear more suitable for rearing this species of *Trichogramma* than *S. cerealella* eggs, though the latter host has been used widely for rearing *Trichogramma* spp. in various other countries.

Table 11. Host suitability: Comparison of *C. partellus* and *S. cerealella* eggs as hosts for *Trichogramma* development in the laboratory (25.6° C, 60% relative humidity)

Biological criterion	Host	
	Chilo eggs	*Sitotroga* eggs
Period of development (oviposition to adult emergence)	9.0 days	9.0 days
Progeny (no. per female parasitoid)	34.5	30.7
Sex ratio (male:female)	1:3	1:3
Parasitism	97.5% (n = 832 eggs)	67.6% (n = 1238 eggs)

As regards *P. furvus*, the suitability of the pupae of its natural host, *C. partellus*, was compared with that of *Galleria melonella*, which is used as host for rearing other lepidopteran parasitoids. A single pupa (within a day of its formation) of each of the two host insect species was exposed to a single mated female parasitoid (within a day of emergence) until the latter died. The period of development of the parasitoid was almost the same (21–23 days) on the pupae of both the host species. Similarly, the male:female ratio in the progeny emerging from both the hosts was the same—1:2. However, the progeny production from *Galleria* was higher than that from *Chilo*. Hence, on the whole, *Galleria* pupae should be more suitable for the production of the parasitoids.

Parasitization Efficiency of Selected Parasitoids

Studies were initiated to examine the parasitization efficiency of *Trichogramma* sp. and *P. furvus* in the control of *C. partellus* in cages in the field. The developmental period for the parasitoid on *Chilo* eggs in the field was almost the same as that observed on *Chilo* eggs in the laboratory. The sex ratios of the progeny in the field and laboratory were also similar. The progeny produced and parasitism in the field, though slightly less than that in the laboratory, were still quite high. These studies indicate that *Trichogramma* adults, when released in the vicinity of the plants bearing *Chilo* eggs, can effectively seek and parasitize the eggs.

With reference to the pupal parasitoid, *P. furvus*, the developmental period and sex ratio in the field were almost the same as that in the laboratory. However, the progeny production per pupa in the field was only about one-half of that in the laboratory. Thus, the parasitization efficiency in the field cage was not as high as that in the laboratory and needs to be improved.

BIOLOGY AND BEHAVIOUR OF *DENTICHASMIAS BUSSEOLAE* HEINRICH

J. W. Bahana

Studies on the development of the parasitoid *Dentichasmias busseolae* Heinrich at various constant temperatures revealed that development was fastest at 35° C, when the parasitoid took 13.4 ± 1.7 days to mature, and slowest at 15° C, when it took 37.1 ± 1.3 days. At both extremes of temperature, there was a high mortality of early instars. Thus the optimal temperature for development was 25–30° C.

Adult *D. busseolae* fed on a honey-water mixture (20% honey) lived longest—45 ± 10 days. Those fed on fresh sorghum stalks (unextracted juices) lived shortest—only 10 ± 3 days. Females generally lived longer than males.

The greatest mean number of eggs (186) was obtained in females that were fed on the honey-water mixture. Females that were not fed oviposited a few but unviable eggs.

The maximum number of emergences of *D. busseolae* adults occurred between 0600 and 1200 hours. No emergence was recorded between 2000 and 0400 hours. There was no difference in the pattern of emergence of the sexes. Mating was observed throughout the daylight hours but little mating was noted during hours of darkness.

TETRASTICHUS SESAMIAE: A PUPAL PARASITOID OF *MARUCA TESTULALIS*

J. B. Okeyo-Owuor

Tetrastichus sesamiae Risbec (Hymenoptera: Eulophidae) has been reported to parasitize the pupae of the cowpea

pod borer, *Maruca testulalis* Geyer (Lepidoptera: Pyralidae), at the ICIPE Mbita Point Field Station, in western Kenya. To develop methods for using this parasitoid in a pest management programme, information was collected in 1986 on its biology, particularly its mating, oviposition, longevity, progeny production and development.

Mating and Oviposition Behaviour

T. sesamiae adults emerged from parasitized host pupae during the day between 0700 and 1200 hours, with the majority emerging between 0800 and 0900 hours. Mating started immediately after adult emergence, with the males being more active than the females. Courtship and mating in one pair could take up to one minute. Both sexes mated several times throughout their lifetimes. Oviposition occurred in both mated and unmated females and there was no distinct time lapse between mating and oviposition. *T. sesamiae* laid eggs over a period of up to 6 days during which time up to 5 host pupae were preferred for oviposition. Teasing eggs from the abdomen of females revealed that fecundity was variable and that among unfed virgin females the number of eggs ranged from 13 to 121; the largest number of eggs was found when dissecting the females 24 hours after emergence (mean = 63.5 ± 7.5).

Longevity, Progeny Production and Development

Longevity of *T. sesamiae* was variable, with the means ranging from 4.3 ± 0.6 to 13.9 ± 4.2 days, depending on the quality of food substrate. Unfed parasitoids lived no longer than 5 days. However, the longevity of parasitoids fed on various acqueous concentrations of sucrose and honey increased. Adults fed on a honey-water solution (20% honey) lived longest. Progeny production per female ranged from 0 to 263 depending on food quality. The highest progeny occurred in females fed on the honey-water solution. Progeny production also depended on the age of the host pupae. In 0-day-old pupae, the mean progeny production per female parasitoid was 142 ± 11.3 compared with 67.4 ± 15.5 production in 5-day-old pupae. When the parasitoids were exposed to pupae older than 5 days, parasitization occurred, but the progeny failed to develop to adult parasitoids.

A NEMATODE (*PANAGROLAIMUS* SP.) FOR THE CONTROL OF CROP BORERS

W. A. Otieno

Insect nematodes can serve as important biological control agents against crop pests because of the worms' ability to seek and destroy their insect hosts, which are usually hidden in stem tunnels or pods. The use of insect nematodes to control stem borers in orchard crops is already being practised in many countries.

Because temperature influences infectivity of the nematode, eight temperatures were selected for testing nematode response (15° C to 40° C). Greater wax moths, *Galleria melonella* (last larval instars), were exposed to pre-parasitic infective juvenile nematodes (20 000/10 *Galleria* larvae). After 48 hours most larvae died. Dead larvae were transferred to an incubator (Baird and Tatlock) and tested at different temperatures. The duration before emergence of the nematode was recorded for each temperature.

At temperatures lower than 18° C and higher than 35° C the nematode became inactive. The optimum temperature range for the nematode was between 25° C and 30° C. At 15° C it took 15 days after infection for the new juveniles to emerge; at 30° C it took only 4 days. Nematode activity and the time it takes the nematode to develop are thus apparently partly determined by temperature.

SEASONAL INCIDENCE OF A FUNGUS (*BEAUVERIA* SP.) IN *B. FUSCA* AND *C. PARTELLUS* IN SORGHUM AGRO-ECOSYSTEMS

W. A. Otieno

It was reported earlier (*ICIPE 1985 Annual Report*) that a local isolate of *Beauveria* sp. was causing high natural mortality in the maize stalk borer, *B. fusca*, in farmers' fields in the neighbourhood of Mbita Point Field Station. To obtain a clear picture of the impact of *Beauveria* on the cereal stem borers (*B. fusca* and *C. partellus*), a long-term ecological study on its occurrence has been initiated.

A weekly sampling was taken over fourteen weeks (covering an entire cropping season) on farmers' fields at four different sites. About 100 sorghum plants per site were dissected and all live and dead larvae recovered and recorded. Evidence for the fungus being the conclusive cause of death was ascertained in the laboratory through incubation (at 30° C) and microscopy (phase-contrast compound microscope, "Leitz 20-EB Ortholux").

APPLICATION OF *NOSEMA* SP. TO SORGHUM PLANTS INFESTED WITH *CHILO PARTELLUS* EGGS

M. O. Odindo

It was reported in the *1985 ICIPE Annual Report* that the application of *Nosema* spores suspension to sorghum plants infested with first-instar *Chilo partellus* larvae effectively controlled the borer. Since such a sprayed material may not reach the interior of the funnel where first- and second-instar larvae feed, an investigation was conducted in 1986 to determine whether the eggs or the larvae emerging from these eggs on the exposed outer leaves would be infected and killed by the pathogen.

Sorghum plants were grown in three plots in a screenhouse and were tested 3 weeks after planting. Plants in the first two plots were infested with egg masses pasted on the bottoms of the leaves.

The plants of group 1 (*Nosema* treated) were inoculated by a foliar application of a semi-purified acqueous

suspension of *Nosema* spores immediately after egg infestation. The plants of group 2 (untreated/infested control) were infested with eggs and treated with distilled water. The plants of group 3 (untreated/uninfested control) were left untreated and uninfested.

The foliar damage by the larvae on the untreated/infested plants was much greater than that on *Nosema*-treated or untreated/uninfested plants. The larval damage to the stem, measured in terms of tunnnel length as a percentage of plant height; was much higher for untreated/infested plants (21.5%) than for the *Nosema*-treated (2.5%) or for the untreated/uninfested (3.9%) plants (Table 12). Similarly, the numbers of infestation and emergence holes per plant were much higher in untreated/infested plants than in *Nosema*-treated or untreated/uninfested plants. The number of larvae recovered per plant was higher for untreated/infested plants than for untreated/uninfested plants or *Nosema*-treated plants. The percentage of plants bearing fully formed heads was lower in untreated/infested plants (64.9%) than in untreated/uninfested plants (96.6%) or *Nosema*-treated plants (98.3%).

Table 12. Size of plants and tunnelling in sorghum infested with eggs of *C. partellus* and treated with *Nosema* sp.

Treatment of plants	Height of plants (cm) (mean ± SD*)	Stem-tunnel length (cm) (mean ± SD*)	Plant height tunnelled (%)
Infested, inoculated	165.5 ± 16.3[a]	4.1 ± 7.5[a]	2.5[a]
Non-infested	171.3 ± 24.2[a]	6.7 ± 10.9[a]	3.9[a]
Infested, non-inoculated	139.7 ± 18.0[b]	30.1 ± 15.7[b]	21.5[b]

Mean values in a column bearing different superscript letters are significantly different at $P = 0.01$ by Duncan's multiple range test.
* SD: standard deviation.

To examine the effect of direct application of the suspension of *Nosema* spores to the eggs, moths were allowed to lay eggs on wax paper and the eggs were then sterilized. One group of egg batches was treated with a drop of suspension of *Nosema* spores; another group of egg batches was treated with distilled water. The percentages of eggs hatching in both groups were almost equally high: 83.0% for the *Nosema*-treated eggs and 87.9% for the control; the difference was not significant at $P = 0.05$.

The above results demonstrate that spraying a suspension of *Nosema*-spores in an appropriate concentration on sorghum plants that bear *C. partellus* eggs has no ovicidal effect, but the activity of the suspension of spores lasts long enough to infect and kill the larvae emerging from the eggs when they hatch. Consequently, the damage to plants and yield loss due to the stem borer is greatly reduced.

In 1987 the pathogen will be tested under field conditions. It is envisaged that these studies, by identifying the most appropriate period in which to apply pathogens, will lead to effective use of the microsporidian in an integrated pest management programme.

BIOTAXONOMY OF THE CASSAVA GREEN SPIDER MITE, *MONONYCHELLUS*: A MORPHOLOGICAL STUDY

L. M. Rogo

The cassava green spider mite, *Mononychellus* spp. (Tetranychidae), was brought to Africa from South America through infested cassava cuttings. Two species, *Mononychellus tanajoa* Bondar and *M. progresivus* Doreste, have been identified as the most important pests of cassava in Africa. These two species are very closely related. In the past the females of one species were differentiated from the females of the other by the length of the dorsal central body setae (D1, D2 and D3) in relation to the longitudinal distances between the bases of these setae. However, the validity of the presence of the two species became questionable, necessitating a review of the taxonomic status of the *Mononychellus* spp. in Africa. The following studies of ICIPE's cassava scientists were therefore designed to re-examine the relative importance of the existing diagnostic characters to establish the precise identity of *Mononychellus* spp. present on cassava in Africa.

(1) Studies on *Mononychellus* spp. from their countries of origin (Brazil and Venezuela) based on parameters used by previous workers revealed no correlation between the body length and the length of the dorsal central body setae (D1–D3). Although the length of the dorsal central body setae had been used by several workers as a diagnostic character for *M. tanajoa* and *M. progresivus*, our measurements revealed that it was difficult to separate *M. tanajoa* from *M. progresivus* because the measurements of the dorsal central body setae varied from short to long in a continuous gradient. Moreover, there was no variation in the tibia 1 setal count in specimens of *M. tanajoa* from Brazil and *M. progresivus* from Venezuela: the leg segment always had 9 tactile setae and 1 sensory seta. All the males examined had terminalia similar to that described for *M. progresivus*.

(2) Studies conducted on *Mononychellus* spp. from Africa involved the measurements of parameters used by previous workers and additional parameters for numerical taxonomy. The lengths of all the dorsal body setae (5 dorsal centrals, 4 laterals, 3 propodosomals and the humeral), representing a total of 13 characters, were measured on 12 operational taxonomic units from 9 locations in Kenya and from 1 location each in Uganda and Tanzania, making a total of 132 operational taxonomic units. Using a computer programme of Principal Component Analysis (PCA), the data were analysed. The analysis provided a new set of data known as the Principal Component Scores (1–10). The first three principal component scores that had the highest percentage variance were plotted against one another into scatter plots so as to compare the relationships among the operational taxonomic units. The PCA also provided the normalized eigenvectors (weightings).

The analysis indicated that the highly weighted and therefore the most variable characters (listed in order) were the laterals (L1, L2), the third dorsal central body

setae (D3) and L3. The first three principal component scores plotted against each other showed some highly varied forms, especially from Msambweni (Kenya Coast) and Musoma (Tanzania). The relationships displayed suggest that in the populations so far examined there exists only a single species with several forms or biotypes. This was further confirmed by the low percentage variances of 36.3% and 11.2% on the first and second principal component scores, respectively.

GENETIC TAXONOMY OF THE CASSAVA GREEN SPIDER MITE COMPLEX

T. N. Murega

Hybridization experiments were carried out on six strains of the cassava green spider mite (CGM), *Mononychellus* spp. A total of 18 cross combinations, including reciprocal crosses, were tested.

Various degrees of intrapopulation and interpopulation semi-incompatibilities occurred in the F_1, F_2 and F_3 generations. The arrhenotokous mode of parthenogenesis (haplo-diploidy) also occurred: unfertilized diploid mothers ($2n = 6$) gave rise to haploid sons only ($n = 3$). The semi-incompatibility shows a lack of complete genetic divergence in these inherently heterogenous populations. Complementary morphological studies showed the existence of long, short and intermediate setal forms, the latter occupying an area of overlap between the other two setal forms. All three forms are capable of partial gene exchange.

Because these forms are insufficiently isolated, they have not accumulated enough genetic differences to make them genetically distinct. There is genetic evidence of evolutionary divergence taking place under natural selection, but this divergence is not so irreversible as to result in the attainment of a species status.

These studies, therefore, strongly suggest that CGM consists of a single species of several complex forms and probably biotypes that are not fully isolated geographically.

THE POTENTIAL OF MITE PATHOGENS FOR BIOLOGICAL CONTROL OF THE CASSAVA GREEN SPIDER MITE

J. Bartkowski

Field and laboratory tests have been carried out to determine the potential of pathogens to control the cassava green spider mite, *Mononychellus* spp. Dead mites were recovered from 24 field locations that were visited in a test. Fungi were found in 30.9% of the mite cadavers, and 22 fungal isolates were recovered. However, laboratory bioassays showed that some of these isolates were saprophytes.

The isolates MP 9, MP 15, MP 17, MP 18, MP 20, MP 21 and MP 22 caused a percentage of mortality in mites that ranged from low (5.3%) to high (73.3%). The isolates MP 14 and MP 19 belong to known genera of mite pathogens, *Entomophthora* (= *Neozygites*) and *Hirsutella*, respectively. Some of these fungal isolates can be easily cultivated in a potato-extract medium. Some of the isolates are not yet identified conclusively since they differ from known pathogenic species of mites or insects. Laboratory tests with *Beauveria bassiana* isolated from local lepidopteran pests show that the mite is susceptible to this fungus.

Preliminary investigations show the presence of pathogenic fungi in Kenyan populations of the cassava green spider mite. The isolates that caused a high level of mite mortality in laboratory and potted plant bioassays are being tested in small field plots to determine their potential for field application.

BIOLOGICAL CONTROL OF THE VECTORS OF CITRUS GREENING DISEASE

C. K. P. O. Ogol

The objectives of this research were to survey the vectors of citrus greening disease in Kenya, to collect and identify the parasitoids and hyperparasites of the vectors and to determine the feasibility of controlling the vector by insectary rearing of the major parasitoids and timely release of such parasitoids in appropriate areas.

Field surveys conducted in various parts of Kenya to determine the incidence and distribution of citrus greening disease and its vector, *Trioza erytreae*, revealed that both the disease and the vector occurred everywhere except in the warm lowland areas, suggesting that the vector and the greening causing bacteria-like organism are heat intolerant.

A number of parasitoids and hyperparasites—which include two *Tetrastichus (Tamarixia)* species, *T. sicarius, Dilyta* sp., *Aphanogmus triozae, Syrphophagus cassatus* and *Syrphophagus* sp. nov.—were found to parasitize *T. erytreae*. Of these, *Tetrastichus* sp. 1 was the most predominant (70.3%). A mean rate of parasitism of 16.5% was obtained from field samples.

Parasitoids were reared on a psyllid culture maintained on potted citrus seedlings grown in cages. A study was conducted on some aspects of the biology of *Tetrastichus* sp. 1.

Though parasitoids were not released in fields, a psyllid culture and *Tetrastichus* sp. 1 parasitoid were left to co-exist in cages. The psyllid culture was reduced to almost nil within a two-month period, indicating the potential of this parasitoid to control the psyllid.

INCIDENCE OF PARASITOIDS AND PATHOGENS ON CROP BORERS IN RELATION TO AGRO-ECOLOGICAL ZONES

G. W. Oloo, M. O. Odindo, W. A. Otieno

To find out how the distribution of natural enemies of crop borers varies from area to area in various ecological zones, a project was started in 1986 to collect samples of parasitoids and insect pathogens. The first area selected for this work was the Coastal Agricultural Research Station, Mtwapa, at the Kenya Coast, which has a hot and

humid climate, with high bimodal rainfall distribution (March to June and September to November).

The cowpea pod borer, *Maruca testulalis*, and cereal stem borer, *Chilo orichalcociliellus*, recovered from cowpea and sorghum crops, respectively, were maintained on a natural diet until pupation or death. Larval cadavers were examined for the presence of parasitoids or pathogens. The results showed a high incidence of monococci and mycoses (Table 13). Of interest was the absence of protozoans and viruses. Nematodes occurred only in *C. orichalcociliellus* and at a low level.

Table 13. Incidence of pathogens in *M. testulalis* and *C. orichalcociliellus* at Mtwapa, Coast Province, Kenya

	Infections (%)	
Pathogen	*M. testulalis*	*C. orichalcociliellus*
Bacteria		
Cocci	41.7	32.7
Bacilli	30.6	11.5
Fungi		
Mycelia/conidia	9.7	19.2
Hyphal bodies	5.6	7.7
Yeasts	—	19.2
Nematodes	—	1.9

Among the parasitoids, *Pediobius* sp. and *Apanteles* sp. were recovered from *C. orichalcociliellus* and *Sesamia calamistis*, respectively (Table 14). *Trichogramma* sp. was also recovered regularly when *C. partellus* and *C. orichalcociliellus* eggs were seeded on the maize plants.

Table 14. Level of infestation and parasitism on borers at the Coastal Agricultural Research Station, Mtwapa, Kenya

		Total number of parasitoids recovered	
Pest species	Mean larval numbers/plant	*Pediobius* sp.	*Apanteles* sp.
Chilo partellus	0.09	—	—
C. orichalcociliellus	0.25	—	72*
Sesamia calamistis	0.05	142†	162§

* Progeny from 1 *Chilo orichalcoceliellus* 5th-instar larva.
† Progeny from 1 *Sesamia calamistis* pupa.
§ Progeny from 3 *S. calamistis* 4th- and 5th-instar larvae.

In the future these studies will be repeated and expanded to include other ecological zones.

INSECT MASS-REARING TECHNOLOGY

In 1986 the Insect Mass-Rearing Technology (IMRT) section for the first time made efforts to develop an effective liquid artificial diet for the phytoseiid mites (predators) of the cassava green spider mite. In addition, IMRT continued to supply target insects and animals and to offer its services to various ICIPE programmes and units.

ARTIFICIAL DIET FOR PHYTOSEIID MITE

R. S. Ochieng

To sustain the predacious phytoseiid mite, *Amblyseius teke* P & B, in transit and also on release in the field before it encounters the host cassava green spider mite, several artificial diets of solid and liquid forms were developed and tested. Among them, the liquid diet ICD 286—which consists of 10 g each of milk powder (lactogen) and commercial bee honey, 30 g egg yolk, 1 g Wesson's salt and 50 ml distilled water—was found to be the most promising.

The liquid substrate was prepared and dispensed, with a 5-ml disposable syringe, on the bottom of a small plastic medicine cup turned upside down. Parafilm was stretched over the substrate to provide a thin feeding membrane for the mites (Figure 1). A paper comb was placed on the parafilm to confine the mites on the substrate and to provide a refuge for the mites. A piece of plasticine was used to fix the medicine cup firmly on the bottom of a plastic lunch box (16 cm long, 10 cm wide, 6.5 cm deep) (Figure 1). Cotton wool of 1.5-cm thickness was placed on the bottom of the lunch box and soaked with water to provide a barrier against mite escape. The top of the lunch box was then covered with black cotton cloth firmly fixed with a plastic lid with six holes (each 1 cm in diameter) to provide ventilation.

The quality of the diet as a medium for development and reproduction of the phytoseiid predator *A. teke* was determined by conducting comparative tests on the natural diet (red spider mites) and the artificial diet; the biological data is presented in Table 15. The results clearly show that although the rate of development of *A.*

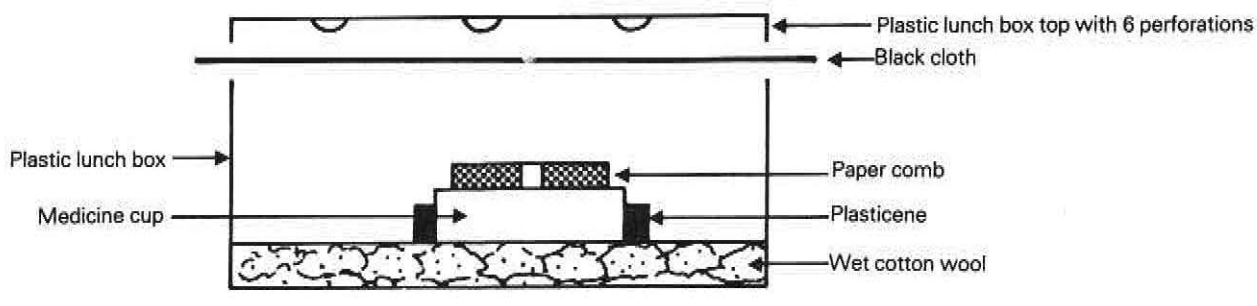


Figure 1. Apparatus for rearing the phytoseiid mite *Amblyseius teke*.

Table 15. Development and reproduction of the predacious mite, *A. teke* P & B, on the liquid artificial diet ICD 286 as compared with that on the natural prey, *Tetranychus* sp., in laboratory feeding experiments at 26° C

Biological criterion*	Artificial diet	Natural diet (prey)
Developmental period		
Egg	2.0 days	2.0 days
Larva	0.5 days	0.5 days
Protonymph	2.0 days	1.0 days
Deutonymph – adult	2.0 days	1.0 days
Pre-oviposition period	5.0 days	2.0 days
Total life cycle (egg – adult)	10.9 days	5.9 days
Fecundity (eggs/female)	32.0	36.0
Eclosion rate	93.1%	93.8%
Sex ratio (male:female)	1:4	1:4
Longevity (adult female)	26.0 days	21.0 days
Survival rate (egg – adult)	89.9%	72.3%

*Observations made on 100 eggs, each egg placed on a medicine cup with the diet to develop to adult stage.

teke was slower on the liquid diet ICD 286 than on the natural prey, the fecundity, eclosion rate, sex ratio, longevity and stamina of the mites fed on the artificial diet were comparable to that of mites fed on the prey. On the artificial diet, data of fifteen generations were recorded.

A colony of *Glossina pallidipes* was maintained at 6000 mated females with a provision to increase the numbers on request. In Nairobi a *G. morsitans* colony was maintained at a maximum of 5000 to 6000 mated females.

Shortfalls arose when tsetse colonies became contaminated with aflatoxin in rabbit blood, causing heavy adult mortalities. To overcome this food contamination problem, a quality-control process has been initiated in which feed newly delivered by a manufacturing firm is given to three marked rabbits for one month. Ninety newly emerged tsetse adult females are then fed on these animals and their biological performance is followed. If any abnormality is noticed, that particular feed stock is destroyed.

ICIPE–IRRI RESEARCH PROJECT

The ICIPE-IRRI Research Project on the Rice Brown Planthopper is supported by core funds from ICIPE, Nairobi, Kenya, and by partial funds from the International Rice Research Institute (IRRI), Los Baños, Laguna, the Philippines. We are deeply indebted to Dr. M. S. Swaminathan, Director-General of IRRI, and Professor Thomas R. Odhiambo, Director of ICIPE, for their keen interest in the project and for providing us with excellent research facilities. We also take pleasure in thanking, at IRRI, Dr. Mano D. Pathak, Director of Research and Training, and Dr. B. M. Shepard, Head of Entomology Department, and, at ICIPE, Dr. Dean Haynes, Deputy Director, and Professor K. N. Saxena, Programme Leader, Crop Pests Research Programme, for their interest, suggestions and cooperation.

ICIPE–IRRI RESEARCH PROJECT ON THE RICE BROWN PLANTHOPPER, *NILAPARVATA LUGENS* (STAL)

Ramesh C. Saxena

The ICIPE-IRRI Research Project on the Rice Brown Planthopper (BPH), *Nilaparvata lugens* (Stal), a major rice pest, was initiated in August 1977 at IRRI, Los Banos, the Philippines. The project was initially supported by funds given by the Australian Development Assistance Bureau to ICIPE and IRRI. The research programme is now supported by ICIPE core funding and by IRRI funding.

The project has collected significant information on such subjects as BPH-rice plant interactions, host range, biotypes, morphometric variations, cytogenetics, hybridization, inheritance, mating behaviour, colour morphs, enzyme polymorphism, wing morphism, flight behaviour, migration, disease transmission, effects of traditional agricultural practices, trap crop and use of botanical pest control agents. The techniques developed and the principles formed from the above findings are now being applied in the study of rice pest management and varietal resistance to pests other than BPH, such as the whitebacked planthopper (WBPH), *Sogatella furcifera* (Horváth); the green leafhopper (GLH), *Nep-hotettix virescens* (Distant); the striped stem borer, *Chilo suppressalis* (Walker); the leaffolder, *Cnaphalocrocis medinalis* (Guenée); and the rice caseworm, *Nymphula depunctalis* (Genée).

In 1986 our studies included such topics as the biochemical basis of BPH resistance, variation in specific proteins in four BPH biotypes, host preferences of the grass-infesting BPH biotype, genetic polymorphism in green leafhopper *Nephotettix* species and effects of rice plant volatiles on the behaviour of *C. suppressalis* larvae. The concept of using a trap crop against *N. virescens*, the vector of tungro virus, was successfully implemented. The golden apple snail, *Pila leopordvillensis* D'Orbigney (subclass, Prosobranchia; order, Mesogastropoda; family, Pilidae), was observed to be a pest of young rice seedlings in freshly transplanted fields.

Studies on the use of neem (*Azadirachta indica* A. Juss) seed derivatives for rice insect pest management were expanded further with two research grants: one from the Asian Development Bank (ADB) and one from the Swiss Development Corporation (SDC). National programmes in Bangladesh, China, India and the Philippines are collaborating with IRRI and the East-West Center, Hawaii, in an ADB-sponsored project. Adaptive experiments are being conducted under farmers' field conditions to assess the effectiveness of neem derivatives for controlling major rice pests.

A simple method was developed for extracting neem-seed "bitters" as a crystalline, brown powder, which is water soluble, systemic, relatively photostable and non-phytotoxic. This extract effectively checked the population increase of planthopper and leafhopper pests but was harmless to their natural enemies. Its efficacy is being evaluated in field trials.

Under a SDC-sponsored project, the effectiveness of derivatives of neem and other promising plants such as sweetflag (*Acorus calamus* L.) and turmeric (*Curcuma longa* L.) is being tested against the pests of stored rice. A technique, based on ethylene production by young rice seedlings, was developed to estimate comparative insect infestation in stored rice.

The results of the above studies are reported below.

BPH Biocidal Factors

Dosage-mortality curves from bioassays of silica gel column fractions of IR 8 (susceptible) and IR 26 (resistant) showed that the most active fractions had relatively low R_f values—R_f 0.15 for IR 8 and R_f 0.11 for IR 26—on thin-layer chromatography on silica gel using 80:20:1 (by volume) hexane-diethyl ether-acetic acid. Similar results were obtained with BPH biotype 2, although the dosages for 50% mortality were higher than those for biotype 1. Chemical characterization of these fractions by scientists at the United States Department of Agriculture Western Regional Research Center showed that the main component was palmitic acid. The active components are still being characterized.

Responses of Rice- and Grass-Infesting BPH Biotypes

Recently a population of *N. lugens* was found thriving on *Leersia hexandra* Swartz, a weed grass common in rice fields. We studied orientational and settling responses, feeding behaviour, metabolism of ingested food, growth, adult survival, egg production, oviposition and hatchability of eggs of the two *N. lugens* populations on TN 1 rice plants and on *L. hexandra* grass. TN 1 plants were most suitable for the establishment of the rice-infesting population, as demonstrated by their feeding responses (Figure 2). Individuals derived from one host did not thrive on the other host due to a significant reduction in feeding, assimilation of food, growth, longevity and fecundity (Table 16).

Protein Patterns on BPH Biotypes

Soluble proteins of newly emerged adults of rice-infesting biotypes 1, 2 and 3 and of the grass-infesting biotype were studied using polyacrylamide gel electrophoresis. Proteins were detected by staining with a 1% commasie blue:12.5% trichloroacetic acid mixture (1:25 v/v). A general zymogram of each biotype was prepared by

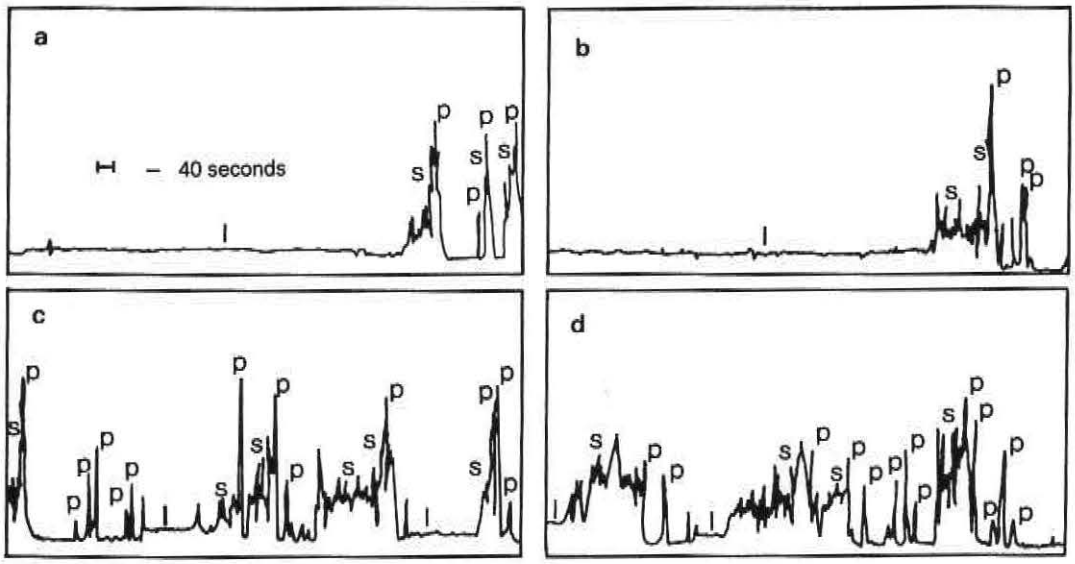


Figure 2. Electronically recorded waveforms during *N. lugens* feeding by (*a*) rice-infesting females on TN 1 plants, (*b*) grass-infesting females on *L. hexandra* plants, (*c*) rice-infesting females on *L. hexandra* plants and (*d*) grass-infesting females on TN 1 rice plants. P = probe. S = salivation. I = ingestion. (Right to left.)

Table 16. Growth, longevity and fecundity of rice- and grass-infesting *N. lugens* adults on TN 1 rice plants and on *L. hexandra* grass

N. lugens	Plant	Nymphs becoming adults (%)	Longevity (days)		Fecundity (no. of eggs laid per female)
			Male	Female	
Rice infesting	TN 1	97 ± 4.8	21.6 ± 1.6[a]	24.9 ± 1.5[a]	514 ± 133[a]
Rice infesting	*L. hexandra*	0.0	2.9 ± 0.5[b]	2.6 ± 0.2[b]	0[b]
Grass infesting	TN 1	0.0	2.0 ± 0.4[c]	2.1 ± 0.3[c]	0[b]
Grass infesting	*L. hexandra*	95 ± 7.1	18.3 ± 1.7[a]	22.5 ± 1.9[a]	356 ± 75[a]

Within a column, mean values bearing the same superscript letters are not significantly different at the 5% level by Duncan's multiple range test.

superimposing the bands found in replicates. The intensity of bands was noted.

Thirty bands were detected for the four biotypes. Biotypes 1, 2 and 3 had 25, 22 and 21 bands, respectively, and the grass-infesting biotype, 21 bands.

Similarity index values (Table 17) were computed by dividing the number of similar bands by the sum of similar and dissimilar bands. Proteins in biotypes 2 and 3 showed the greatest similarity, followed by proteins in biotypes 1 and 3, in biotypes 2 and 1, in biotype 2 and the grass-infesting biotype, in biotype 1 and the grass-infesting biotype, and in bioytpe 3 and the grass-infesting biotype.

Epicuticular Wax of BPH Biotypes

Epicuticular wax of BPH adults was examined for differentiating individuals of BPH biotypes reared on their respective hosts for 7 days. Hexane extracts after overnight soaking of either 200 males or 100 females of BPH biotypes 1, 2 and 3 and the biotype infesting grass, *Leersia hexandra*, were concentrated and injected into a column of 4% OV101 on Chromosorb W-HP 100-120 mesh. Biotypes could not be differentiated due to variations in the elution time and height of chromatographic peaks. In one set, the three rice BPH biotypes were distinguished by two peaks eluting at 24° C and 209° C; the grass-infesting biotype had a large peak at 390° C, but other trials were inconclusive. Even rearing biotypes 2 and 3 on TN 1 plants instead of on their respective hosts, Mudgo and ASD 7, affected the gas chromatograph pattern of their epicuticular waxes. Extraction by dipping in chloroform, instead of hexane, for 2–15 seconds did not improve the reproductivity of scans.

Genetic Polymorphism in GLH

Genetic polymorphism in *N. virescens* was studied using horizontal starch gel electrophoresis. Out of 18 enzyme loci investigated, 14 were polymorphic. Other enzyme loci are being examined to estimate the extent of genetic differentiation within the species.

Soluble Proteins of Three GLH Species

Using polyacrylamide gel disc electrophoresis, 45 protein bands were detected among *N. virescens*, *N. malayanus* and *N. nigropictus* species. *N. malayanus* and *N. virescens* each possessed 36 bands, while *N. nigropictus* had only 28 bands. Six bands (numbers 19, 22, 31, 37, 38 and 39) were specific for *N. malayanus*, four bands (numbers 12, 33, 34 and 35) were specific for *N. virescens* and one band (number 17) was specific for *N. nigropictus*.

Similarity index values were computed (Table 18). Proteins in *N. malayanus* and *N. virescens* showed the greatest similarity, followed by proteins in *N. nigropictus* and *N. virescens* and lastly by proteins in *N. malayanus* and *N. nigropictus*.

Brain Cells and Chromosomes of BPH

Using a lacto-aceto-orcein staining technique, we observed mitotic brain cells of fourth-instar BPH nymphs. Premetaphase chromosome counts established the normal diploid complement at 2n = 30 (28 autosomes and an XX [female] or XY [male] sex chromosome system). The X and Y chromosomes had different shapes and the X chromosomes were always bigger than the Y chromosomes.

Early metakinetic chromosomes were short and rod shaped; each chromosome had two chromatids. At metaphases the holokinetic chromosomes occupied the spindle body. During anaphase and telophase the chromatids were segregated at opposite poles. Total chromatin was 11.9μ in female and 5.74μ in male BPH. Females possessed longer chromosomes than males. In later cytokinesis two daughter nuclei were formed. During the regular mitotic cycle in BPH biotype 1, prophase was the longest stage, followed by telophase, metaphase and anaphase, in that order. Some brain cells showed an increase (agmatoploidy) or decrease (hypoploidy) in chromosome numbers.

Chromosomes of *Nephotettix malayanus*

Study of spermatogenesis showed that *N. malayanus* has the normal diploid complement 2n = 13 (6IIA + X0).

Table 17. Similarity index of the soluble proteins among four biotypes of *N. lugens*

	Biotype 1	Biotype 2	Biotype 3	Grass-infesting biotype
Biotype 1	—	0.72	0.75	0.64
Biotype 2		—	0.78	0.67
Biotype 3			—	0.58
Grass-infesting biotype				—

Table 18. Similarity index of the soluble proteins among the three species of green leafhopper, *Nephotettix* spp.

	N. malayanus	*N. nigropictus*	*N. virescens*
N. malayanus	—	0.5610	0.6591
N. nigropictus		—	0.6579
N. virescens			—

During diakinesis, spermatocytes possessed 6 synapsed homologs plus a darkly stained univalent X-body, which was usually isolated from the bivalent autosomes. During metaphase 1 the X-body fused with the autosomes at the equatorial plate. Spontaneous chromosomal aberrations occurred in about 15% of the spermatocytes during diakinesis.

Chromosomes of *N. nigropictus*

An examination of primary spermatocytes at diakinesis showed that *N. nigropictus* had a genomic complement of 7 bivalent autosomes and a univalent X chromosome. The diploid chromosome number was therefore 2n = 15 (7IIA + X0). Pachytene analysis showed that the whole genome of males consisted of eight linkage groups. At diakinesis 24% of the cells contained a reduced number of bivalents and 5% possessed an increased number of chromosomes.

Chromosomes of *Leptocorisa oratorius*

An examination of primary spermatocytes at diakinesis showed that the rice bug possessed 7 bivalent autosomes plus a univalent X-body, the genomic complement being 2n = 15 (7IIA + X0). In addition to the standard genomic chromosomes, a short, open, ring-like fragment was consistently observed near the nuclear periphery. Its heterochromaticity and size indicated that it was a supernumerary (S) chromosome. It is nonhomologous and does not pair with standard chromosomes.

Chromosomes of Rice Weevil, *Sitophilus oryzae*, and Maize Weevil, *S. zeamais*

An examination of primary spermatocytes at diakinesis shows that the rice weevil possesses 19 chromosomes—2n = 19 (9IIA + X0)—while the maize weevil possesses 21 chromosomes—2n = 21 (10IIA + X0).

Trap Crops for GLH and Rice Tungro Virus (RTV), Management

We tested the concept of using trap crops as an alternative to intensive chemical control of GLH. RTV-susceptible IR 42 was used both as a trap crop and as a main crop. Trapped fields had 2, 3 or 4 trap-crop border rows, which were planted 15 days earlier than the main crop and were sprayed weekly up to 60 days after transplanting with cypermethrin at 0.05 kg ai/ha. The main crops in fields with trap crops were not treated with insecticide. Fields without trap crops but sprayed with cypermethrin were the treated control; unsprayed fields were the untreated control. Each treatment was replicated four times using a randomized complete block design.

At 65 days after transplanting (DT), RTV incidence was significantly higher in the untreated control than in trapped or insecticide-treated fields (Table 19). Relatively more GLH nymphs and adults were recorded in the untreated control than in the trapped or insecticide-treated fields. Yield was significantly higher in trapped and insecticide-treated fields than in the untreated control (Table 20). Although yield was highest in insecticide-treated fields, the cost of the cypermethrin applied lowered the net gain from the yield.

We can thus divert GLH to a trap crop where GLH can be destroyed with an insecticide. The restricted use of insecticide, besides creating a significant gain in yield while saving insecticide, conserves the pest's natural enemies.

Table 19. Rice tungro virus (RTV) incidence 65 days after transplanting in rice fields with and without a trap crop (IRRI, May–September 1986)

Treatment*	Date planted	Proportionate area/ha	Proportionate RTV incidence† (%)	Combined RTV incidence (%)
TC (2)	May 9	0.074	0.3	
				8.5[b]
MC	May 23	0.926	8.2[b]	
TC (3)	May 9	0.109	0.5	
				7.5[b]
MC	May 23	0.891	7.0[b]	
TC (4)	May 9	0.144	0.5	
				5.2[b]
MC	May 23	0.856	4.7[b]	
Treated control	May 9	1.000	6.4[b]	6.4[b]
Untreated control	May 23	1.000	36.8[a]	36.8[a]

Within a column, mean values bearing the same superscript letters are not significantly different at the 5% level by Duncan's multiple range test.

* TC: trap crop, MC: main crop. Numbers in parentheses are the numbers of rows of the trap crop in trapped fields.

† The percentage of proportionate RTV incidence in the trap crop was not analysed.

Table 20. Comparative value of crop yields after deducting cost of cypermethrin applied in rice fields with and without a trap crop (May–September 1986)

Treatment	Proportionate area/ha		Combined yield	Value of yield*	Cypermethrin applied†	Cost of treatment§	Value of yield less cost of
	Trap crop	Main crop	(t/ha)	($/ha)	(l/ha)	($/ha)	$/ha)
2 TC.MC	0.074	0.926	4.5[a]	787.50	0.592	14.21	773.29[a]
3 TC.MC	0.109	0.891	4.2[a]	735.00	0.872	20.93	714.07[a]
4 TC.MC	0.144	0.856	4.4[a]	770.00	1.152	27.65	742.35[a]
Treated control	0	1.000	4.9[a]	857.50	8.000	192.00	665.50[ab]
Untreated control	0	1.000	3.3[b]	577.50	0	0	577.50[b]

Within a column, mean values bearing the same superscript letters are not significantly different at the 5% level by Duncan's multiple range test.

* U.S.$ = P20; cost of palay (NFA price) = $0.175/kg.

† Cypermethrin was applied eight times to trap crop rows and to the treated control fields (0.05 kg ai/ha) during the cropping.

§ Cost of treatment includes only cost of cypermethrin applied throughout the cropping; cost of cypermethrin in July 1986 was $24/l.

Table 21. Growth and development of first-instar *N. lugens, S. furcifera* and *N. virescens* nymphs on TN 1 rice plants sprayed with neem-seed-kernel extract (IRRI, 1986)

Insect	Days after spraying	Nymphs becoming adults (%) at each conc (ppm)					
		0	100	500	250	5000	10 000
Brown planthopper	0	82[b]V	82[ab]V	23[b]W	0[d]X	0[c]X	0[b]X
	2	93[a]V	82[ab]V	78[a]W	33[c]X	2[c]Y	0[b]Y
	4	87[ab]V	77[b]V	82[a]V	60[b]W	33[b]X	0[b]Y
	6	90[ab]V	90[a]V	85[a]V	82[a]V	62[a]W	17[a]X
Whitebacked planthopper	0	87[a]W	90[a]W	28[b]	7[c]Y	0[b]Y	0[a]Y
	2	92[a]W	93[a]W	58[a]	25[b]Y	0[b]Z	0[a]Z
	4	90[a]W	85[a]W	78[a]	48[a]X	3[ab]Y	2[a]Y
	6	92[a]W	87[a]WX	73[a]	30[b]Y	13[a]Y	2[a]Z
Green leafhopper	0	93[a]X	85[a]Y	10[b]Z	0[c]Z	0[b]Z	0[a]Z
	2	92[a]X	93[a]X	83[a]X	2[c]Y	0[b]Y	0[a]Y
	4	93[a]X	87[a]X	88[a]X	17[b]Y	3[b]Z	0[a]Z
	6	92[a]W	90[a]W	87[a]W	60[a]X	17[a]Y	0[a]Z

Within a column, mean values bearing the same superscript letters are not significantly different at the 5% level by Duncan's multiple range test. Within a row, significance is designated by capital letters. Average of 6 replications, 10 first-instar nymphs per replications.

Neem–Seed–Kernel Extract (NSKE) Vs. BPH, WBPH and GLH

A simple procedure was developed for extracting neem-seed "bitters" (limonoids) as a crystalline powder that is water soluble, relatively photostable and non-phytotoxic. Only 10–20% first-instar nymphs of BPH, WBPH and GLH reached the adult stage when caged on rice plants sprayed with a 500-ppm solution of NSKE (Table 21). Nymphs died at concentrations ≥ 2500 ppm. NSKE residual activity persisted on treated plants kept outdoors for 6 days. Soaking the roots of rice seedlings in NSKE solution also disrupted the growth of GLH nymphs, indicating systemic action (Table 22). A similar effect on the growth and development of BPH, WBPH and GLH nymphs was observed when they were caged on rice plants grown in soil incorporated with NSKE (Figure 3). The fecundity of BPH, WBPH and GLH

Table 22. Growth and development of first-instar *N. virescens* nymphs on rice seedlings whose roots were soaked in neem-seed-kernel extract (IRRI, 1986)

Dosage* (ppm)	Nymphs becoming adults (%)	Growth period	Growth index†
100	57[a]	16[a]	3.5[b]
1000	13[b]	6[b]	0.8[c]
5000	0[b]	0[b]	0[c]
0 (control)	90[a]	16[a]	5.7[a]

Within a column, mean values bearing the same superscript letters are not significantly different at the 5% level by Duncan's multiple range test. Average of 3 replications, 10 first-instar nymphs per replication.

* Batches of 150 14-day-old TN 1 seedlings were soaked separately in different concentrations of neem-seed-kernel extract.

† Growth index: percentage of nymphs becoming adults/mean developmental period (days).

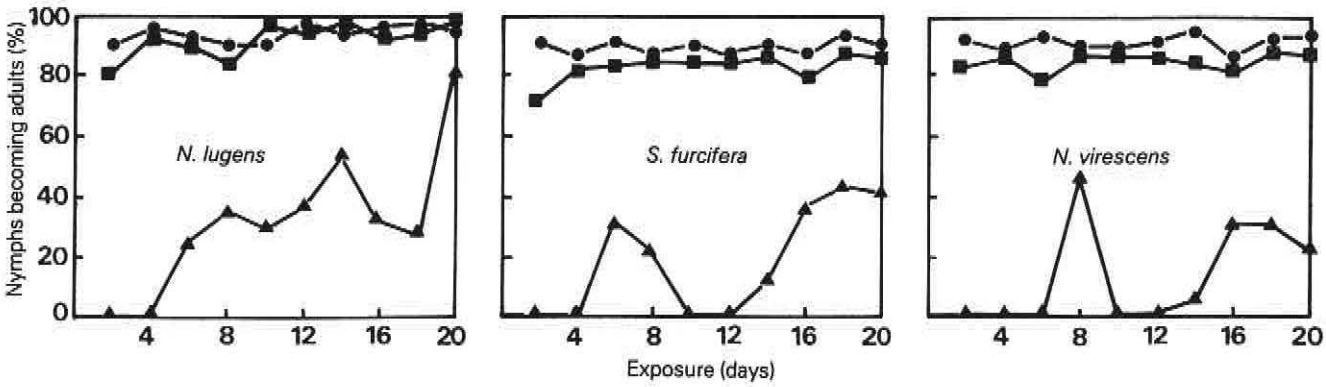


Figure 3. Systematic effect of neem seed kernel extract (NSKE) on the growth of first instar *N. lugens*, *S. furcifera* and *N. virescens*.
●–● 0 ppm NSKE, ■–■ 100 ppm NSKE, ▲–▲ 10,000 ppm NSKE.

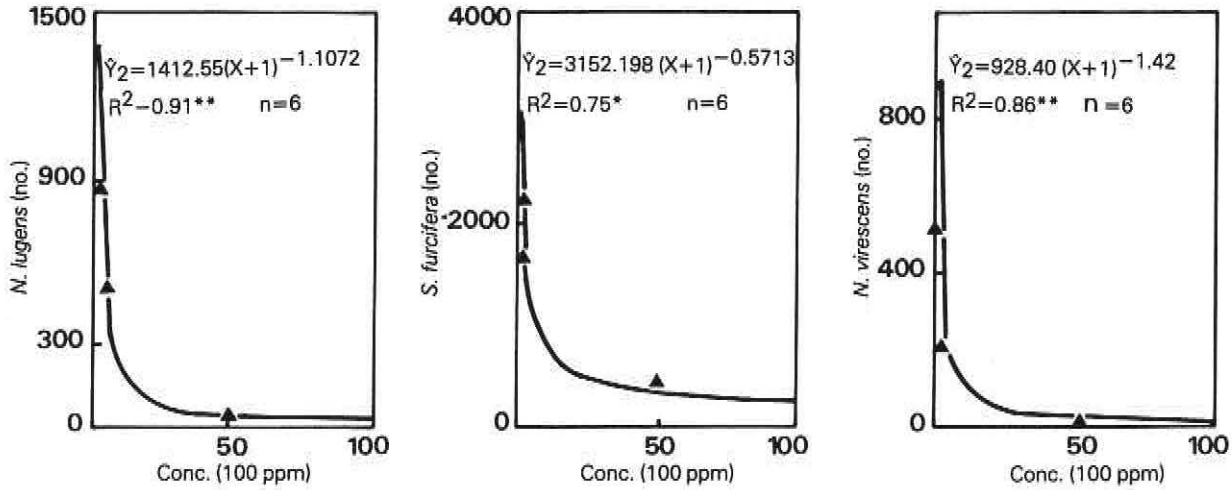


Figure 4. Population increase from a pair of male and female (*a*) *N. lugens*, (*b*) *S. furcifera* and (*c*) *N. virescens* on plants sprayed with neem-seed-kernel extract.

females was markedly reduced on NSKE-treated plants. The increase in planthopper and leafhopper populations on NSKE-treated plants was negligible in contrast to the population increase on untreated controls (Figure 4).

Effect of Neem Oil (NO) and NSKE on BPH Mating

Neem-seed derivatives are known to affect insect behaviour and physiology. We tested the effect of NO or NSKE on BPH mating behaviour. Fifteen newly emerged females were each treated topically with 1, 2.5 or 5 μg of NSKE in 0.2 μl of acetone-water solution or NO in 0.2 μl of acetone. Control females were treated with acetone-water or acetone. Two days later each female was paired with one responsive male on a 30-day-old TN 1 plant to which was attached a single needle-type ceramic cartridge. Mating signals emitted by both sexes were recorded and fed into a DC chart recorder.

In controls males emitted 2- to 3-second long croaking signals to which females responded by drumming sounds of 15- to 35-second durations (Figure 5a). Copulation was completed after 6 to 10 minutes of characteristic alternate mating calls. In contrast, NSKE- or NO-treated females produced an initial 3- to 10-second-long signal (Figure 5b) followed by extremely prolonged signals, which lasted up to 65 seconds (Figure 5c). Female signals were interspersed with faint croaking male sounds. Mating calls continued for more than 30 minutes without successful copulation. The initial female signal, which prompted the male to initiate mating, was altered in NSKE- or NO-treated females. Repeated prolonged females calls indicated that this alteration delayed or disrupted mating. Hatchability of eggs was reduced to 76% in females treated with 5 μg of NO.

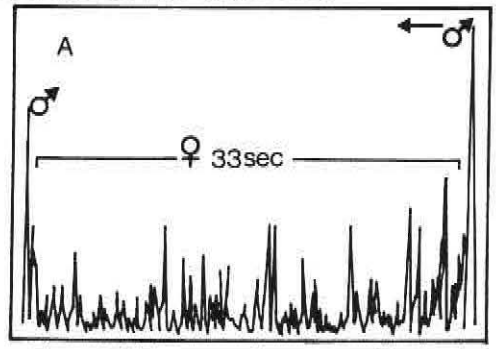


Figure 5. *N. lugens* mating patterns:(a)control,

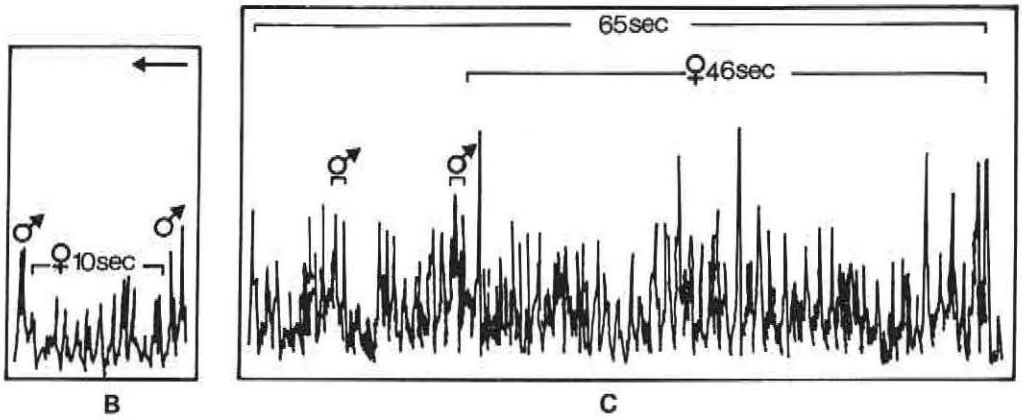


Figure 5. *N. lugens* mating patterns: (b) and (c)= when females were treated with 5 μg of neem seed kernel extract or neem oil.

Effect of NSKE on BPH Reproductive Potential

The first generation BPH males emerging on rice plants sprayed with 100 or 500 ppm of NSKE solution had significantly lower frequencies of meiotic cells than had the untreated control (Table 23). This may account for the reduced reproduction fitness of BPH individuals observed on rice plants sprayed with neem derivatives.

Table 23. Frequencies of meiocytes and non-meiocytes in *N. lugens* males reared on plants sprayed with neem-seed-kernel extract

Treatment (ppm)	Non-meiocytes (no.)	Meiocytes (no.)	Meiotic index
100	221[a]	82[b]	0.278[b]
500	273[a]	81[b]	0.224[b]
0 (control)	375[a]	233[a]	0.384[a]

Within a column, mean values bearing the same superscript letters are not significantly different at the 1% level by Student's *t* test. Average of 10 replications.

Use of Tolerant Cultivar, Pathogen and Neem Oil to Control Black Bug

We evaluated the efficacy of integrating the tolerant cultivar IR 13149-71-3-2, the pathogen *Metarhizium anisopliae* and the "electrodyn" formulation of neem oil to control the black bug in farmers' fields at three locations in Palawan. Simultaneously, we evaluated *M. anisopliae* and/or neem oil for protecting susceptible IR 64 against the pest.

Significantly lower black-bug infestation was recorded in plots sprayed fortnightly with neem oil than in control plots in the three locations (Table 24). Yield was significantly higher in plots sprayed with neem oil than in control plots, irrespective of whether the cultivar was tolerant or susceptible. A single spray of *M. anisopliae* was not enough to protect the crop from black-bug damage. Egg parasitism was low, but none of the treatments adversely affected parasitism.

Table 24. Efficacy of integrating susceptible (IR 64) or tolerant (IR 13149-71-3-2) cultivar, an insect pathogen and an "electrodyn" formulation of neem oil to control black bug (Malinao, Palawan, April–September 1986)

	Bugs/10 hill (no.) at DT[†]					Egg parasitism	Unfilled grains	Yield
Treatment*	30	45	60	75	90	(%)	(%)	(t/ha)
IR 64								
MA	1[a]	82[b]	60[ab]	41[b]	47[ab]	6.8[a]	65[a]	1.03[b]
NO	0[a]	48[c]	45[b]	24[c]	24[b]	4.4[a]	53[b]	1.49[a]
MA and NO	0[a]	103[ab]	84[a]	33[b]	50[a]	5.6[a]	63[ab]	1.07[b]
Control	1[a]	145[a]	84[a]	73[a]	55[a]	7.0[a]	66[a]	0.92[b]
IR 13149-71-3-2								
MA	0[a]	89[b]	79[ab]	49[b]	57[ab]	8.2[a]	46[a]	1.66[b]
NO	0[a]	51[c]	48[b]	35[b]	40[b]	5.1[a]	30[c]	2.34[a]
MA and NO	0[a]	83[b]	90[ab]	58[b]	58[ab]	8.3[a]	49[b]	1.89[b]
Control	0[a]	136[a]	125[a]	84[a]	73[a]	10.2[a]	49[a]	1.98[b]

Within a column, mean values bearing the same superscript letters are not significantly different at the 5% level by Duncan's multiple range test. Average of 3 replications.

* MA: *M. anisopliae*. NO: neem oil. Control: untreated.

† DT: days after transplanting.

Effect of NO and NSKE on a BPH Predator

We evaluated the effect of neem-seed derivatives on *Cyrtorhinus lividipennis*, a BPH predator. In toxicity tests, the highest dose, 20 μg NO per adult, caused 83% mortality in BPH adults but only 26% mortality in the mirid bug (Table 25). The predator's mortality with the same dose of NSKE was negligible. The growth and development of mirid nymphs on rice plants sprayed with 10,000-ppm NSKE was unaffected (Table 26).

Table 25. Mortality of *N. lugens* and *C. lividipennis* 24 hours after topical application of neem oil or neem-seed-kernel extract (IRRI, 1986–87)

Treatment	Mortality with neem-oil application (%)	Mortality with neem-seed-kernel-extract application (%)
μg/0.2μl/female		*N. lugens*
5	15^{bc}	18^{bc}
10	25^{b}	24^{b}
20	83^{a}	55^{a}
0 (control)	20^{bc}	2^{d}
μg/0.1μl/female		*C. lividipennis*
5	22^{bc}	15^{bc}
10	20^{bc}	11^{cd}
20	26^{b}	8^{cd}
0 (control)	9^{c}	11^{cd}

Within a column, mean values bearing the same superscript letters are not significantly different at the 5% level by Duncan's multiple range test. Average of 10 replications, 10 females per replication.

Table 26. Physiological responses of *C. lividipennis* to neem oil and neem-seed-kernel-extract treatments (IRRI, 1986)

Treatments	Developmental period (days)	Nymphs becoming adults (%)	Growth index
Neem oil (%)			
3	6.33	85.0^{ab}	12.9
6	6.78	55.0^{bc}	13.5
12	—	0.0^{c}	—
25	—	0.0^{c}	—
50	—	0.0^{c}	—
Control	6.00^{ab}	96.6^{a}	16.7
Neem-seed-kernel extract (ppm)			
100	6.86^{a}	79.2^{abc}	13.70
500	7.35^{a}	96.6^{a}	13.05
2500	6.31^{ab}	66.0^{abc}	10.17
5000	5.93^{ab}	58.4^{abc}	10.33
10 000	5.13^{b}	37.2^{c}	8.85
Control	7.15^{a}	92.0^{ab}	12.84

Within a column, mean values bearing the same superscript letters are not significantly different at the 5% level by Duncan's multiple range test. Average of 5 replications.

However, spray applications of ≥ 6% NO reduced considerably the development of mirid nymphs. The reduced viability of mirid nymphs was due to the failure of BPH nymphs, the food source of the predator, to survive on NO-treated plants. Spray application of NO or NSKE did not affect the egg predation ability of adult mirid bugs (Table 27). Mortality in BPH nymphs was significantly higher on plants treated with NSKE and

Table 27. Brown planthopper eggs damaged by *C. lividipennis* adults on rice plants treated with neem oil or neem-seed-kernel extract (IRRI, 1986–87)

Treatment	Eggs damaged (%)
Neem oil concentration (%)	
3	69
6	37
12	42
25	43
50	46
0 (control)	66
Neem-seed-kernel-extract concentration (ppm)	
100	61
500	66
2500	42
5000	49
10 000	52
0 (control)	66

Average of 5 replications.

provided with the predator than on untreated control plants or on plants without the predator (Table 28). BPH population build-up on plants treated with NSKE was significantly lower than that on the unsprayed control plants or on plants devoid of the predator (Figure 6).

Table 28. Mortality of brown planthopper nymphs on neem-seed-kernel-extract-treated rice plants with and without predator, *C. lividipennis*, 10 days after treatment (IRRI, 1986–87)

Neem-seed-kernel-extract concentration (ppm)	Nymph mortality (%) Predator absent	Predator present
100	2.3^{d}	7.0^{cd}
500	6.5^{cd}	8.5^{cd}
2500	12.5^{bc}	18.6^{b}
5000	18.0^{b}	25.2^{a}
10 000	16.4^{b}	26.1^{a}
0 (control)	2.5^{d}	6.5^{cd}

Within a column, mean values bearing the same superscript letters are not significantly different at the 5% level by Duncan's multiple range test. Average of 5 replications.

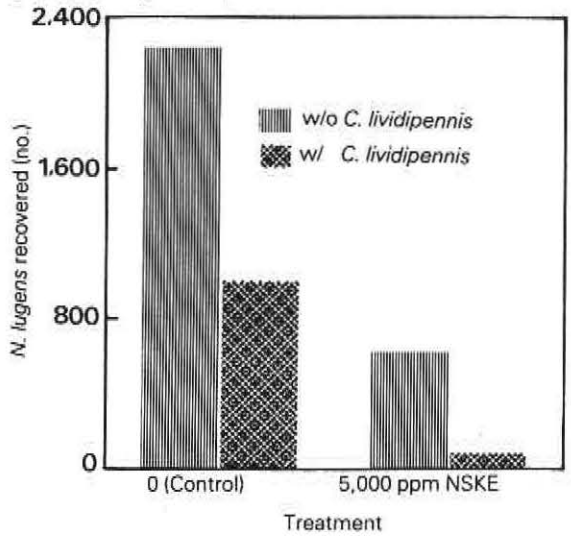


Figure 6. Cumulative increase in *N. lugens* population (total from 5 replications) on rice plants treated with neem seed kenel extract (NSKE).

BPH population was lowest on plants sprayed with NSKE and provided with the mirid bug.

Effect of Selected Plant Derivatives on the Red Flour Beetle

Oils of turmeric (*Curcuma longa*), sweetflag (*Acorus calamus*), neem and 'Margosan O'—a neem-based insecticide—were tested for their repellency, insecticidal effect and growth-and-reproduction inhibiting activity against the red flour beetle, *Tribolium castaneum*. During an 8-week test period, turmeric oil and sweetflag oil showed strong repellency for the first 2 weeks, but their repellency decreased thereafter and decreased faster than that of neem oil or 'Margosan O' (Table 29). 'Margosan O' was the most repellent at 1000 ppm. Compared with Actellic 25 EC, the insecticide check, the oils and 'Margosan O' lacked insecticidal effect but adversely affected the growth and development of *T. castaneum*.

Ethylene as a Marker for Estimating Level of Insect Infestation in Rice

The amount of ethylene produced by rice seedlings has been used as an indicator of seed vigour. We found a correlation between the degree of rice-seed infestation by a primary storage pest, *Rhizopertha dominica*, and ethylene production from seedlings grown from infested seeds. Ethylene production, shoot length and seedling dry weight all decreased progressively with an increase in insect infestation (Table 30, Figure 7). Ethylene, a biochemical entity, can thus serve as a marker for estimating the degree of insect infestation and seedling vigour. It can also serve as a tool to screen rice for varietal resistance to storage insects.

Table 29. Repellency of turmeric oil, sweetflag oil, neem oil and 'Margosan O' to *T. castaneum* adults at different rates of application and time intervals

Treatment	Rate ($\mu g/cm^2$ paper)	Repellency (%) at weeks after treatment			
		1	2	4	8
Turmeric oil	800	92^{a}	73^{a}	70^{a}	51^{bc}
	400	88^{ab}	70^{a}	64^{ab}	46^{b-e}
	200	81^{cd}	60^{c}	54^{d-f}	42^{de}
Sweetflag oil	800	88^{ab}	75^{a}	69^{a}	48^{b-d}
	400	86^{bc}	68^{ab}	60^{b-e}	45^{b-e}
	200	79^{de}	58^{c}	50^{f}	40^{e}
Neem oil	800	80^{de}	72^{a}	70^{a}	59^{a}
	400	78^{de}	70^{a}	63^{a-c}	54^{ab}
	200	70^{f}	60^{c}	56^{c-f}	45^{b-e}
'Margosan O'	800	78^{de}	69^{a}	66^{ab}	53^{a-c}
	400	72^{ef}	61^{bc}	61^{b-d}	50^{b-c}
	200	66^{f}	56^{c}	52^{ef}	44^{c-e}
Control	0	5^{g}	6^{d}	2^{g}	4^{f}

Within a column, mean values bearing the same superscript letters are not significantly different at the 5% level by Duncan's multiple range test. Average of 4 replications.

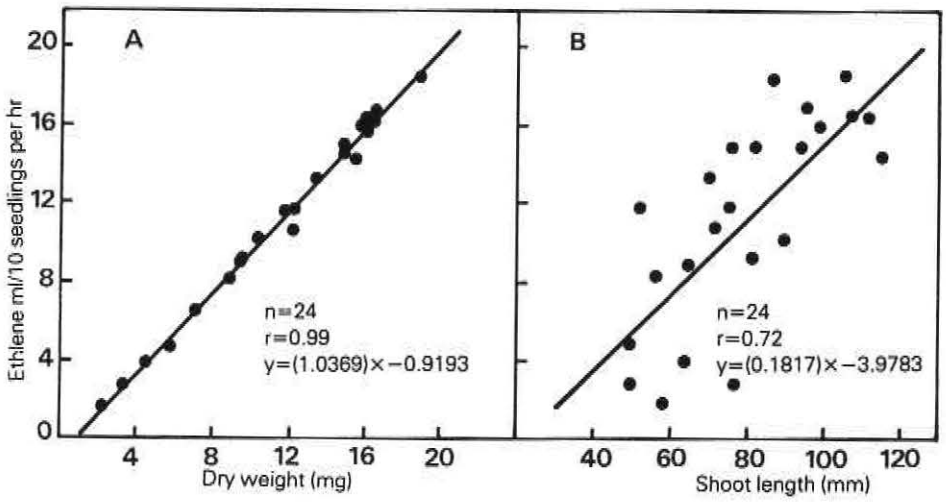


Figure 7. Regression lines showing correlations between (a) ethylene produced by seedlings and shoot length and (*b*) ethylene produced by seedling and the weight of the seedlings.

Table 30. Effects of different infestation levels of *Rhizopertha dominica* on the expression of seed vigour (IRRI, 1986)

Storage period (wk)	Ethylene production* (C_2H_4nl/10 seedlings per h)	Shoot length* (mm)	Dry wt† (mg)
With infestation			
0	15.44[b]	15.75[b]	107.52[a]
6	8.72[d]	9.38[d]	67.19[c]
7	5.05[e]	5.93[e]	66.20[c]
8	2.46[f]	3.15[f]	61.56[c]
Without infestation			
0	17.66[a]	18.10[a]	104.59[a]
6	15.45[b]	15.53[b]	90.75[ab]
7	11.88[c]	12.62[c]	64.68[c]
8	12.22[c]	12.35[c]	80.33[bc]

Within a column, mean values bearing the same superscript letters are not significantly different at the 1% level by Duncan's multiple range test.
* Determined after 4 days.
† Determined after 16 days.

Golden Apple Snail: A New Pest of Rice

The golden apple snail, *Pila leopordvillensis* D'Orbigney, is an aquatic gastropod. The snail originated in South America and was introduced in the Philippines as a culture material, supposedly to be farmed in cement tanks, ponds or other controlled environments. Recently the snail and its egg masses were seen in abundance in the *Azolla* propagation ponds of the University of the Philippines at Los Baños and in adjoining irrigated rice fields on the IRRI experimental farm.

The snail feeds voraciously on *Azolla*. Adults measuring 22 to 26 mm can consume up to 15 g of *Azolla* fronds in 12 to 24 hours. If *Azolla* is not present, the snail feeds on other succulent aquatic vegetation, such as newly transplanted rice. A full-grown snail can consume a blade of rice in 3 to 5 minutes. The snail is most active at dusk, night and dawn. Damage is severe in low-lying portions of newly transplanted fields. Damaged plots are characterized by missing seedlings and by floating, cut leaves.

The snail may be controlled with organotin molluscicides, but these chemicals are toxic to fish and tadpoles. We recommend that snail egg masses be picked up regularly.

ICIPE–IITA RESEARCH PROGRAMME

The ICIPE-IITA Research Programme on Cowpea Improvement was established in October 1985 to combine the expertise of ICIPE in the areas of insect behaviour and ecology, host-plant resistance and the genetics of host-plant resistance with the applied expertise of the International Institute of Tropical Agriculture (IITA), Nigeria, in cowpea improvement. The objective of the programme is to develop insect-resistant cowpea varieties suitable for the resource-poor farmer in Kenya and other countries in eastern and northeastern Africa.

1986 was the first full year of operation of the programme and emphais was given to establishing (1) a strong varietal cowpea testing programme in southwestern and central Kenya, (2) a cowpea breeding programme to serve Kenya and other countries in eastern and northeastern Africa and (3) links with other cowpea research programmes in Kenya.

ICIPE–IITA RESEARCH PROGRAMME ON COWPEA IMPROVEMENT

J. Ehlers

Cowpea Varietal Testing Programme

Over 130 elite and local cowpea lines from IITA, ICIPE and the Katumani National Dryland Farming Research Station (NDFRS) were compared in replicated trials in several important cowpea-growing areas in different agro-ecological zones of southwestern and central Kenya during both the long and short rainy seasons. Varieties that showed promise included IT83D-442, IT82D-889, IT82E-25, TVx 3343-01J and TVx 3866-04J. The latter three varieties have performed particularly well under poor growing conditions. All of these varieties have seed colours and qualities acceptable to farmers in Kenya and other countries in eastern and northeastern Africa.

It was clear from both an examination of the crops and seed-yield data that most cowpea varieties developed at IITA were well adapted to the warm lake basin around Lake Victoria. However, IITA lines were generally outperformed by local varieties at Katumani, a highland in central Kenya, probably because of poor adaptation to cool temperatures.

Pests were the most important constraint to high grain yields. In experiments conducted with 18 lines on insecticide-treated and untreated plots (four replicates each) at three locations, seed-yield losses averaged about 1 t/ha, or 50% of the protected yields. Losses varied greatly among lines; early flowering/maturing lines incurred losses averaging 30% while later flowering lines incurred losses of more than 75%. In fact, a clear inverse relationship was observed between the flowering date and unprotected seed yield and a clear positive relationship among the 18 lines occurred between the flowering date and the percentage of loss in seed yield (Figure 8). This suggests that most differences in seed-yield losses among the lines were due to some lines escaping pest attack, and that any differences in the lines' resistance/tolerance to pests were likely masked by the effect of earliness and increasing post-reproductive pest population pressure. Such information suggests caution in relying on natural pest infestations when screening material of variable maturity for pest resistance.

Similar relationships between seed yield and flowering date of lines were observed in other trials conducted in southwestern Kenya where varieties were grown without insecticides. Varieties flowering 2 or 3 days earlier, planted early and grown without insecticide may be able to consistently yield over 1 t/ha of seeds in many locations. Experiments to test this hypothesis are planned for 1987.

In Africa almost all cowpeas are intercropped with a cereal, yet varietal evaluations of cowpeas are usually

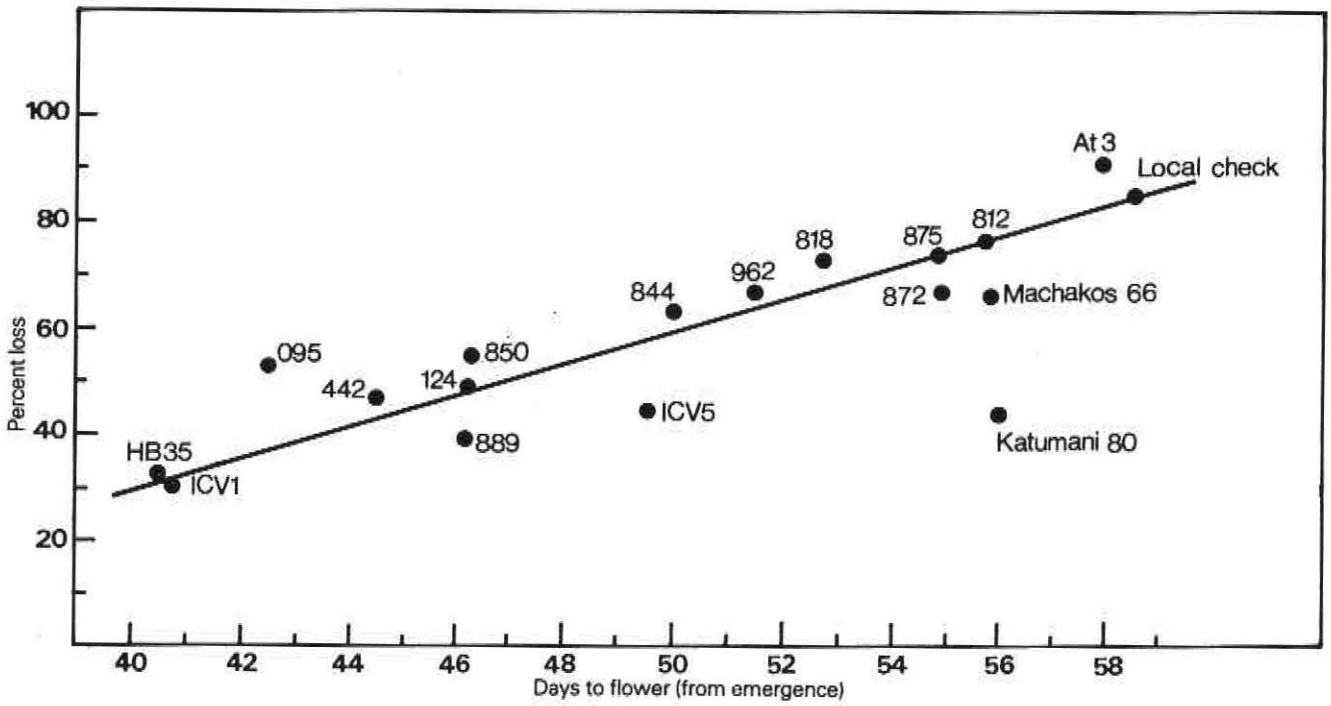


Figure 8. Relationship between loss of seed yield due to insect pests and days to flowering from eighteen cowpea cultivars grown at three locations in southwestern Kenya (long rainy season, 1986).

conducted under monocropping. An experiment was conducted to determine whether data collected on cowpea lines grown as a monocrop are relevant to the same lines grown as an intercrop and thus whether varietal tests need to be conducted with intercrops rather than monocrops. The seed yields of twelve lines when monocropped and intercropped and when grown with and without insecticides were compared. The entry rankings for seed yield of the monocrops and intercrops were similar either when treated with insecticide or when untreated (Table 31). This experiment will be repeated, but these first findings suggest that a monocropping system may be used to identify superior varieties that will be used in an intercropping system.

Table 31. Seed yields and correlations of performances of 12 cowpea varieties when intercropped and monocropped and when sprayed and not sprayed with insecticide (short rainy season, Ogongo, Kenya, 1986)

Cowpea variety	Days to flower	Seed yield (kg/ha)			
		Sprayed with insecticide		Not sprayed with insecticide	
		Monocrop	Intercrop	Monocrop	Intercrop
Kisumu Market	56.0	3319	1403	0	0
AT3-1/80f	55.3	2537	1114	0	20
IT83D-442	43.1	2535	1133	321	272
IT82D-889	43.3	239	939	362	362
Katumani 80	54.2	2341	862	215	235
ICV 1	40.3	2219	829	1102	322
Machakos 66	53.5	2179	527	280	154
IT82D-812	54.5	2163	865	176	8
HB35/4/ID	40.5	2111	725	796	389
ICV 5	45.9	1990	913	28	91
IT84E-124	46.4	1778	749	540	225
IT83S-850	45.9	1739	802	377	290
LSD* (0.05)			429		
Correlation†			0.809§		0.753§

* LSD: least significant difference.
† Correlation between seed yields when varieties are monocropped and intercropped.
§ Significantly different at $P < 0.01$.

The effects of intercropping rather than monocropping on total pest damage and flower thrip numbers were also studied. Intercropping significantly reduced numbers of both nymph and adult thrips in flowers but not in shoot tips. Seed yield losses due to all pests were consistently—but not significantly—less when varieties were intercropped rather than monocropped. Seed yield loss for both monocrops and intercrops was highly correlated with days to flowering ($r = 0.73$ and 0.78, respectively), as in previous experiments. This correlation is further evidence that a major determinant of seed yields in unprotected variety trials, and perhaps in farmers' fields as well, is pest escape.

Cowpea Breeding Programme

A cowpea pedigree breeding programme was established in 1986. Over 1000 lines were assembled and, depending on when they were received, are in various stages of agronomic evaluation. Included among these lines are 260 entries from the Katumani National Dryland Farming Research Station collection, 32 entries from the University of California at Riverside and 14 varieties from ICIPE. Lines known to be resistant to thrips, aphids and Maruca pod borer (*Maruca testulalis*) are included among the over 800 elite multiple disease resistant lines received from IITA.

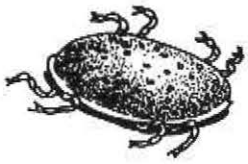
To date, over 200 hybrid F_2, F_3 or F_4 populations have been created at ICIPE, largely from crosses between locally improved varieties and (1) elite multiple-disease-resistant varieties or (2) insect-resistant lines from IITA. Approximately 3000 single-plant selections have been made from the advanced populations grown with minimal protection from insect pests (2 insecticide sprays).

Collaboration with Kenya Cowpea Programmes

A close working relationship between cowpea researchers from the ICIPE/IITA programme and cowpea researchers at the Katumani National Dryland Farming Research Station (in central Kenya), which has a mandate for cowpea improvement, was established in 1986. Collaborative yield trials using locally improved varieties and varieties from IITA were conducted at two locations in central Kenya in both the long and short rainy seasons. In general, as mentioned previously, varieties developed at IITA performed poorly in the Katumani area.

Germplasm was exchanged. Katumani NDFRS received IITA cowpea international trials from the ICIPE/IITA programme, as well as ICIPE/IITA programme trials and F_3 bulk populations from several appropriate crosses. The ICIPE/IITA programme received a germplasm collection consisting of 260 local accessions. A much larger collaborative effort, comprising trials in the coastal region and screening nurseries in high elevation areas, is planned for 1987.

Livestock Ticks



Livestock Ticks Research Programme

The Livestock Ticks Research Programme (LTRP) has concentrated on the provision of short- and long-term solutions to the problems ticks cause domestic animals. LTRP studied productivity losses due to ticks and aims to develop tick-eradication strategies that will be both acceptable to, and practical for, the resource-poor farmer. LTRP research has three main objectives: to develop a vaccine against the most common tick species in Africa, to develop methods by which cattle naturally resistant to ticks may be selected and to develop tick control strategies that use a minimum amount of acaricides.

MAJOR ACTIVITIES

P. B. Capstick

In 1986, in collaboration with the Chemistry and Biochemistry Research Unit and the Institute of Zoology, at the University of Neuchatel, studies were intensified to isolate and characterize the antigens responsible for immune effects in cattle. Proteins and protein subunits have been differentiated and related to both natural immunity and artificially induced responses in rabbits (see Mongi and Aganyo, below, and see also papers by Essuman and Dhadialla and by Vundla and Labongo in the Chemistry and Biochemistry Research Unit chapter of this *Annual Report*). At least one protein of defined molecular weight with known activity is in the process of being purified and expanded to obtain sufficient material for immunization experiments (Rutti, B., personal communication). Nevertheless, a considerable volume of biochemical studies needs to be completed before we shall be able to ascribe individual proteins to specific biological immune effects.

LTRP studies on tick immunity in sheep and goats described below by Wishitemi and by Maranga and Capstick give considerable support to the belief that immunity induced in these species can substantially affect the tick life cycle and pasture population levels. The results of attempts to immunize cattle were disappointing (Capstick, Dhadialla and de Castro, below), but the serum from all three species should help to isolate relevant antigens. Our understanding of natural feeding induced immunity is increasing through the above studies and through vaccine studies on salivary gland antigens (Nyindo, Chesang and Muteria, below).

It is essential in the field to be able to distinguish immune from tick naive animals; the intradermal test described below by Capstick, de Castro and Nyindo helps to differentiate the one from the other, but the antigen used is a combination of many antigens, and full understanding of the dynamics of acquired resistance is not possible until pure antigens are available. J.W. Chiera's studies have a significant bearing on the choice of tick strains for antigen isolation and the challenge of immunity.

Studies commencing at Mutara Ranch on domestic stock to correlate inherited characteristics with natural resistance are a logical follow-up to the studies on breed differences at Intona Ranch (De Castro, Capstick, Malonza, Rinkanya and Kiara; de Castro and Ndungu; and De Castro; below). The selection criteria being developed at Mutara Ranch will be important and will complement the successful use of vaccines and modified dipping regimens.

Until cattle vaccines against East Coast fever, anaplasmosis, babesiosis and heartwater are widely available in East Africa, there is little possibility of the widespread use of strategic and other reduced dipping regimens in the area that would minimize insecticide use, except in those countries or areas, such as Burundi and Rusinga Island, with cattle already resistant to tick-borne disease. Such regimens require a full understanding of tick development and tick survival data, correlated with data

on climate and ecology, before useful population models can be created. The work reported below by Newson, Punyua and Ngoko; Newson and Ngoko; Newson, Malonza and Gatheru; and Gigon enables us to test such regimens in selected locations until tick-borne-disease vaccines become available.

It is now accepted practice to assess tick and tick-borne disease control regimens in terms of the effects of those regimens on farmers' productivity. The significant upgrading of effort in the studies on Rusinga Island reported below by Latif, Punyua and Capstick; Punyua, Latif and Capstick; and Punyua and Otieno is providing a productivity data base in a resource-poor area where tick-control interventions can be realistically assessed in economic terms. The introduction of socio-economic surveys to elucidate income sources, reported below by Ssennyonga, will do much to raise the quality of possible interventions on Rusinga Island.

IMMUNOCHEMICAL IDENTIFICATION, ISOLATION AND CHARACTERIZATION OF *RHIPICEPHALUS APPENDICULATUS* TICK MIDGUT ANTIGENS RECOGNIZED BY IMMUNE RABBIT IgGs TO TICK INFESTATIONS

A. O. Mongi, C. A. Aganyo

One possible approach to controlling ticks and tick-borne diseases is to use acquired host resistance to tick infestation. Attempts have been made to induce tick resistance by immunizing laboratory animals and cattle with tick-derived-antigen extracts. Despite the increasing literature in this field, the immunochemical nature and number of tick antigens involved in the acquisition of resistance, as well as the tick tissue organs involved in their reproduction, have not been clearly described. Furthermore, the immunoglobulin classes involved in the observed protective immune response(s) against tick infestations have not been specifically described. This report describes our attempts to identify, isolate and characterize *Rhipicephalus appendiculatus* tick midgut antigens recognized by purified immune rabbit IgGs to tick infestations and possibly involved in the observed resistance to ticks. We also attempted to immunize laboratory animals with the affinity purified antigens to see if these antigens provoked in animals a protective immune response against feeding ticks greater than that which usually occurs in animals naturally infested with ticks.

A profile of the ion exchange chromatography of the affinity purified IgGs employed in the subsequent immunochemical studies is shown in Figure 1.

Shown in Figure 2 are tick midgut proteins of partially fed female *R. appendiculatus* ticks separated by sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) and assayed in immunoblots for reaction with the affinity purified immune rabbit IgGs to tick infestations. Each of the affinity purified immune IgG fractional peaks detected protein subunits ranging from 12 000 to 92 000 daltons. Immunoadsorption studies

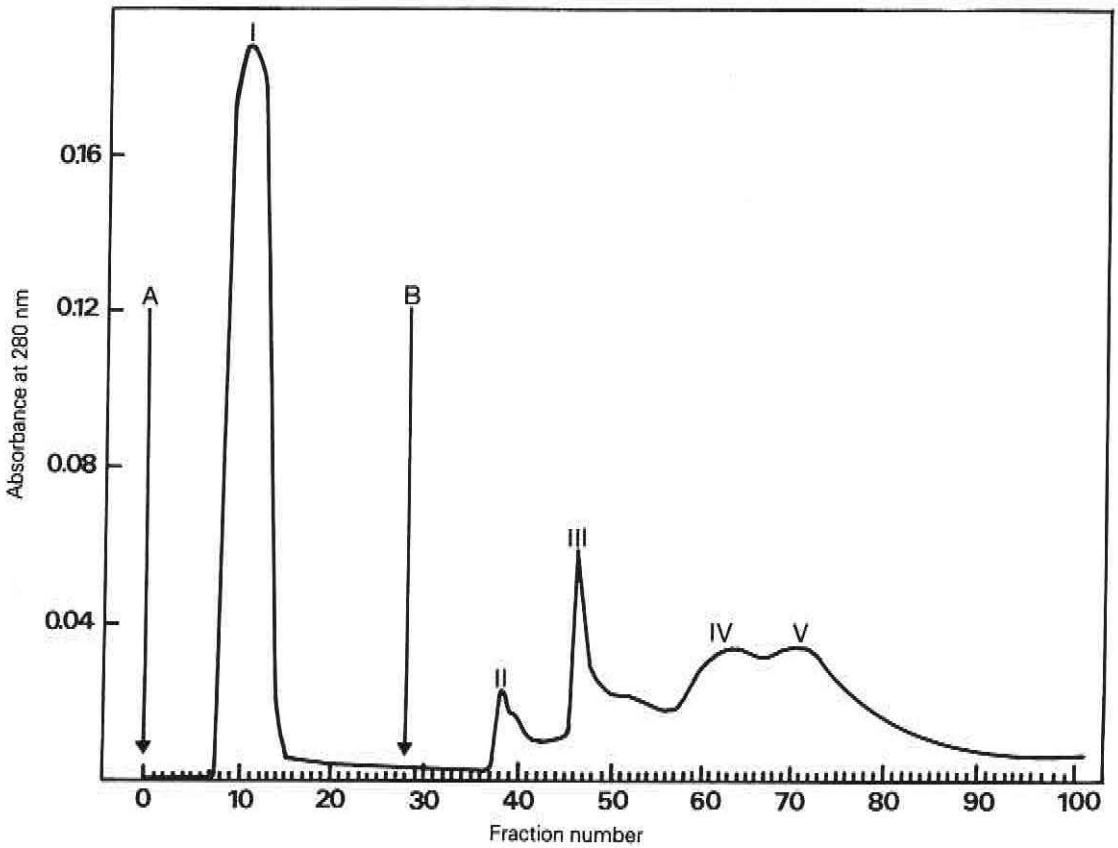


Figure 1. Elution profile of rabbit IgGs immune to tick infestations after ammonium sulfate cut from DEAE-52 cellulose ion-exchange chromatography employing an equilibrating buffer (0.01 M PO_4, pH 8.0) (arrow *A*) followed by a 0-1 M NaC gradient in the equilibrating buffer (arrow *B*). Detected peaks by absorbance at 280 nm are numbered I to V

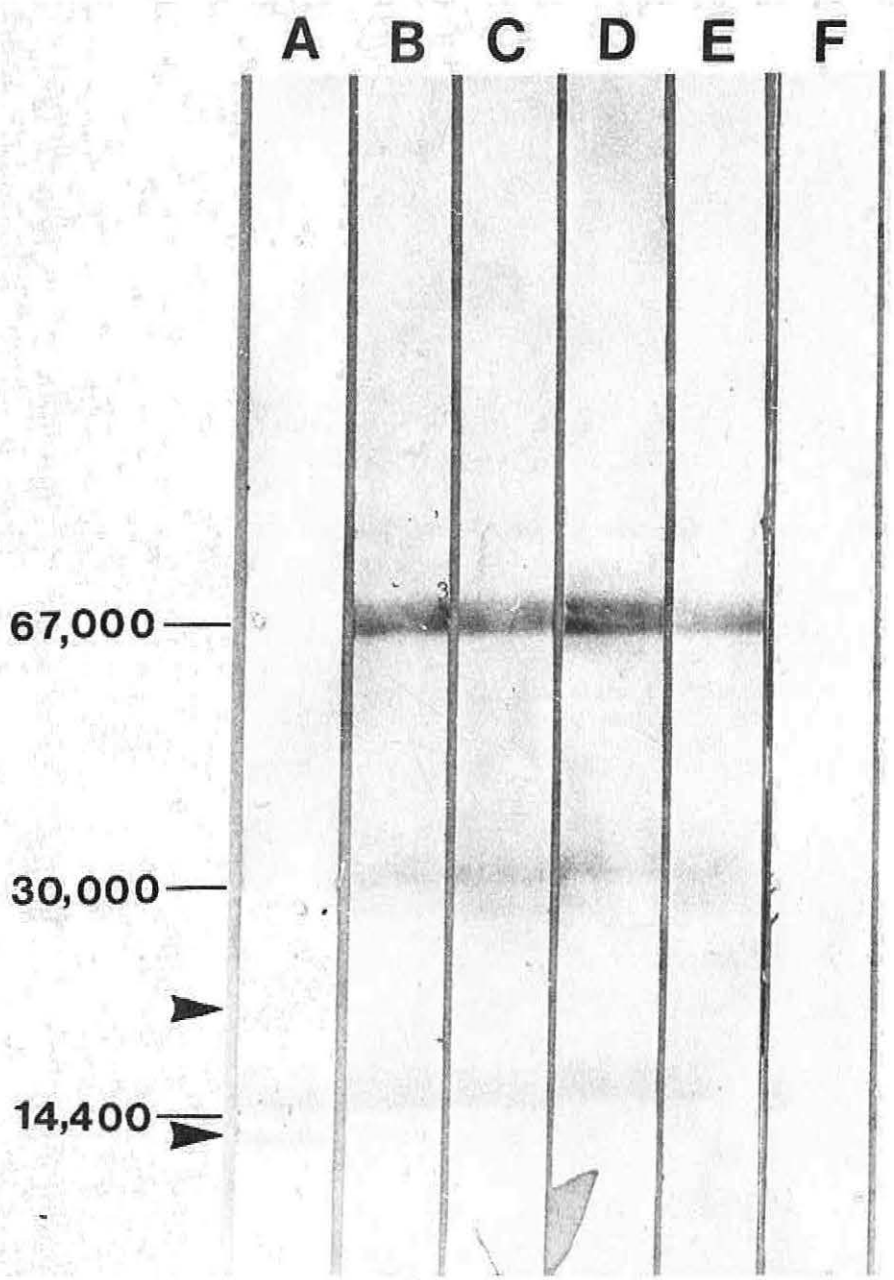


Figure 2. Patterns of *R. appendiculatus* tick midgut proteins separated by 5%–20% gradient SDS-PAGE, transferred to nitrocellulose membranes, immunoblotted with rabbit serum immune to tick infestations and developed with goat anti-rabbit IgG. Tracks *A, B, C* and *D* correspond to the DEAE-52 purified IgG fractional peaks. Track *F* had normal rabbit serum as control.

employing fractional peak I of one of the purified IgGs to tick infestations in order to purify tick midgut antigens (Figure 3) possibly involved in their production revealed the presence of an aggregated native protein of molecular weight greater than 500 000 daltons as resolved by PAGE and detected by silver staining (Figure 4). However, SDS-PAGE analysis of the purified protein revealed the presence of protein subunits with molecular weights ranging from 12 000 to 160 000 daltons (Figure 5).

The reproductive potential of ticks fed on rabbits immunized with the affinity purified proteins was affected slightly more than the reproductive potential of ticks fed on control rabbits. The proteins also elicited immediate skin reactions followed by delayed skin reactions, which persisted for over 36 hours when employed to skin test rabbits previously exposed to ticks. Unexposed control rabbits tested under the conditions gave only weak reactions.

In conclusion, antibodies to tick infestations were purified and used to purify a tick midgut protein molecule. The isolated protein was immunogenic and induced resistance to tick feeding as demonstrated by the slight decrease in egg viability. The protein also induced immediate and delayed hypersensitivity reactions when injected into rabbits resistant to ticks. The evidence shown here indicates that the midgut proteins studied do have an effect on resistance to ticks. Further studies aimed at isolating large quantities of the tick midgut antigens are in progress.

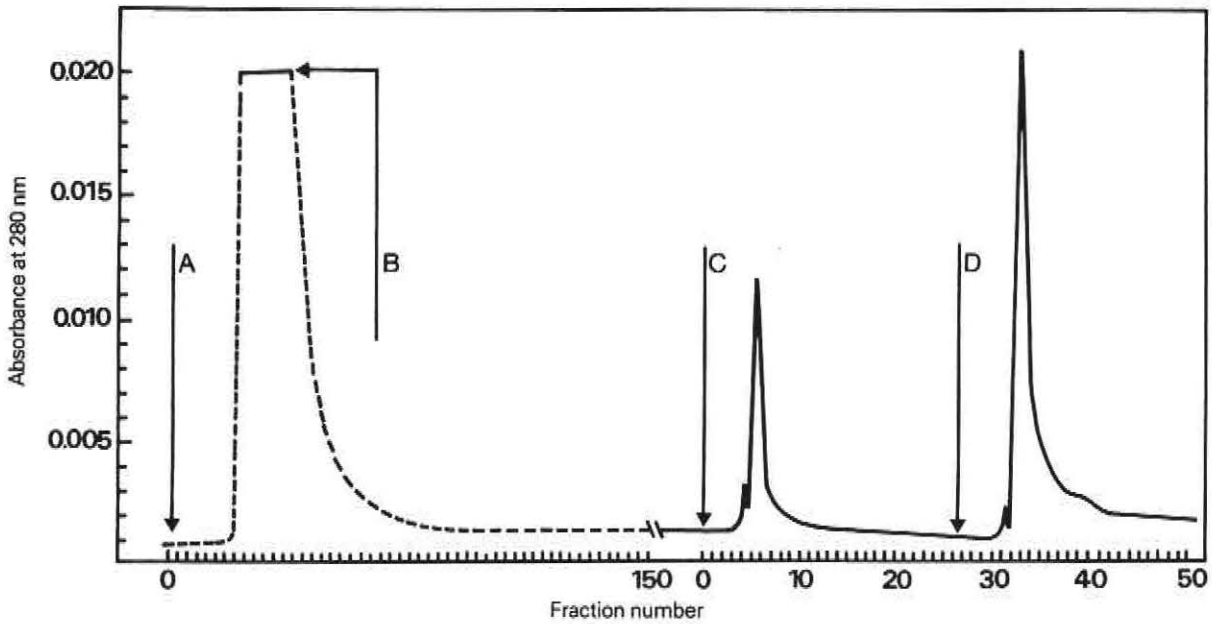


Figure 3. Elution profile of *R. appendiculatus* tick midgut proteins previously immune adsorbed to DEAE-52 purified rabbit IgG immune to tick infestations, fractional peak I, coupled to CNBr-activated sepharose 4B. The immunoadsorbent column was washed with the equilibrating buffer, as indicated by arrows *A* and *B*, until absorbance at 280 nm reached baseline. Elution of the immunocolumn arrow *C* was performed with 0.1 M glycine pH 2.5 and followed immediately by arrow *D* with 50% (v/v) ethylene glycol pH 11.5 in the equilibrating buffer. The samples were neutralized with 1 M Tris-HCl pH 8.0, concentrated and stored at −20° C until required.

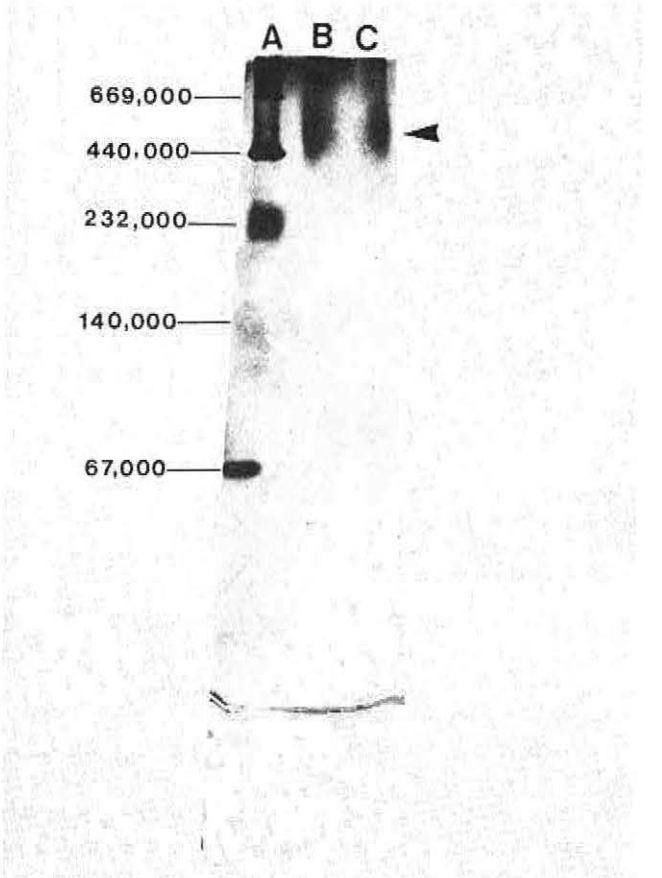


Figure 4. Analysis of *R. appendiculatus* tick midgut proteins separated by 5%–20% gradient PAGE and visualized by silver staining. In track *A* are indicated the standard high molecular weight markers. In tracks *B* and *C* are indicated the affinity purified tick midgut proteins eluted from the immunoadsorbent column, previously coupled with the DEAE-52 purified rabbit IgG immune to tick infestations, fractional peak I.

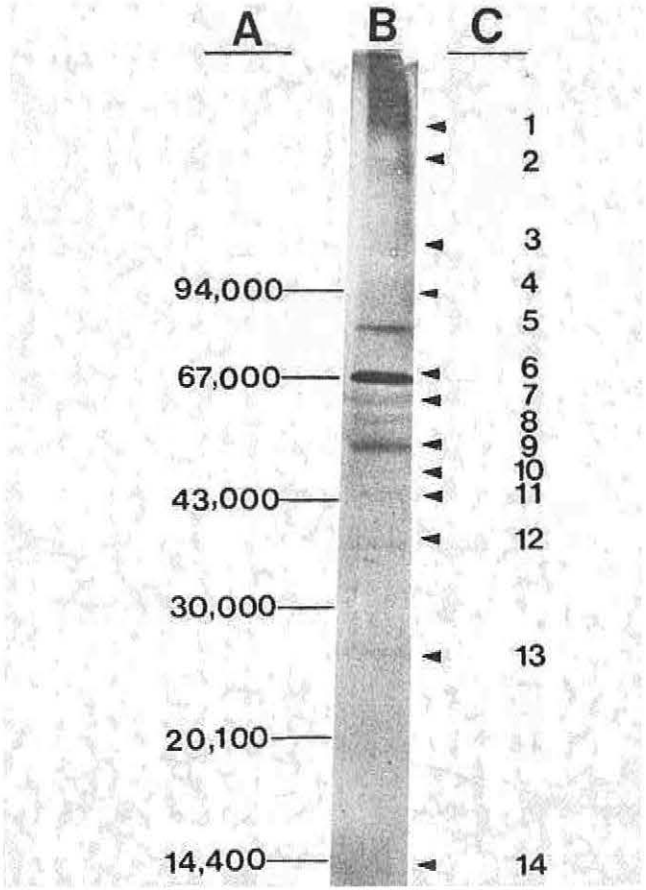


Figure 5. Analysis of *R. appendiculatus* tick midgut proteins separated by 5%–20% gradient SDS-PAGE under reducing conditions and visualized by silver staining. In track *A* are indicated the standard low molecular weight markers. In track *B* are indicated the affinity purified tick midgut eluted from the immunoadsorbent column. In track *C* the arrows and numbers are a diagrammatic representation to facilitate enumeration of the visualized polypeptides.

INDUCTION OF IMMUNITY IN SHEEP TO *RHIPICEPHALUS APPENDICULATUS* ANTIGENS

B. E. L. Wishitemi

In 1986 an experiment was conducted to test the immunization effects of injecting into tick-naive red Maasai sheep (bred especially for this experiment) antigens comprising parts of the tick *Rhipicephalus appendiculatus*. The experiment consisted of 24 sheep divided into 6 groups of 4. One group of sheep was given injections of soluble midgut antigens, a second group solubilized midgut membrane antigens, a third group soluble female reproductive organ antigens, a fourth group both solubilized midgut membranes and soluble female reproductive organ antigens (50:50). A fifth group was an adjuvant control, a sixth group a negative control (no treatment). Each immunization comprised 3 injections: a primary inoculation (sensitizing dose) was given on day 0, a second inoculation (first booster) on day 42 and a third inoculation (second booster) on day 56.

On day 70 all six groups were challenged by the application of ear bags: 50 adult ticks (25 males and 25 females) were put on the right ear of each animal and 100 larvae and 50 nymphs on the left ear. At the same time, each group of animals was put into separate paddocks, each paddock measuring 900 m^2 and each artificially seeded with 20 800 nymphal ticks.

The feeding success of ticks was used as an index of sheep resistance to the tick. A significant reduction in tick viability occurred during and after tick feeding in larval (89.5%), nymphal (76%) and adult (82%) stages and particularly in those ticks that fed on sheep immunized with solubilized tick midgut. The engorged weight of adult ticks in this group was only 9% of that of the control ticks. In addition, the mean egg weight of ticks was reduced from that of the control groups by 94% and the hatchability of the few eggs laid was adversely affected.

The percentage of larvae and nymphs undergoing ecdysis was significantly reduced from that of the control groups to 18% and 25%, respectively, in ticks feeding on sheep immunized with solubilized tick midgut.

The group of sheep immunized with a suspension of tick reproductive organs showed a significant reduction in the fecundity of engorged female ticks: only 46% of the females laid eggs, egg mass was reduced by 64% and the egg mass/tick weight conversion ratio was reduced by 64%.

These results are statistically highly significant and the effect of the induced immunity was a much reduced tick population in the paddock grazed by sheep immunized with solubilized midgut proteins.

STUDIES OF *RHIPICEPHALUS APPENDICULATUS* IMMUNITY IN GOATS

C. B. Maranga, P. B. Capstick

The goat is an important domestic animal in East Africa because it is able to live in arid environments with poor vegetation. Little is known of the development of tick immunity in goats following either natural exposure of goats to ticks or attempts to induce immunity in goats.

In 1986 we conducted experiments to assess the development of naturally acquired (feeding response) tick immunity in goats and then compared this natural immunity with immunity induced in goats by an inoculation of crude tick midgut antigens. Tick naive goats were bred especially for these studies. We induced immunity with an artificial challenge of tick larvae, nymphs and adults placed on goats' ears and then put each inoculated goat in a paddock seeded with ticks. We then observed the effect of tick feeding on tick population development. These experiments included studies to determine the effects of the transfer of maternal immunity from naturally immune dams to their offspring, as well as an assessment of the effect of goat dermal responses to infestations of feeding ticks.

The results to date indicate that the goat responds well to tick antigens: goats inoculated with tick antigens produce a high level of immunity to natural tick infestations, inoculations of isolated tick midgut protein mixtures and a combination of both types of immune induction.

The following effects on the tick life cycle are likely to be significant: larval, nymphal and adult engorged weights were reduced by up to 75%, and egg-mass weight induced by a combination of both types of immunity was reduced by up to 76%.

The numbers of tick deaths caused by ticks feeding on immunized goats were significant in all groups; the numbers of tick deaths caused by ticks feeding on goats immunized by tick midgut approached 37%.

A varying percentage of adults and nymphs fed on immunized goats turned black; those that did so usually died. Some white, reddish-pink and bright red larvae and nymphs were seen; these colours were probably caused by host erythrocytes or haemoglobin leaking into the haemolymph following gut damage in ticks engorging on immunized animals. Many of the adults that survived were infertile and others laid eggs of which only a low percentage hatched, further reducing the fecundity of ticks from immunized goats.

The percentage of eggs that hatched was less than 50% in the experimental groups. Similar results were produced by experiments on the transfer of maternal immunity: mothers that have been naturally immunized with ticks transfer considerable colostral immunity against ticks to their progeny.

Dermal responses indicate that the nature of the cellular infiltrates changes in character and magnitude during feeding and these differ markedly in successive infestations. The principal cells involved in these infiltrates are eosinophils, mast cells, basophils and neutrophils. These cells have also been found by other workers to attack tick tissues once the gut of a tick feeding on an immunized host has been ruptured.

Studies have shown that a protective function of eosinophil major basic protein has been demonstrated in a number of host-parasite systems. Other studies have shown that in addition to modulating the effect of mast cell/basophil-derived mediators, the eosinophils dam-

age the cheliceral receptors or the gut epithelia of the tick, by their major basic protein or other enzymes, thus leading to poor feeding by the tick. Similar results occurred during this study.

The immunity to ticks produced in goats (1) by natural tick infestation, (2) by giving goats injections of midgut tick antigens and (3) by a combination of both methods has effectively controlled the development of tick populations in experimental paddocks. If the goats' immunity to ticks persists long enough in practice, it is possible that immunization of goats would greatly reduce the economic losses due to ticks.

In summary, tick-resistant goats reduced tick populations by impairing feeding, leading to a reduced production of larvae. This tick resistance is an acquired immune response associated with both humoral and cellular reactions. It should be possible to use induced immunity to reinforce naturally acquired immunity to reduce tick damage.

IMMUNIZATION OF CATTLE WITH TICK ANTIGENS

P. B. Capstick, T. Dhadialla, J. J. de Castro

Following reports of successful immunizations of cattle with crude extracts of *Boophilus* and *Dermancentor* tick spp., an attempt was made to vaccinate 6-month-old Friesian steers with crude antigen extracts adjuvanted with Freund's complete and incomplete adjuvants.

Suspensions were prepared of the following tissues and stages of *Rhipicephalus appendiculatus* ticks: salivary gland, midgut from 6-day-old fed adults, all internal organs, a mixture of midgut and reproductive organs, unfed larvae and nymphs. These suspensions were emulsified with the Freund's adjuvant and given in a course of three intramuscular injections to groups of four Friesian cattle that had been raised with continuous acaricide cover. The animals were then each challenged on both ears with 100 larvae, 50 nymphs and 50 adult ticks. Tick engorged weights, deaths, moulting efficiency, egg-mass weights and hatchability were then recorded.

There were significant effects on larvae, nymphs and adults. Larval engorged weights were reduced, 28% of the larvae were killed and moulting was reduced to 46%. Nymphs died mainly during feeding. Larval and midgut suspensions were the most effective antigens, producing 29.5% and 25% tick deaths, respectively. Effects of the vaccination on adult ticks were generally minor, with only small reductions in engorged weights.

A wide variation in individual responses to the vaccinations occurred within groups of cattle, some animals showing excellent responses. The serum from these cattle will be used in attempts to identify the responsible antigens in the crude suspensions.

The overall responses of the cattle to these vaccinations were not as good as those reported as obtained from similar vaccinations in sheep and goats. This may be due to such factors as insufficient antigen, immune incompetence due to the young age of the animals vaccinated and antigenic competition. The experiments will be repeated under different conditions and using antigens designed to eliminate these possibilities.

This study was carried out in collaboration with the Veterinary Research Department of the Kenya Agricultural Research Institute and the United States Agency for International Development.

COMPARATIVE IMMUNOGENICITY OF A SALIVARY GLAND ANTIGEN AND NATURAL TICK INFESTATION

M. Nyindo, R. Chesang, P. Muteria

A study was carried out in 1986 to determine whether a salivary gland antigen prepared in the laboratory would induce protection against a tick challenge comparable or close to the protection produced by adult ticks, nymphs or larvae of *Rhipicephalus appendiculatus* in adult rabbits. Furthermore, it was of interest to determine whether cross protection existed between the three life stages of this important tick species, that is, whether animals made resistant to larval infestation, for example, would reject adult ticks to the same degree that they reject subsequent larval infestation and vice versa.

A soluble antigen (SGA) was prepared from the salivary glands of adult ticks after having fed on rabbits for 3 days. Sixteen rabbits were selected at random and divided into four groups of four rabbits each. Each animal of the first group was inoculated with 10 mg protein of SGA in Freund's incomplete adjuvant. Two booster injections were administered at 3-week intervals. A third booster was injected subcutaneously without adjuvant.

The second group of rabbits received 3 adult tick infestations, each infestation comprising 30 males and 30 females. The third group was infested 3 times with nymphs, while the fourth group received larval infestations. Two weeks after the last injection was administered to rabbits in the first group, each animal in the four groups was challenged simultaneously with 30 male and 30 female adult ticks, 100 nymphs and 100 larvae. Engorgement weights of the ticks were determined and the percentages of ticks that moulted and eggs that hatched were recorded.

Use of a SGA in rabbits (Table 1) produced a favourable response: the engorgement weights of ticks at all growth stages were less than the engorgement weights of ticks in the control groups. When rabbits exposed to 3 larval infestations were challenged (Table 2), they too mounted a good immune response against the ticks, a response similar to that mounted by rabbits vaccinated with SGA. When rabbits infested with nymphs were challenged, they responded in a similar way to rabbits exposed to larvae. When rabbits exposed to 3 adult tick infestations were challenged, they mounted a dramatic response, particularly against adult ticks (Table 3).

These results show that a soluble antigen(s) from the salivary glands of *R. appendiculatus* is a possible immunogen which, when used in rabbits, reduces the engorgement weights of ticks similar to the engorgement weights of ticks on rabbits previously deliberately

Table 1. Weights of adult ticks, nymphs and larvae dropping from rabbits immunized with SGA

Animal no.	Weights(mg) Adult ticks ± S.E.*	Nymphs	Larvae
33	158.9 ±77.3	3.67	0.46
34	205.8 ±78.3	3.68	0.34
35	198.5 ±80.3	5.10	0.37
36	198.4 ±94.4	4.36	0.39
Control	343.3 ±73.6	7.56	0.50
Control	292.2 ±76.6	7.72	0.54

* S.E.: standard error.

Table 2. Weights of adult ticks, nymphs and larvae dropping from rabbits previously exposed to three larval infestations

Animal no.	Weights (mg) Adult ticks ± S.E.*	Nymphs	Larvae
37	227.7 ±101.7	3.80	0.37
38	189.7	4.10	0.34
39	164.3 ±188.3	4.58	0.35
40	256.1 ±82.3	5.70	0.30
Control	361.7 ±88.2	7.76	0.57
Control	303.0 ±44.5	7.72	0.54

* S.E.: standard error

Table 3. Weights of adult ticks, nymphs and larvae dropping from rabbits previously exposed to three adult tick infestations

Animal no.	Weights (mg) Adult ticks ± S.E.*	Nymphs	Larvae
48	51.0 ±58.5	2.97	0.37
49	47.6 ±39.8	3.36	0.37
50	37.2 ±22.5	3.50	0.36
51	27.5 ±21.5	3.30	0.36
Control	293.2 ±76.6	7.76	0.57
Control	303.0 ±44.5	7.72	0.54

* S.E.: standard error.

infested with larvae. However, more research is required on how to handle the antigen and the best way of administering it to rabbits so that its effects equal those engendered by adult ticks. Work is in progress to determine the physical nature of the SGA immunogen.

A previous exposure of rabbits to adult ticks usually caused, on challenge, the death of adults ticks, as well as a reduction in the percentages of ticks that moulted and eggs that hatched. These effects were not seen in the animals sensitized with SGA or the animals exposed to larval or nymphal infestations. Immunity induced by infestations of adult ticks affected challenge with all stages of ticks. However, immunity induced by infestations of tick larvae and nymphs did not have much effect on adult ticks.

ASSESSMENT OF HOST TICK RESISTENCE BY INTRADERMAL TEST

P. B. Capstick, J. J. de Castro, M. Nyindo

In experiments conducted by LTRP in 1985, both larval extract and the extract from embryonating egg cell cultures gave allergic type intradermal reactions when injected into tick-naive and tick-susceptible cattle and their reactions could be used to test for exposure to ticks. These experiments were extended in 1986. Because of its already bacterially sterile nature, tick cell culture extract was used in all experiments and the tests carried out in groups of cattle whose tick history was known.

Twenty-four cattle, which had been kept under constant acaricidal cover since birth and which therefore were presumed tick naive, were tested. Ten animals (42%) gave positive reactions. A further 19 animals naturally exposed to infestations of *Rhipicephalus appendiculatus* were also tested: 40% of 19 animals failed to react. Two wild buffaloes under continuous tick challenge gave positive reactions when tested.

It is clear from these results that, because the test is giving both false positive and false negative results, the antigen mixture from tissue culture is not giving a reliable indication of previous exposure to ticks. LTRP plans to define and extract the antigen responsible for the allergic response before using the test as a screen to determine the tick exposure status of cattle in the field.

RESISTANCE INDUCED BY THE LABORATORY AND FIELD-DERIVED STRAINS OF *RHIPICEPHALUS APPENDICULATUS*

J. W. Chiera

A 1986 LTRP study on the hatchability of *Rhipicephalus appendiculatus* tick eggs determined that there were no differences in hatchability (1) between eggs of the laboratory strain and eggs of field strains, (2) between eggs of females engorged on hosts previously exposed to ticks and eggs of females engorged on hosts not previously exposed to ticks and (3) between eggs of females fed on rabbits and eggs of females fed on cattle. However, the following differences did occur. For engorged females of similar weights, a heavier egg batch was produced by females fed on cattle than by those fed on rabbits. These tick egg batches produced heavier tick eggs

from cattle hosts than from rabbit hosts and, consequently, larger tick larvae from cattle hosts than from rabbit hosts. The field-strain females, after feeding on either rabbits or cattle, produced a significantly larger egg batch than the laboratory-strain females. In addition, when maintained on susceptible hosts, all unfed instars of the laboratory strain were found to be significantly smaller than unfed instars of the field strains.

These results show that the rabbit host reduces the size of unfed ticks. This raises the possibility that the rabbit host exerts selection pressure for smaller ticks, causing the present small size of the *R. appendiculatus* ticks that have been maintained on rabbits in Muguga, Kenya, for many years. If rabbits do exert such a pressure, it is essential to consider the implications where size of ticks is an important parameter. For example, use of the laboratory strain would result in underestimating certain aspects such as tick survival, which is dependent on tick size.

INVESTIGATIONS INTO CATTLE BREED DIFFERENCES IN RESISTANCE TO TICKS AND THE SELECTION OF INHERITED RESISTANCE CHARACTERISTICS

J. J. de Castro

Results from previous years work in LTRP suggest that in the development of host resistance to ticks, differences occur within and between breeds of cattle. We now know that cattle can be overwhelmed by heavy field-tick infestations and the diseases ticks transmit. These results, together with recent findings, have led us to re-think the use of naturally acquired host resistance to ticks in tick control. The following reports describe some of the studies conducted in 1986.

A Comparison of Different Breeds of Cattle For Tick Resistance

J. J. de Castro, P. B. Capstick

The following breeds and cross-breeds of cattle were assessed for tick resistance on the basis of tick burden: Ayrshire (*Bos taurus*) cross zebu (*B. indicus*), Friesian (*B. taurus*) cross zebu, Hereford (*B. taurus*) cross zebu, Boran and Maasai (*B. indicus*). After being immunized against theileriosis, ten animals from each breed were selected and maintained in one herd at Intona Ranch, Narok District, Kenya. They were challenged for 4 weeks with natural tick infestations of *Amblyomma cohaerens, A. variegatum, Boophilus decoloratus, Rhipicephalus appendiculatus* and *R. evertsi* . After 2 weeks of challenge, the *B. taurus* crosses were infested with approximately 3 times more adult ticks than the pure *B. indicus* cattle. By the end of the 4-week period approximately one-fifth of the *B. taurus* cattle had succumbed to heartwater and the trial was discontinued.

Differences in the Rates of *R. appendiculatus* Pick-Up between Breeds of Cattle

J. J. de Castro

Five Hereford cross zebu (tick susceptible) and five Maasai (tick-resistant) cattle were herded together and all adult *R. appendiculatus* from the left ear of each animal were collected daily for 7 days. Results indicate that Maasai cattle daily picked up fewer ticks than the Herefords (ratio 42:100). The reasons for these differences are being studied.

Selection of Boran Cattle for Tick Resistance at Mutara Ranch

J. J. de Castro, P. B. Capstick, M. Malonza, F. Rinkanya, H. Kiara**

Culling individuals of a herd of cattle that carry the heaviest tick burdens in that herd has been used to improve tick resistance in cattle. Cattle resistance to one-host ticks has been proved to be inherited and there is experimental evidence that resistance to three-host ticks may also be inherited. A project was started in 1986 (in collaboration with the Agricultural Development Corporation, the Ministry of Agriculture and Livestock Development and the Veterinary Research Department of the Kenya Agricultural Research Institute) to rank all young bulls for tick resistance at Mutara Ranch, Rumuruti, Kenya. This ranch is the home of the national Boran stud, and selection for desirable characteristics in Boran bulls takes place when the bulls are 2 years old. The characters being assessed for resistance ranking are tick numbers and species on the bulls, the sizes of engorging adult female ticks on the bulls, and the bulls' skin thickness, coat colour and response to intradermal injection of tick antigens. These studies should make it possible for tick resistance to be added to the desirable characteristics looked for when selecting bulls for breeding and will, in the long-term, considerably improve the breed's tick resistance, with obvious advantages for the farmers in the region.

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Changes in the Size of Ticks Preserved in an Alcohol/Water Mixture

J. J. de Castro, J. Ndungu

Ticks are usually preserved in an alcohol-water mixture (70% alcohol) for subsequent study (species identification, measurement, etc.). The present study is being conducted to establish the size changes of ticks collected at Mutara Ranch and preserved in this way. Female *R. appendiculatus* were measured on a daily basis before and during feeding to engorgement and then placed in the mixture. The same ticks have been measured monthly for the last eight months. Results indicate little

change in scutal size but a progressive increase in the length of the body of the females. The work is still in progress.

SURVIVAL OF *RHIPICEPHALUS APPENDICULATUS* ON THE GROUND

R. M. Newson, D. K. Punyua, P. O. Ngoko

This study is a continuation of work started in 1985 in collaboration with other scientists in the Nairobi Cluster. Batches of unfed adults, nymphs, larvae and engorged females of *Rhipicephalus appendiculatus* (all provided by the International Laboratory for Research on Animal Diseases) were placed on the ground in nylon gauze bags in protective wire containers at the Kenya Agricultural Research Institute, Muguga, and Intona Ranch, Narok District (three times in 1985 and once in 1986) and at Mbita Point Field Station (once in 1985). These batches of ticks are being examined at approximately one-month intervals, and the study will be completed in 1987.

At Muguga and Intona, the relative humidity found in thick grass near the soil surface is always close to saturation, and the main variable in this experiment has been temperature. Some survival data from all the sites are still being collected but preliminary results, expressed as 50% mortality times, are given for each site (Table 4).

Previous work in LTRP has shown that populations of unfed ticks (larvae in particular) show very good survival for most of their life-span with a final brief period of high mortality. In the present study the survival pattern for each cohort of exposed ticks is following a more uniform trend, although there is marked variation between batches that are sited as little as 1 m apart. Larvae of *R. appendiculatus* normally ascend the grass soon after hatching and confinement in high humidity at soil level appears to kill the larvae rapidly. The more usual survival pattern was shown during the last exposure after the nylon gauze bags were modified to give more air to the ticks.

The percentage of engorged females that laid eggs has been uniformly high (in the absence of most forms of predation) although the percentage of eggs hatching was more variable (Table 4).

The results obtained at Mbita Point, with warmer and drier ground conditions, suggest a duration to 50% mortality similar to the other sites, but followed quickly by the mortality of the remaining 50%.

A similar, but more comprehensive, experiment is now under way that will make use of the local strain of tick at each site. Tubular nylon bags being used in this experiment allow the ticks to ascend and descend within the vegetation. Development times and survival percentages during embryogenesis and moulting will also be recorded and the microhabitats will be monitored comprehensively by electronic data loggers. These data will be used to help create a tick population model.

TICKS ON CATTLE IN THE NGURUMAN TSETSE PROJECT

R. M. Newson, P. O. Ngoko

Tick samples have been examined that were obtained from experimental cattle in weekly and monthly collections from 1984 to 1986 made by the staff of a Tsetse Research Programme project on the Nguruman Escarpment, Kenya.

The results confirm that *Rhipicephalus appendiculatus* and *Amblyomma variegatum* occur on the wooded Nguruman Escarpment where the temperature and moisture are suitable for them. These species are replaced by *Rhipicephalus pulchellus* and *Amblyomma*

Table 4. Survival results for *R. appendiculatus* exposed at Muguga, Intona and Mbita Point*

	Date of Exposure			
	May 1985	Aug. 1985	Dec. 1985	June 1986
Muguga				
50% adult mortality (days)	273	313	(203)	(>200)
50% nymphal mortality (days)	195	112	83	(>200)
50% larval mortality (days)	—	—	—	131
Females laying (%)	96	95	96	95
Eggs hatching (%)	98	43	12	35
Intona				
50% adult mortality (days)	235	(445)	(170)	(>220)
50% nymphal mortality (days)	219	(222)	(173)	(>240)
50 larval mortality (days)	—	—	—	154
Females laying (%)	97	85	97	90
Eggs hatching (%)	78	63	84	69
Mbita Point				
50% adult mortality (days)	—	—	225	—
50% nymphal mortality (days)	—	—	126	—
Females laying (%)	—	—	92	—
Eggs hatching (%)	—	—	10†	—

*Figures in parenthesis: observations still in progress.
† Approximate.

gemma on the hot dry plains. *Hyalomma impeltatum*, rare in most parts of Kenya, is locally abundant on the plains. It is not regarded as a vector of livestock disease. *Rhipicephalus evertsi* is present on the escarpment and on the plains.

COMPARISON OF CONTAINERS FOR TICK DEVELOPMENT STUDIES IN THE FIELD

R. M. Newson, M. Malonza, J. Gatheru

A comparison is being made between two types of containers, in view of the problems experienced with condensation when using flat nylon gauze bags to hold batches of adult ticks, tick larvae and eggs under very humid conditions in tick survival studies. One container is a small tubular bag of the same stiff nylon bag, sealed flat at each end but with the seams in planes at right angles to one another, thus giving a spacious container. The other is a glass tube with a screw cap containing a ventilation port that is covered by fine stainless steel gauze. The development of batches of *Rhipicephalus appendiculatus* eggs and of engorged females in these containers is being monitored in thick grass at Muguga.

The results suggest that although the glass tubes have several advantages, such as robustness and simplicity, they may also provide warmer conditions than those outside. The survival rates of larvae hatching in the two types of containers will be a crucial factor in selecting the type of container to be used in further studies.

ECOLOGICAL STUDIES ON *AMBLYOMMA VARIEGATUM*

F. Gigon

Problem Definition

Amblyomma variegatum is a new subject in LTRP ecological studies. Although it has not been investigated to the same extent as *Rhipicephalus appendiculatus*, it appears that this species causes considerable economic losses to farmers, for example, by causing mechanical damage to the skin, secondary infection and heavy blood loss leading to anaemia. If tick researchers succeed in creating an anti-*R. appendiculatus* vaccine, it is likely that *A. variegatum* will become the main subject of tick study in Kenya. Thus a basic knowledge of the life cycle of *A. variegatum*, of its survival in the field in relation to climate and of its host-seeking behaviour should be determined as soon as possible.

It is now common practice to design mathematical models to simulate the trends and dynamics of animal populations. Such models have already been developed for several tick species, but field-collected data on *A. variegatum* are still needed before such models can be adapted for *A. variegatum* in East Africa. Once such models are developed, they can then be used to predict the results of proposed tick control regimens, as required for integrated pest control.

This study of *A. variegatum* has been divided into the following four areas.

(1) A study of the survival of the various stages of *A. variegatum* under field conditions to be conducted in three contrasting biotopes selected from the range of *A. variegatum* potential distribution.

(2) A survey of the meteorological and micrometeorological field conditions to be conducted in conjunction with the survival experiments.

(3) A collection of data on the life cycle of *A. variegatum* for the purpose of developing suitable models.

(4) A study of host-seeking behaviour to better understand the crucial transition between the off-host and on-host phases.

Results

The microclimate was found to be extremely variable depending on both the time of day and the area. In particular, daily humidity and temperature patterns vary greatly, putting stress on the ticks' physiology and causing the ticks to use large amounts of energy, which threatens their survival. On the other hand, these features of the microclimate, though qualitatively similar, vary greatly with height, type of vegetation cover, grazing pressure, etc. Thus, it is essential that the micrometeorological measurements be taken and the survival experiments be conducted at the actual sites and locations at which the ticks occur.

The natural location of the *Amblyomma* species during off-host phases is within the vegetation layer and as close as possible to the ground (the species never digs into the ground). This location does not seem to alter until a passing host provides the required stimuli.

Since this *Amblyomma* species is not a questing one, classical methods for studying the tick life cycle are not applicable to this species. Much effort has been spent in developing a new sampling technique, combining the already known attractancy of CO_2 with that of the recently isolated aggregation pheromone (ortho-nitrophenol). This effort has been encouraging and is receiving necessary input from a laboratory at the Institute of Zoology, University of Neuchatel, Switzerland.

Use of this new trapping method may give information about host-seeking behaviour, since the method is based on some of the stimuli probably involved. Indeed, field observations of grazing cattle show that their exhalations bring ticks resting at ground level to a state of intense but random activity and motility, leading to a possible host-meeting.

Future work will include field survival experiments, conducted in parallel with suitable meteorological and micrometeorological data collections. The life cycle of *A. variegatum* still remains to be investigated; because no suitable off-host counting method exists, on-host counts will be undertaken for these investigations.

CATTLE DISEASE SURVEY ON RUSINGA ISLAND, LAKE VICTORIA

A. A. Latif, D. K. Punyua, P. B. Capstick

The only breed of cattle present on Rusinga Island is the small East African zebu. A livestock disease survey was started in September 1986 on ten farms (which carry in total about 200 cattle) to collect data for baseline productivity assessment before commencing interventions to improve tick control. All calves born on these farms were recruited for the study. The farms were visited once a month for sampling and once a week for clinical observation. We report below some of the preliminary results from five months of observations. Tick-borne diseases and helminths were the major problems for cattle on the island.

Tick-Borne Diseases

Three of the tick species reported on the island are known transmitters of disease: *Rhipicephalus appendiculatus* is the vector of *Theileria parva*, the causative agent of East Coast fever (ECF); *Amblyomma variegatum* is the vector of heartwater, *Theileria mutans* and other diseases; and *Boophilus decoloratus* transmits *Babesia bigemina* and *Anaplasma marginale*.

Calves

A total of 37 calves were born on the ten farms during the months of June, July and August. There seems to be a natural synchronization of calving on the island, the cause of which is unknown. The number of *R. appendiculatus* begins to decline by a factor of three during this period, reducing the ECF challenge to calves. Regular clinical and parasitological examinations were commenced when these calves were 1–3 months old; 43% showed *Theileria* piroplasms. Over the next three months severe ECF reactions were diagnosed in 36% of the calves and by December all calves had been infected. Although the parasitaemias for both *Theileria* macroschizonts and piroplasms were high and pyrexia persisted for several days, none of the calves died.

B. bigemina and *A. marginale* were diagnosed in 6- to 8-month-old calves in November and December. These infections coincided with a peak of *B. decoloratus* infestation in October. *B. bigemina* was detected on 50% of the ten farms (9 out of 19 calves were positive). *A. marginale* was recorded on 70% of the farms (9 out of 25 calves showed the parasite in blood smears). The parasitaemia for both diseases was generally low; there were no deaths due to either. *Theileria velifera*, a non-pathogenic protozoa, was common but its incidence was not recorded.

Adult cattle

Direct examination revealed that 56%–79% of the cattle showed *Theileria* piroplasms of low parasitaemia each month. A serological survey conducted on the island with the collaboration of Dr. A. S. Young, from the Kenya Agricultural Research Institute, showed that 65% of the cattle had positive antibody titres to *T. parva* schizont antigen. One 2-year-old bull died suddenly; the cause of death was attributed to cerebral ECF infection. Four other cases, one of turning sickness and three of blindness (due to lens opacity), were diagnosed. These were believed to be due to chronic ECF infection. These animals are still under close observation.

Helminths

Examination of calf faecal samples revealed high infestations with *Trichostrongylus* sp.; at the age of 1–3 months, 70% of the calves were infested. Oral treatment with Nilzan or Nilverm (Cooper-Wellcome) was carried out and this reduced the infestation to 11%. A month after treatment the infestation rate had returned to its original level. Within the following two months all remaining calves became infested and there was a steady increase in faecal egg counts (70% of the animals showed more than 1000 egg/g faeces). The epidemiology, the pattern of larval contamination and the effect on calf growth rate will be studied further in 1987. Other internal parasites recorded during this investigation were *Fasciola gigantica, Paramphistomum* sp., *Strongyloides* sp. and *Coccidia* sp.

STUDIES ON HOST/TICK RELATIONSHIPS ON RUSINGA ISLAND, LAKE VICTORIA, KENYA

A. A. Latif, D. K. Punyua, P. B. Capstick

Cattle Resistance to Tick Infestation

Monthly whole-body tick collections from five animals (greater than four years old) on one farm showed different infestation patterns (Figure 6). Significant differences in tick pick-up was observed among the animals; these differences remained almost constant for five consecutive collections, that is, the most resistant animal carried between 200 and 400 ticks while the least resistant carried between 400 and 1200. This ranking of host tick populations will be investigated for one year.

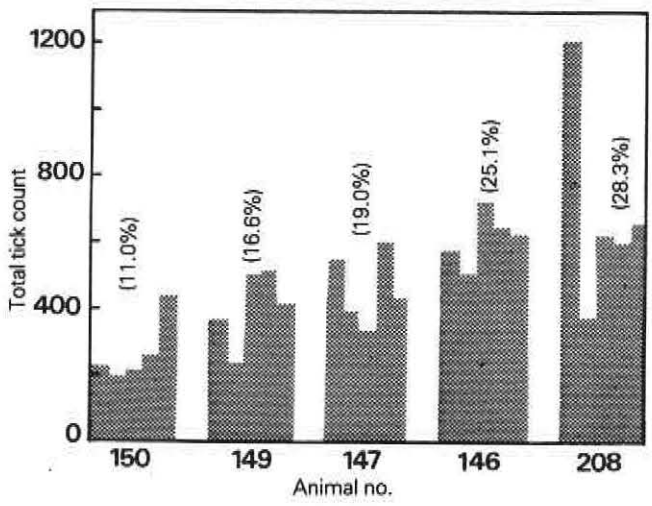


Figure 6. Monthly pick-up of ticks (all species and stages) by 5 cattle for 5 months: Farm no. 36 (Rusinga). Percentage of ticks carried by individual animals per total number of ticks carried by 5 animals is shown in parentheses.

Total tick counts are not the only selection factor for measuring tick resistance in breeding programmes. The animals were also ranked for their ability to allow attaching ticks to engorge. Figure 7 shows the size distribution of female *Rhipicephalus appendiculatus* collected from the most resistant and most susceptible animals (animals numbered 150 and 208, respectively). The resistant animal had a higher percentage of early feeding ticks than the non-resistant animal and no fully engorged ticks were recovered; 8% of the ticks on the susceptible animal were fully engorged. Assessment of the degree of tick resistance of these animals is possible only when comparisons are made with feeds on tick naive animals. These studies are under way.

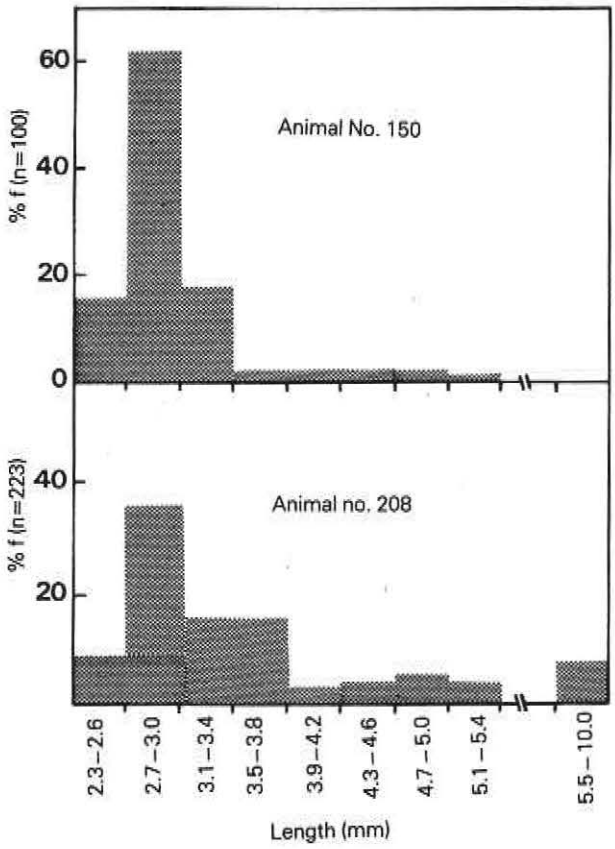


Figure 7. Per cent of frequency of size of female *R. appendiculatus* from whole-body monthly tick collections from two cattle: Farm no. 36.

Ranking for other species (*Amblyomma variegatum, Boophilus decoloratus*) is in progress and the size distribution at the immature stages will give an insight into the expression of host resistance.

Tick Damage

Ticks need to be controlled not only because they transmit diseases but also because their feeding damages the host. *Amblyomma* sp. damage cattle udders, causing losses of teats and quarters. A survey was conducted on Rusinga to investigate the existing damage. On the ten collaborating farms, a total of 52 milking cows were examined manually by milking each teat. The results showed that 27 cows (51.9%) had one, two or three teats and quarters with loss of function. Of the affected cows, 59.3% had lost one quarter, 18.5% had lost two quarters and 22.2% had only one milking teat. These losses adversely affect calf growth rate and milk productivity.

STUDIES ON THE POPULATION DYNAMICS OF LIVESTOCK TICKS ON RUSINGA ISLAND, LAKE VICTORIA

D. K. Punyua, A. A. Latif, P. B. Capstick

As reported in the *1985 ICIPE Annual Report*, Rusinga Island was selected as a suitable site for demonstrating the effect of interventions in the tick control practices on animal productivity and for making a survey of tick species and numbers. This survey demonstrated that there are four common tick species on the domestic stock on the island: *Rhipicephalus appendiculatus, R. evertsi evertsi, Amblyomma variegatum* and *Boophilus decoloratus*. In 1986 a survey was begun on the host tick population fluctuations of the four common tick species and the relationship of these fluctuations to climatic variations. A total of 45 cattle, 25 sheep and 25 goats were selected and sampled each month.

Results

R. appendiculatus, the most dominant of the four common species, was more prevalent on cattle than on the other two sampled hosts. Adult ticks of this species increased markedly and reached a peak in March (Figure 8). Although this peak of activity was expected to remain throughout the rainy season (March–May), there was an unexpected fall in tick numbers after March and the numbers continued to decline and then remained low throughout the rest of the year. The low activity after May can be explained by low rainfall after May; the sudden drop in activity at the height of the rainy season may have been due to agricultural and husbandry practices. For example, cattle grazing is restricted as soon as fields are planted, thus perhaps limiting host-tick interaction. Due to the low infestation levels, the immature stages did not show any marked population changes throughout the year.

R. evertsi evertsi is a two-host tick species that finds its host only through larval and adult activity. Although the adults were found to feed in equal numbers on cattle, sheep and goats, the nymphs and larvae were shown to prefer sheep and goats to cattle. There were only low adult infestations on the sheep throughout the year, and cattle and goat infestations were insignificant.

At larval and nymphal stages the ticks were active on sheep and goats at the same time of year and gave two peaks, one in January/February and the other in June/July. Although the two peaks of nymphal/larval activity coincided with the dry seasons of the year, the fact that they came soon after the short and long rains suggests that the rainy season has an influence on tick survival.

The data on *A. variegatum* shows that adults, nymphs and larvae are active at the same time of year. There are three peaks of activity—January/February, June/July and September/October—which coincide with the dry seasons. This data was unexpected because *A. variegatum* in other parts of the country becomes active dur-

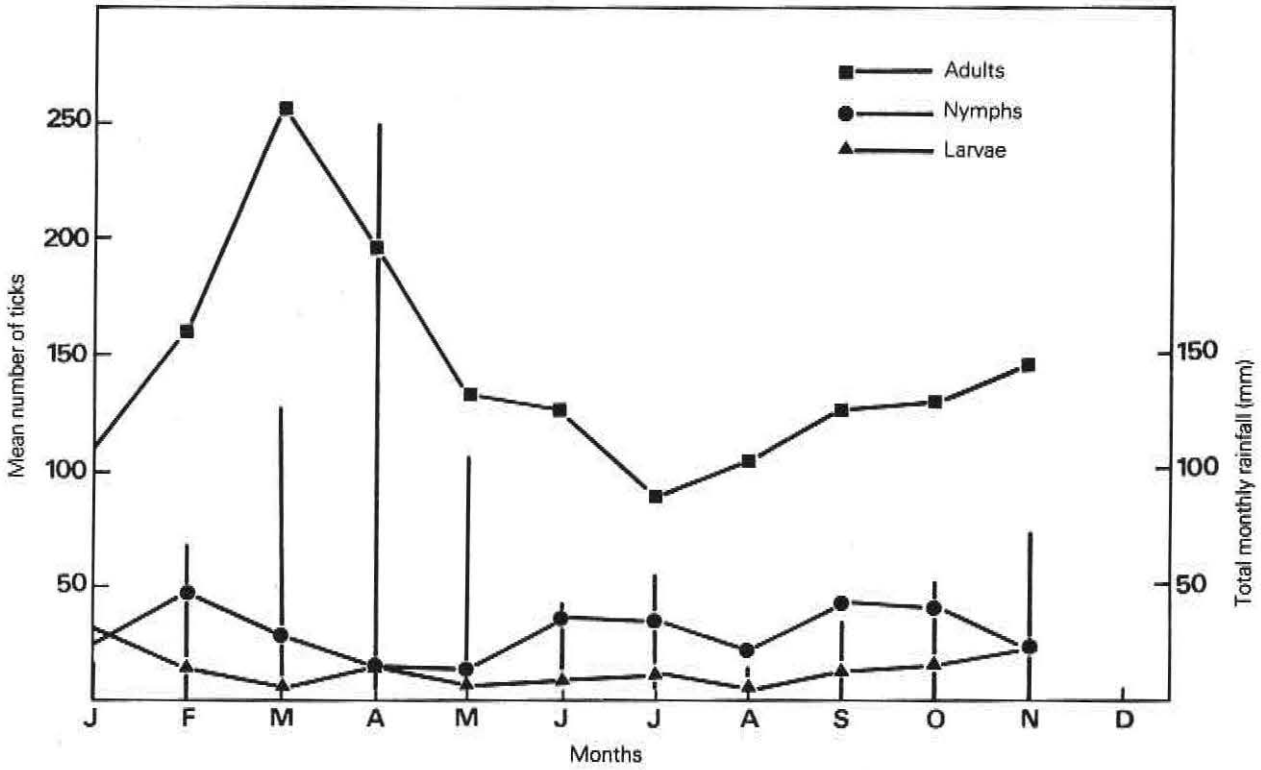


Figure 8. *Rhipicephalus appendiculatus* population changes on cattle on Rusinga Island.

ing the rainy season. The Rusinga Island population of *A. variegatum* appears to behave like *A. lepidum*, which is a dry-country species.

The larvae of *B. decoloratus* (the larval stage of this species is the only host-seeking stage) were found in very low numbers on all three host species. Nymphal and adult stages were found on cattle with three distinct peaks of activity: March, June and September/October. The peak in March coincided with high rainfall while the June and September/October peaks coincided with the dry seasons.

No population study of this tick species in East Africa has been reported; thus it is impossible to compare the data of this study with data from similar studies conducted in similar climates. Nevertheless, the intervals between activity peaks in this study suggest that tick population development is a more critical factor than climate in determining tick activity. Understanding tick population changes is critical to understanding the effect of such changes on disease and tick resistance by the hosts.

TSETSE SURVEY ON RUSINGA ISLAND

D. K. Punyua

Rusinga Island, Lake Victoria, Kenya, is approximately 20 km from the tsetse and trypanosomiasis endemic areas of Lambwe Valley. As part of a 1986 general survey on tick diseases on the island, 204 buffy coats from cattle were examined; no trypanosomes were seen. Because livestock move on and off the island, this finding was unexpected. Preliminary trapping using four traps set up along the lakeshore for four days revealed the presence of *Glossina fuscipes*. A total of 642 flies were captured and identified. A detailed survey of tsetse and trypanosomiasis on the island is planned for 1987.

CHOICE, COMBINATION AND RANKING OF SOURCES OF SUBSISTENCE ON RUSINGA ISLAND

*J.W. Ssennyonga**

This is a report of the provisional results from the first round of a three-stage research project on Rusinga Island, Lake Victoria, Kenya, titled Choice, Combination and Management of Household Sources of Subsistence in a Chain of Complementary Production Systems. Rusinga islanders make their living in several ways: they grow crops, herd animals, fish, work for wages, run small businesses or combine two or more of these activities. It is not known how households choose, combine and manage their individual or combined subsistence work or what is the relative importance in dietary, cash income and employment terms of each of these subsistence activities or their combinations.

Given the wide choice of subsistence work on the island and the lack of reliable information in this area, selecting households to study posed an immediate problem. A quick survey, dubbed Rapid Reconnaissance Survey, was designed to provide baseline material for sampling the households. 350 households, or 25% of the estimated 1400 households on Rusinga Island, were randomly selected for a sample. Field work started in mid-November 1986 and was completed a month later.

Most households are engaged in several production systems. For example, only 29 of the surveyed house-

holds (8.3%) earn their living by only one kind of subsistence work; 158 households (45%) combine 3 kinds of subsistence work; 121 (35%) combine 2 kinds of subsistence work; 57% combine 3 or more kinds of subsistence work. Of the 17 different combinations of kinds of subsistence work, the mix comprising agriculture, livestock and fishing was used by 118 of the households (33.7%). The mix comprising agriculture and livestock was used by 63 households (18%).

The numbers of households engaged in each kind of subsistence work are as follows: agriculture, 349 (99.7%); livestock, 253 (72.3%); fishing, 206 (58.9%); employment, 83 (23.7%); business, 23 (6.6%). The conspicuous dominance of agriculture is remarkable, as is the finding that more households depend on livestock than on fishing. The number of households earning money through employment is noticeably high for a remote rural island.

The figures on rank order present a non-linear bimodal pattern. For example, whereas agriculture and fishing are the two single most important primary subsistence activities, livestock-raising plays a strong supportive role, accounting for 35% and 59% of second and third rank scores, respectively. But a comparison of the weighted scores shows that on a scale of 100, agriculture scores 43.7, followed by livestock (23.8), fishing (22.8), employment (7.8) and business (2) (see Table 5). Agriculture has a much more commanding position than had been anticipated; more surprisingly, livestock has a higher score than fishing, a finding that runs counter to oral and written accounts describing Rusinga as a fishing island. These results justify the choice of Rusinga Island as a research site for LTRP. However, further research is needed to explain why the islanders give such a high ranking to livestock raising when available evidence shows that animal productivity is extremely low. Another issue for further investigation is the implication of the finding that 57% of the surveyed households are engaged in three or more kinds of subsistence work. Given the fact that these three kinds of subsistence work are done in three or more places, labour, time and other resource allocations are a critical issue.

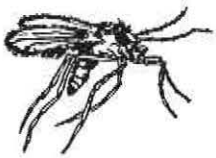
The completed Rapid Reconnaissance Survey, then, apart from providing a basis for sampling, has raised important issues for the next two stages of this research project.

* *Anthropologist seconded from ICIPE's Social Science Interface Research Project to LTRP in October 1986.*

Table 5. Distribution of kinds of subsistence work by rank and weighted scores

Rank	Agriculture	Livestock	Fishing	Employment	Business
1	1230	65	380	70	10
2	356	444	348	112	24
3	33	351	108	75	30
4	6	24	12	32	10
5	0	0	1	0	0
Total no.	1625	884	849	289	74
Total %	43.67	23.76	22.82	7.77	1.99
Rank	1	2	3	4	5

Medical Vectors



Medical Vectors Research Programme

The Medical Vectors Research Programme (MVRP) focuses its attention on the vectors and reservoirs of two major diseases, leishmaniases and malaria, the prevalence of which is a great drawback to health and agricultural development in the tropics.

The major activities of MVRP in 1986 were concentrated on the epidemiology of leishmaniases (visceral and cutaneous). The field activities were centred in the following three foci. In Baringo, investigations into the behaviour, bionomics and ecology of phlebotomine sandflies were continued. Studies on the efficacy of the ICIPE sticky trap as a sandfly control device were carried out. In Kitui, investigations into the vectors and the breeding sites of the vectors of leishmaniases were continued. In West Pokot, epidemiological investigations on visceral leishmaniases were continued. In addition, the behaviour, ecology and vector potential of the malaria mosquito in Marigat, Baringo District, were studied.

In the laboratory, experiments on the biology of wild sandflies and efforts to colonize new species and to maintain already colonized species continued. Factors influencing the vector potential of sandflies were studied and leishmanial parasites were identified and characterized using biochemical and molecular biology techniques.

From these activities, the following research results were derived.

- *The breeding sites of most of the sandfly species in the major endemic foci of leishmaniases have been established and confirmed.*
- *The flight ranges of sandfly species were determined using mark-release-recapture methods for wild sandflies and have revealed that sandflies probably do not fly long distances in search of food.*
- *Use over a long period of the sticky trap to trap sandflies can significantly reduce the numbers of sandflies in a given area.*
- *The choice of breeding sites by some sandfly species may be governed by soil types.*
- Leishmania major *may currently be restricted to rodent burrows due to the relative abundance of rodents on which the flies feed.*
- Phlebotomus duboscqi *is an efficient vector of* L. major *because of its relatively long lifetime.*
- *Some reptilian leishmanial parasites may be human* Leishmania *that have adapted themselves to reptilian hosts.*
- *Micro-organisms, including bacteria and fungi, affect the establishment of* Leishmania *in the sandfly gut.*
- *The breeding and resting sites of major malaria mosquito vectors have been established in Marigat, Baringo District.*

INVESTIGATIONS ON VECTORS OF LEISHMANIASES

M. J. Mutinga, C. M. Mutero, C. Kamau, F. M. Kyai, D. M. Omogo

Investigations on the breeding sites of phlebotomine sandflies continued in 1986 in three major endemic foci of visceral leishmaniases. These investigations have yielded a description of the breeding and resting sites of most of the sandfly species in Kenya. These sites include termite hills, animal burrows, tree holes, human dwellings and animal enclosures. Because the breeding sites have been identified, it will be possible in the future to plan control strategies geared to the immature stages of phlebotomine sandflies and especially to the suspected vectors of leishmaniases.

Studies continued on the efficiency of the sticky trap developed by ICIPE. This trap can reduce sandfly populations significantly and can thus be used as a control device to stop the spread of leishmaniasis. The results indicate that large traps are necessary to trap large numbers of sandflies, that the traps do not need to be attended to daily and that the colour of the trap has some bearing on the numbers of flies caught. Future studies will look for possible attractants to be used in conjunction with the trap.

The mark-release-recapture work was also continued. Results of experiments confirm that sandflies actively seek blood meals. The experiments also indicate that sandflies do not fly long distances in search of food, although they can be blown by the wind some distance (recoveries were made up to 1 km from the release point).

INVESTIGATIONS INTO THE BIOLOGY, FEEDING AND FECUNDITY OF *PHLEBOTOMUS DUBOSCQI*, THE VECTOR OF *LEISHMANIA MAJOR*

M. J. Mutinga, C. Kamau, J. Mwandandu

Phlebotomus duboscqi was captured in Marigat, in Baringo District, Kenya, where it mainly rests inside burrows, and then reared in the laboratory. The flies were fed on fruits and laboratory animals and each generation was monitored from oviposition to death. The gonotrophic cycle and fecundity were observed (Tables 1, 2 and 3). The results indicate that *P. duboscqi* could be a very efficient vector of leishmaniases on the hosts it normally feeds on, because it is able to feed several times on different hosts.

Table 1. Gonotrophic cycles of *P. duboscqi* in several experimental batches of laboratory-reared sandflies of the same generation and blood fed on the same day

	Experimental batches					
	1	2	3	4	5	6
Number of gonotrophic cycles	7	6	4	8	8	5
Number of days survived	45	25	19	43	44	24
Mean number of days of each gonotrophic cycle	6	4	5	5	6	5

Table 2. Survival rate of *P. duboscqi* females in successive gonotrophic cycles of a laboratory-reared colony

Experimental	Gonotrophic cycles							
batch	1	2	3	4	5	6	7	8
1	20	15(75)	15(75)	15(75)	15(75)	15(75)	8(40)	—
2	12	11(92)	9(75)	7(58)	7(58)	7(58)	—	—
3	5	4(80)	4(80)	1(20)	—	—	—	—
4	15	15(100)	15(100)	14(93)	7(47)	7(47)	4(27)	3(20)
5	6	6(100)	4(67)	3(50)	3(50)	3(50)	3(50)	1(17)
6	12	12(100)	12(100)	8(67)	2(17)	—	—	—

Numbers in parentheses: percentage of survival rate of *P. duboscqi*.

LABORATORY COLONIZATION OF PHLEBOTOMINE SANDFLIES

M. J. Mutinga, C. Kamau, F. M. Kyai, D. M. Omogo, J. Ndambuki

Several species of phlebotomine sandflies are now established in the MVRP laboratory, where field breeding conditions were simulated, and are serving as experimental models for investigations into host-parasite interactions. Hundreds of sandflies were supplied in the year to MVRP scientists. Some species have not yet been colonised and efforts to colonize them are in progress.

Table 3. Number of eggs per gonotrophic cycle of *Phlebotomus duboscqi* in six experimental batches

	Gonotrophic cycles								Female fecundity rate per experimental batch
Experimental batches	1	2	3	4	5	6	7	8	
1	15(4)	145(9)	306(9)	333(12)	178(8)	96(10)	29(4)	—	18.4
2	13(10)	241(8)	245(7)	71(3)	21(5)	21(5)	—	—	18.8
3	4(2)	42(1)	13(3)	45(1)	—	—	—	—	18.5
4	0	0	60(3)	148(6)	50(3)	0	23(3)	0	17.3
5	30(1)	2(1)	42(2)	22(1)	63(3)	0	15(1)	6(1)	16.7
6	42(3)	291(8)	17(3)	20(4)	0	—	—	—	15.3
Mean	20.8	144.2	113.8	106.5	78	58.5	22.3	6	

Numbers in parentheses: numbers of *P. duboscqi* laying eggs.

DETERMINATION OF THE VOLUME OF THE BLOOD MEAL OF A SANDFLY

J. B. Kaddu, R. Musyoki, M. P. Nyamori

Previous work on experimental *Leishmania* infection has shown that it is necessary to know the volume of sandfly blood meals in order to estimate the number of *Leishmania* parasites ingested by the flies. Because sandflies are so light, it is impractical to weigh them singly using the standard tools available in East African laboratories. We devised the following method to determine the volume of blood ingested by a sandfly.

Teneral sandflies were starved and weighed in groups of at least five to obtain their unfed weight. Each group was then caged and fed on a hamster. The fed flies were then weighed again to obtain the weight of the blood meal, which may then be converted into volumes of blood per sandfly by pipetting on a balance.

FACTORS INFLUENCING THE VECTORIAL POTENTIAL OF KENYAN SANDFLIES

J. B. Kaddu, M. P. Nyamori, R. Musyoki

The infection of sandflies with non-leishmanial micro-organisms is a factor that is suspected to influence the vectorial potential of sandflies. To investigate this, wild and laboratory-reared sandflies were examined for the presence of bacteria and fungi.

Sandflies were asceptically dissected and cultures of the gut contents were made. The micro-organisms that grew were isolated and identified. The part of the gut in which bacteria and fungi were found is indicated in Figure 1 in relation to the known microhabitat of Kenyan *Leishmania*. The infection rates of bacteria and fungi are indicated in Figure 2. The prevalence of various species of bacteria and fungi was established through a determination of infection rates. Gram-positive bacteria were more common than gram-negative bacteria.

The effect of these micro-organisms on the interaction of *Leishmania* and sandflies is being investigated.

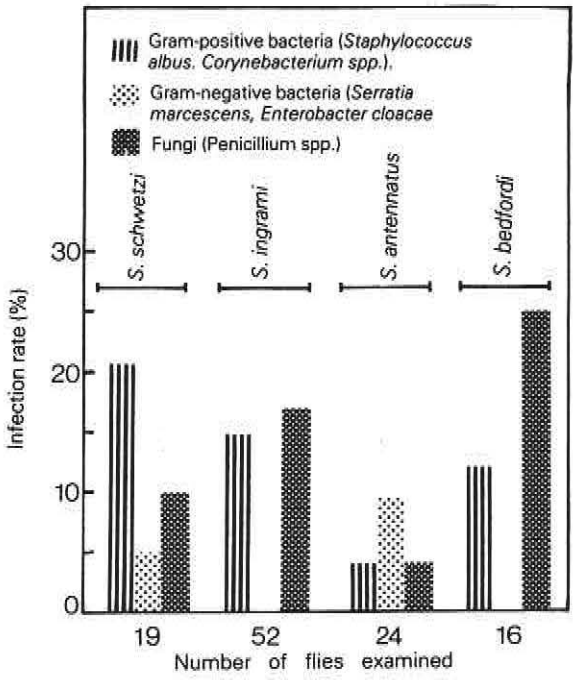


Figure 2. Bacterial and fungal infection rates in laboratory-reared *Sergentomyia schwetzi, S. ingrami, S. antennatus* and wild *S. bedfordi*.

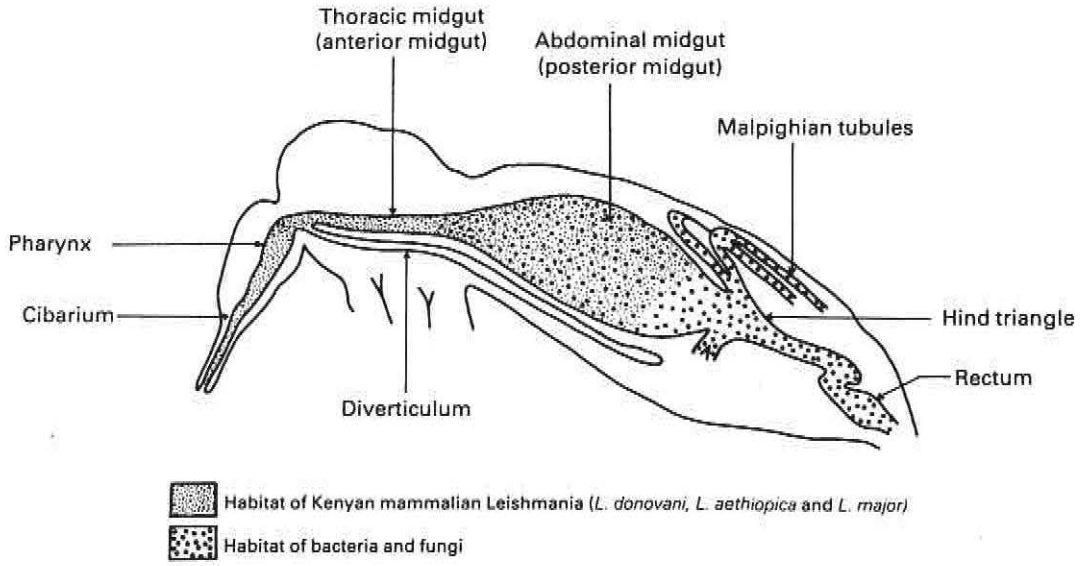


Figure 1. The alimentary canal of a sandfly showing the habitat of Leishmania, bacteria and fungi.

LARVAL COMPETITION IN SANDFLIES

C. M. Mutero, M. J. Mutinga, J. Mwandandu

Recent MVRP studies suggest that during the dry season some medically unimportant sandfly species dominate the medically important species, particularly in specialized breeding places such as termite mounds. Studies on intra- and inter-species larval competition in local sandflies were carried out to test whether certain species may displace others, especially through physical overcrowding.

Larvae of two species from the laboratory colony were reared at varying densities and in vials with the same surface area. In single-species cultures, each of the two species was reared separately at the various larval densities. In two-species cultures, the two species were mixed and reared at the same various larval densities.

Several features of competition were observed, especially in single-species cultures. In particular, the larval developmental period and the adult emergence period showed a positive correlation to increased density. Larval mortality also increased in relation to density. Pupal mortality remained density-independent under the same experimental conditions. The two species studied produced a 1:1 species emergence ratio at low densities of mixed-species cultures. However, one species dominated the other at high larval densities.

Data for a more detailed analysis of the intra- and inter-specific competition is being accumulated.

CLINICAL AND FIELD EPIDEMIOLOGICAL INVESTIGATIONS OF KALA-AZAR (VISCERAL LEISHMANIASIS)

C. M. Mutero, A. Ngindu, M. J. Mutinga, T. K. Arap Siongok, P. Kenya, F. A. Amimo, F. M. Kyai*

A collaborative research project involving ICIPE (MVRP), the Ministry of Health in the Government of Kenya and the Kenya Medical Research Institute (KEMRI) was begun in the West Pokot District of Kenya in February 1986. The main objective of the study was to determine the prevalence of kala-azar disease in the human population, as a pre-requisite to studying the insect vectors and animal reservoirs of the disease.

The West Pokot district has 67 administrative sublocations, of which a random sample of 20 was selected for clinical screening. One per cent of the district's population was surveyed. The number of persons screened from a particular sublocation was proportional to that sublocation's total population. The screening also took account of the district's population age structure. Figure 3 shows an example of the field activity.

The enzyme-linked immunosorbent assay (ELISA) made up the principal diagnostic test for kala-azar, or visceral leishmaniasis, cases in the area. In addition to providing information on prevalence, results from ELISA were used to compare ELISA with the leishmanin skin test as a tool for diagnosing the disease in the field.

Figure 3. Screening for kala-azar in West Pokot, Kenya.

The clinical survey in 19 district sublocations revealed a high percentage of active kala-azar cases in the district, although the distribution of cases varied significantly among the sublocations.

Kenya Medical Research Institute (KEMRI)

SANDFLY POPULATION DYNAMICS AND FACTORS AFFECTING THEM

*Mulenda Basimike**

Sandfly population dynamics and factors affecting sandfly distribution and abundance were investigated at the Perkerra Settlement Scheme, near Marigat, in Baringo District, Kenya, from November 1985 to October 1986.

A large number of sandflies were collected from animal burrows, termite mounds, tree holes, human habitations and animal enclosures. The species of these flies were identified and the flies categorized according to such things as their abundance during the wet and dry seasons. Seasonal changes in sandfly breeding and resting sites and sandfly behaviour on various hosts were also investigated.

Changes in the climate and environment, such as changes in rainfall, relative humidity and temperatures of air and soil, have been monitored and their effects on sandfly populations assessed. The mean numbers of sandflies collected monthly from various sites were correlated with the average monthly rainfall, relative humidity and temperature. A positive correlation between monthly rainfall, relative humidity and sandfly collections from termite mounds and animal burrows was observed, while a negative correlation was observed between temperatures and sandfly collections.

The physical and chemical features of soils of sandfly breeding and resting sites seem to play an important role in determining sandfly distribution and abundance in an area.

**Postgraduate scholar in ICIPE's African Regional Postgraduate Programme in Insect Science (ARPPIS)*

ECOLOGY OF MALARIA VECTORS IN MARIGAT, BARINGO DISTRICT

*Ifeanyi Aniedu**

A project on malaria vectors was initiated in Marigat, in Baringo District, Kenya, late in 1985 with the following two major objectives:

- To investigate the diversity and abundance of the mosquito species in the area.
- To study the seasonal population changes of the anopheline mosquito and to correlate these population changes with irrigation practices and environmental and climatic changes.

After a preliminary survey between October and December 1985, routine sampling started in January 1986. The first phase of the investigation included the identification of the mosquito species and a study of the seasonal abundance and resting habits of the anopheline species breeding in and around Marigat. Two types of mosquito habitat were selected for this study: a permanent, papyrus-covered swamp and an irrigation scheme area.

Fourteen species of mosquitoes have so far been identified as breeding in the study area, especially in the swamp area. Two important malaria vectors were encountered during this study and are being investigated. Only one species was encountered at the irrigation scheme. Its peak activity was in July and September.

Rainfall was found to be the most important factor affecting seasonal population fluctuations at the swamp. However, at the irrigation scheme other factors, including farming and irrigation practices, were observed to affect the vector population significantly.

**Postgraduate scholar in ICIPE's African Regional Postgraduate Programme in Insect Science (ARPPIS)*

IDENTIFICATION AND CHARACTERIZATION OF LEISHMANIAL PARASITES BY ISOENZYME ANALYSIS AND NUCLEIC ACID HYBRIDIZATION

N. N. Massamba, B. N. Odero, R. K. Rotich

The principal objective of the Molecular Biology section of MVRP is to contribute to a better understanding of the epidemiology of leishmaniases. The primary goals of this section are to establish the role of wild leishmanial isolates in the disease transmission, to study intrinsic parasite characteristics and to study leishmanial interspecies relationships.

1986 activities were centred on initiating research and establishing and organizing the Molecular Biology Laboratory, which included purchasing and installing equipment for biochemical and molecular biology work. In the new laboratory we have been able to adapt and mass-culture *in vitro* 25 leishmanial isolates and 5 leishmanial marker strains. Nuclear DNA from these stocks was prepared using established procedures. The fragments of restriction enzyme-digested total DNA were resolved by electrophoresis in agarose gel with ethidium bromide. The gels were then transilluminated with an ultraviolet lamp for quick examination. These preliminary experiments for preparing biological samples helped in the selection of a few isolates for cloning in order to obtain parasite homogenous populations indispensable in constructing cDNA and genomic DNA libraries. This work will lead to the development of species-specific DNA probes.

Five isolates showing characteristic profiles were retained for the above purposes. The following work is in progress: cloning the five isolates, purifying nuclear

DNA, preparing total RNAs and mRNAs from the cloned isolates and constructing cDNA and genomic DNA libraries. The results obtained from this work so far are very encouraging.

Isoenzyme electrophoretic analysis constitutes the other aspect of our research activities. Cellulose acetate electrophoresis has been proposed for preliminary trials on many samples. From the 30 leishmanial isolates and marker strains mentioned above, cell extracts have been isolated and beads prepared for isoenzyme analysis. The samples have been studied for twelve different enzymatic activities. Among the enzymes selected, eight of them showed strong activities, and these will be used as genetic markers for the characterization of the wild leishmanial isolates.

Tsetse

Tsetse Research Programme

The thrust of the Tsetse Research Programme (TRP) has been to develop new tsetse control strategies to reduce trypanosomiasis risk to animal and human life. The objectives of TRP during 1986 were the following.

- *To carry out detailed ecological studies on the quantification of pupal and natural adult mortality factors, including the reproductive biology of* Glossina pallidipes.
- *To use simulation models to increase our understanding of* G. pallidipes *population dynamics.*
- *To test the effectiveness of newly developed odour–baited traps in sampling and suppressing* G. pallidipes *and* G. longipennis *populations.*
- *To monitor the effectiveness of insecticide-control campaigns on* G. pallidipes *population densities and the subsequent decline of animal and human trypanosomiasis.*
- *To examine the role of tsetse humoral immune factors in resistance to pathogens and trypanosomes.*
- *To develop a viable laboratory-bred colony of* G. pallidipes *that can be used to study the biological aspects of the tsetse that have a direct bearing on control.*

Both field and laboratory work have been carried out. Most stress was put on field work at the Nguruman Escarpment research site, in the Rift Valley, Kenya, and at the Lambwe Valley research site, in western Kenya. At Nguruman, the scientists have worked on different aspects of the tsetse problem on a Maasai group ranch.

The progress made by TRP during the year is outlined in this report. The following are particularly noteworthy. TRP is using simulation modelling to improve our understanding of G. pallidipes *population dynamics. Considerable progress has been made at the Nguruman site towards developing a predictive population model that can be used for vector management. A trap using an odour-bait has been developed to control the tsetse and the local community is now fully involved in making and deploying such traps for experimental work on tsetse population manipulation. Such manipulation will be one of the main activities of TRP in 1987.*

The tsetse population in the Lambwe Valley, South Nyanza, Kenya, was subjected to constant insecticide spray operations and has been reduced to such low levels that the transmission of Trypanosoma brucei *has virtually been interrupted. However,* T. brucei *is still being detected in cattle in the study area. Improved odour-baited traps will be deployed in the coming year to see if we can sample ultra-low densities of* G. pallidipes *populations more efficiently.*

Attempts to colonize G. pallidipes *in the past few years have been successful and the colony will now be handed over to ICIPE's Insect Mass-Rearing Unit for routine maintenance. This colony will enable scientists to work with tsetse flies on a regular basis.*

TSETSE POPULATION DYNAMICS

Pupal Ecology

D. Adabie, R. D. Dransfield*

Pupal ecology of *Glossina pallidipes* at the Nguruman Escarpment in the Rift Valley, Kenya, has been studied to identify the characteristics of larviposition sites and to quantify pupal mortality rates. Sampling was carried out using hand searching for two man-hours per site. The efficiency of this technique was measured and found to be about 60%. Larviposition sites were usually found in dense shade under bushes. There was a shift of breeding sites from low-lying areas in the dry season to hilly slopes soon after the rains, when riverine habitats were flooded.

An index of overall pupal loss rate (log number pupae found − log number tenerals caught in traps in the following month) was plotted against the log number of pupae found (Figure 1). The strong linear relationship indicates that overall pupal loss rate is density-dependent. Part of this mortality (although not that from predation) could be quantified by holding field-collected pupae in the laboratory until emergence. The causes of non-emergence were identified as developmental failure, fungal attack and parasitism, although none of these was density-dependent. Parasitism rates by *Exhyalanthrax beckerianus* and *E. lugens* were usually below 10% and apparently inversely density-dependent.

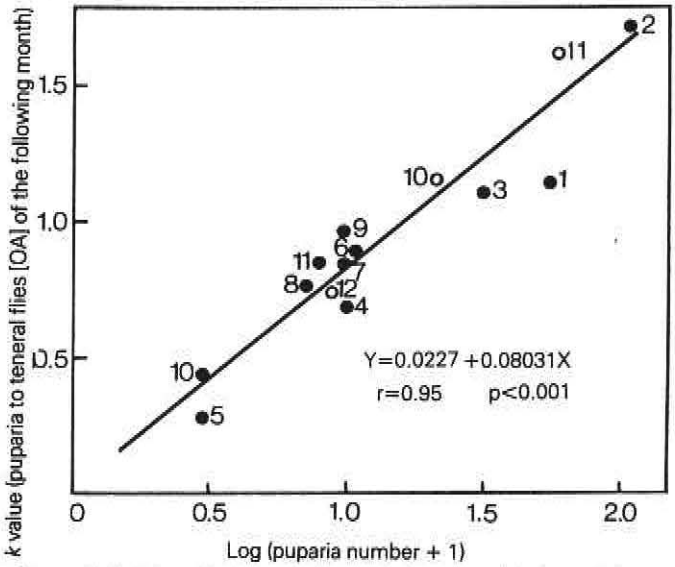


Figure 1. Relationship between loss rate from pupal to teneral stage of *G. pallidipes* and pupal density.

Predation was assessed by burying known densities of puparia in larviposition sites and scoring them for predation two weeks later. Although predation levels were quite high (about 35%), there was no evidence that mortality was density-dependent over the range of densities used (1–36 puparia/m^2). Research is continuing on improved sampling techniques and pupal mortality from predation and fungal attack.

* *Postgraduate scholar in ICIPE's African Regional Postgraduate Programme in Insect Science (ARPPIS).*

Population Modelling

R. D. Dransfield, R. Brightwell

Monitoring adult *Glossina pallidipes* densities and population structures has continued and, together with the work on this species' reproductive biology and pupal ecology, has provided a data base for creating population models of this species. Our main simulation model runs on a physiological time scale with a step length of 11-day degrees. All mortalities are expressed as *k* values. Density-independent mortality of the adults is determined by the relative humidity, to which trapping mortality may be added. Rainfall over 100 mm per month increases pupal mortality through flooding of the larviposition sites. Pupal predation and emigration of young flies are density-dependent and thus serve to regulate population size.

Output from the model was compared with changes in apparent density (catch per biconical trap per day) from May 1983 through June 1985 (Figure 2). The model provided a reasonably good fit to the changes in population size, althouh it overestimated some changes and underestimated others. After June 1985, the number of traps used increased significantly due to mark-release-recapture experiments and the testing of new trap designs. Since the number of flies removed was known and estimates of population size were available from mark-release-recapture data, trapping mortality could be added as a *k* value to the overall adult mortality. In Figure 3 actual and predicted population trends are shown up to January 1986; their similarity is very encouraging.

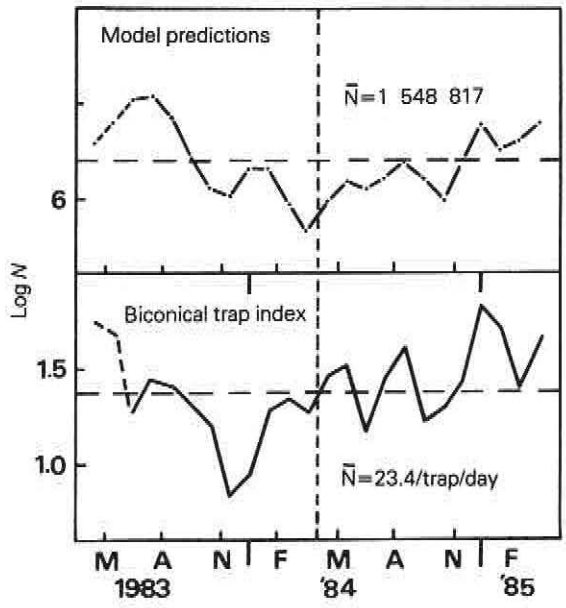


Figure 2. Model predictions and biconical trap index of *G. pallidipes* (female) population at Nguruman.

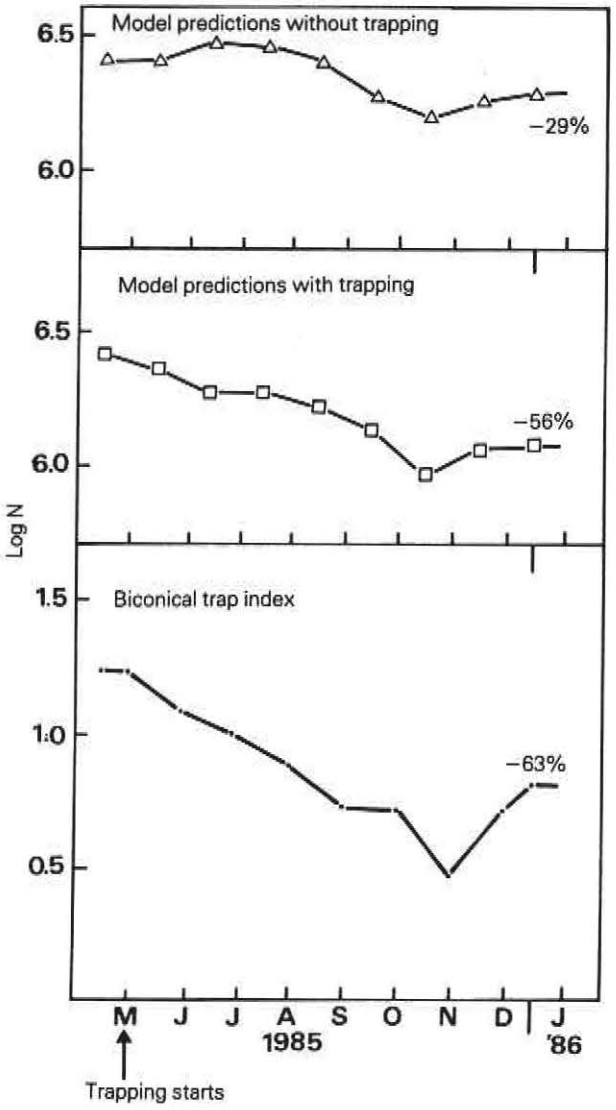


Figure 3. Model predictions and biconical trap index of *G. pallidipes* (female) population subjected to variable trapping intensity.

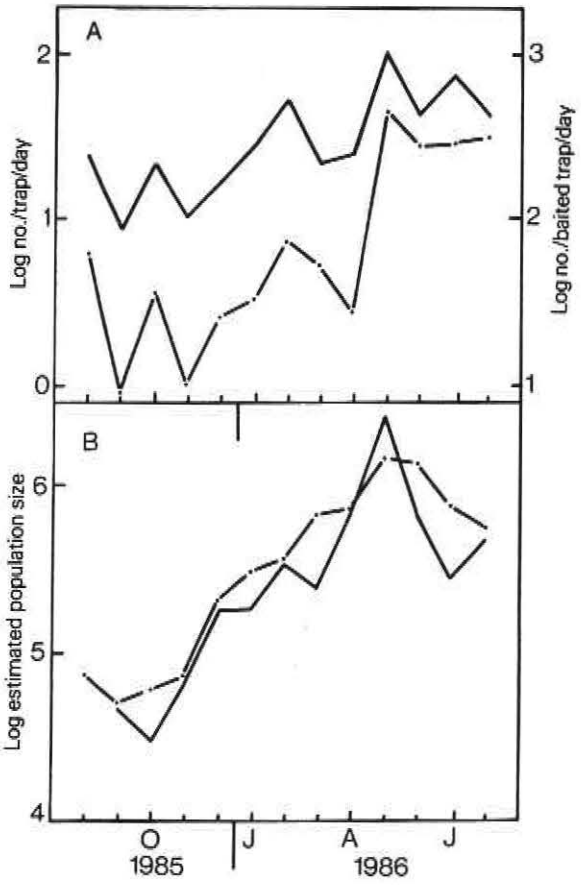


Figure 4. *A*: Catch/trap/day of female *G. pallidipes* in unbaited (open symbols) and baited (closed symbols) biconical traps. *B*: Estimated population size from mark-release-recapture data using Parker's (open symbols) and Bailey's (closed symbols) methods of estimation.

The simulation modelling has indicated that more data are needed in two main areas: the relationship between catch per biconical trap per day and absolute population density and the mechanisms involved in density-dependent mortality.

Extensive mark-release-recapture studies carried out at monthly intervals since August 1985 have provided absolute population estimates of *G. pallidipes* up to August 1986 for comparison with the biconical trap indices (Figure 4). Although individual standard errors of the estimates are usually quite large (50%–90% of the mean), their consistency from month to month gives greater confidence in the results. Both absolute and relative estimates indicate a low population from August to November 1985, increasing to a peak in May 1986. In two months, however, trends in biconical trap catches deviated markedly from those of the absolute estimates: catches declined in November 1985 and April 1986, both months of heavy rainfall and low temperatures. Although this could partly be a result of lower tsetse activity levels, experiments on trapping now suggest that, with the biconical trap in particular, the entry response is affected by temperature. Whilst the changes in catches by biconical traps from day to day is closely related to temperature, at least at temperatures below 30° C, the catches by the newly developed NGU traps are much less affected by temperature (Figure 5), and this clearly must be taken into account in interpreting seasonal changes in trap catches.

To elucidate the mechanisms of density-dependent mortality and emigration, studies have commenced on the effect of fly density and other factors on the feeding success rate. An incomplete ring of electric nets of a radius of 3.5 m was placed around a cow and the percentage of engorged flies on the inside of the nets recorded. In general, very low feeding success rates (about 5%) have been observed; this could be caused either by the screens being placed too close to the cows (thus catching flies circumnavigating the host prior to feeding) or by the strong skin-rippling response to the flies shown by the cattle used. Experiments with electric screens round cows and other host animals are continuing.

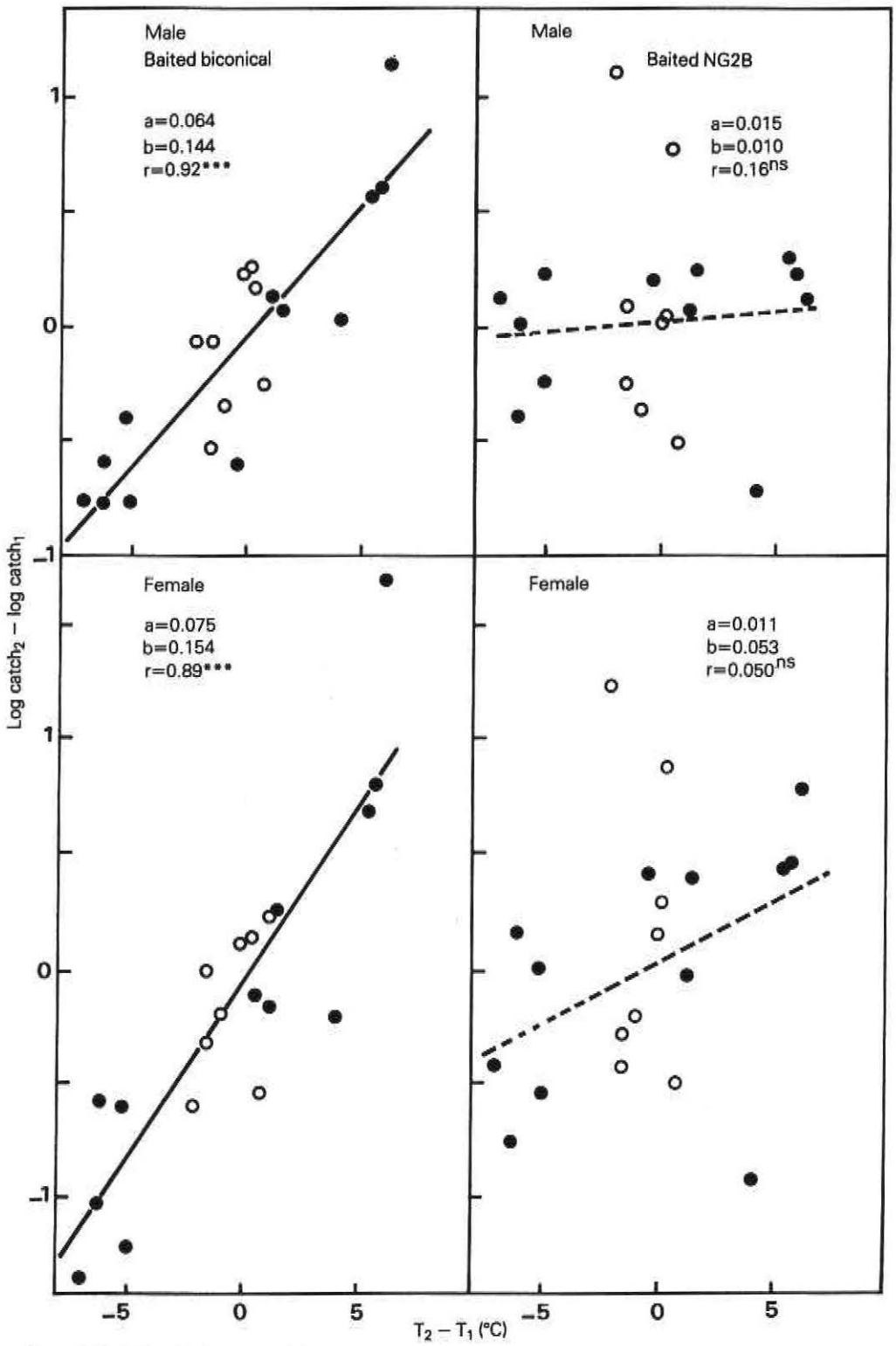


Figure 5. Relationship between (1) log catch on day 2 – log catch on day 1 and (2) the difference in mean temperature between the two sampling occasions.

Tsetse Population Manipulation

R. Brightwell, R. D. Dransfield

Research has intensified in 1986 on developing a trap and odour-bait system suitable for deployment in sufficient numbers to reduce *Glossina pallidipes* populations. Experiments on odour baits have shown that the acetone dose rate can be reduced to 150 mg/h without reducing the catch. Of the new trap designs tested, the NG2B proved to be the most effective, catching 2–11 times more female *G. pallidipes* than a similarly baited biconical trap. The variation in the index of increase was found to be temperature-related (Figure 6) and further

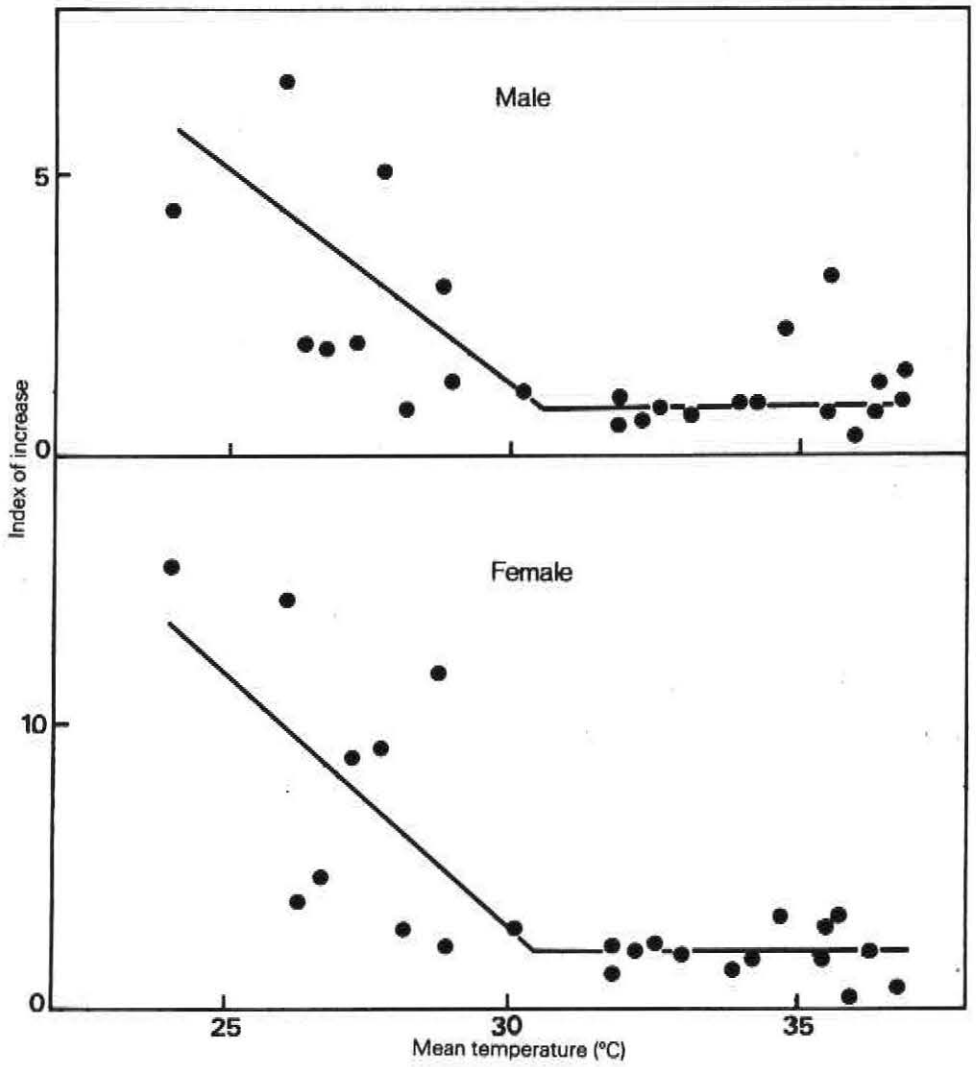


Figure 6. Index of increase for male and female *G. pallidipes* (baited NGU trap/baited biconical trap) in relation to temperature.

investigation suggested that entry response to biconical traps changes with air temperature. The experimental version of the NG2B trap was modified to facilitate its construction by the local Maasai people in their *manyattas* (groups of huts) by eliminating the trap's metal cone and using instead a large polythene bag for the cage. In a latin-square design, the "control" version actually increased catches by 10%, although this was not significant. In this design, flies die rapidly in the bag and are removed by foraging ants, thus obviating the need for chemical killing agents.

Population manipulation using the NG2B trap will commence in January 1987 with two primary objectives. First, the manipulation will provide valuable data for the further development of the population model, particularly with respect to immigration rates and density-dependent mortality. Second, it will enable us to develop full community participation since the traps will be made and maintained by the local people at Nguruman, whose response to this approach has been excellent. Traps are already being made under ICIPE supervision in most *manyattas* in the area. The eventual strategy of control or eradication will evolve from this approach; at present a seasonal deployment of traps in the dry season grazing grounds seems to offer the best prospects.

Ecology and Trapping Studies on *Glossina longipennis*

C. Kyorku, R. D. Dransfield, R. Brightwell*

Although *Glossina pallidipes* is generally regarded as the most important vector of animal trypanosomiasis in Kenya, several other species of tsetse in the country are also known to transmit the disease to cattle. At the Nguruman Escarpment, Rift Valley, Kenya, *G. longipennis* occurs along with *G. pallidipes*, although very few of the former are caught using standard sampling techniques. *G. longipennis* is known to feed on cattle (from blood-meal analysis) and infection rates of this species with *Trypanosoma congolense* are as high as those in *G. pallidipes*. The objective of this study, which

commenced at the end of 1985, was therefore first, to develop suitable trapping techniques for *G. longipennis* that could then provide the basis for future control operations against this species; and second, to use such techniques to improve our knowledge of the population dynamics of this species, initially by using the mark-release-recapture method to estimate population size and other parameters.

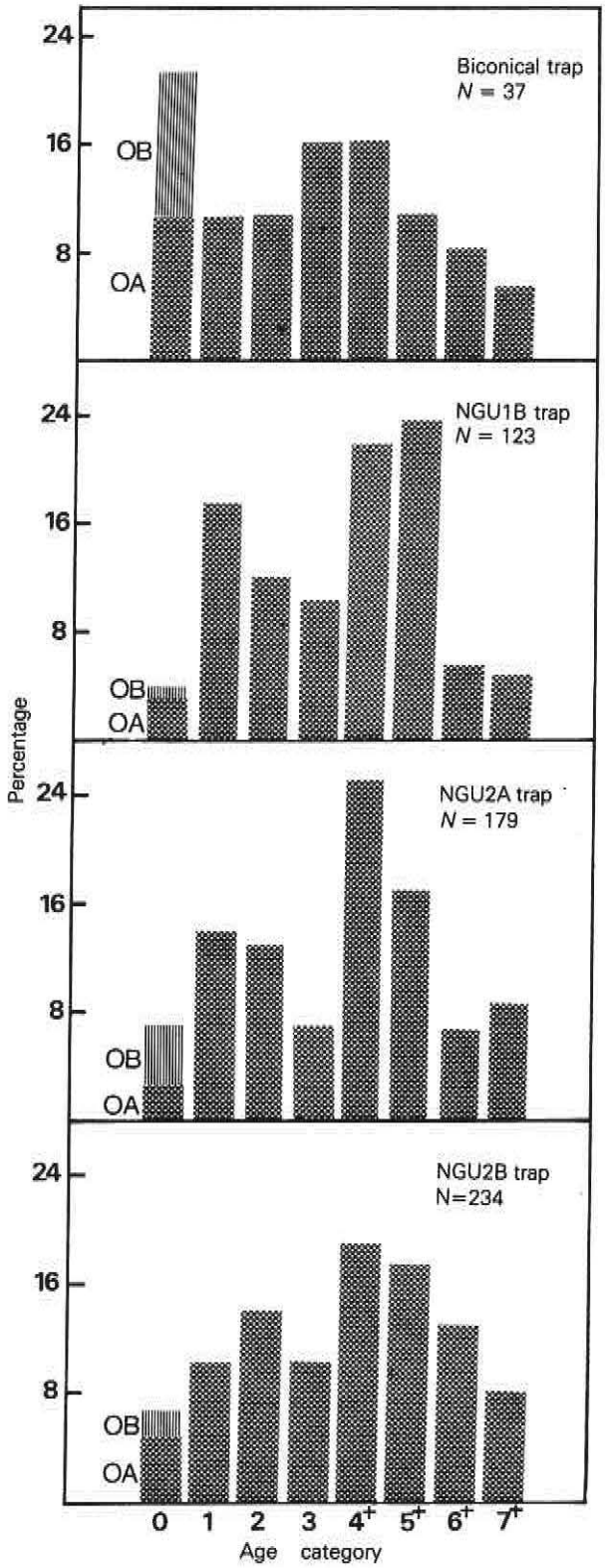


Figure 7. Age distributions of female *G. longipennis* in different trap types.

Various odour attractants and trap designs have been tested. Acetone (150 mg/h) and cow urine (1000 mg/h) have been found to increase catches in biconical traps by three to five times, although no significant increase could be detected when either attractant was used alone. No significant difference was found between cow urine and buffalo urine. To date, the Zimbabwe F3 trap and the more recent NG2B trap (see below) are the most effective traps, catching about four times more flies than a similarly baited biconical trap. Ovarian age-grading of female flies has shown that differences in trap design are more important in influencing the age composition of trap catches than differences in odour baits used. NG2B traps were shown to catch a significantly higher proportion of older flies than similarly baited biconical traps ($X^2 = 31.0$, df = 3, $P < 0.001$) (Figure 7).

Since June 1986, NG2B traps have been used for regular sampling to monitor the changes in relative population densities. Mark-release-recapture studies have also been initiated; these suggest a population size for *G. longipennis* of about 50 000 in an area of approximately 50 km^2. Studies are continuing on the population dynamics of this species.

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EPIZOOTIOLOGY: THE TSETSE–CATTLE INTERFACE

S. R. Nesbitt

Whether the cattle at the Nguruman Escarpment, Rift Valley, Kenya, will pick up a trypanosome infection depends on many factors, most especially on the cattle's contact with tsetse, the tsetse density, the tsetse infection rate and the cattle's susceptibility to the trypanosomes. TRP has monitored tsetse density and infection rates at Nguruman for the last three years. Recently research has intensified on the grazing patterns of the cattle of this area. These patterns vary considerably from year to year, depending on the amount of rainfall. Thus, in the drought year of 1984, cattle remained within the tsetse belt for the whole year, staying on the Ewaso Ngiro Plains after the main rains and moving to the top of the escarpment as the dry season progressed to find adequate grazing. This caused both high challenge and high trypanosome infection rates (40%–50%). In 1985 and 1986, however, the main rains in April were sufficient to move the cattle to Olkeriamatian in April, where they were kept until October, when they moved back to the plains. At Olkeriamatian the challenge was much lower than that on the plains and after Berenil treatment the cattle at Olkeriamatian in 1985 lost nearly all their infections (Table 1). Cattle kept on the Ewaso Ngiro Plains for experimental purposes that year continued to be reinfected despite treating infected animals with Berenil.

It is well known that not all infected blood meals will give rise to infection in the tsetse. Likewise, not all tsetse

Table 1. Effect of location of grazing area on trypanosome infection rate (*T. congolense* and *T. vivax*) in cattle at Nguruman

Month	Olkeriamatian		Ewaso Ngiro Plains	
	Cattle examined (no.)	Infected (%)	Cattle examined (no.)	Infected (%)
May	169	27.2	32	43.8
June	145	14.5	36	50.0
July	135	6.7	14	35.7
August	152	7.2	28	39.3
September	137	2.9	23	39.1
October	86	1.2	22	0.0

feeds will give rise to infection in the host on which they feed. Understanding these barriers to infection is fundamental to understanding the epidemiology of trypanosomiasis in the area. The first step in quantifying the barriers at the tsetse-cattle interface is to estimate the probability of a single blood meal giving rise to infection in the fly. For *Glossina pallidipes* at Nguruman, this was estimated to be 0.0014 for *Trypanosoma congolense* and 0.0042 for *T. vivax* (Figure 8). Given data are available on feeding patterns and host infection rates (in this case infection rates of wild hosts were taken from the literature). The proportion of infected blood meals giving rise to infection in the fly can then be estimated. For *G. pallidipes* this was found to be 7.12% for *T. vivax* and 1.16% for *T. congolense*. *T. brucei* is present but at too low a level to warrant a similar exercise being carried out.

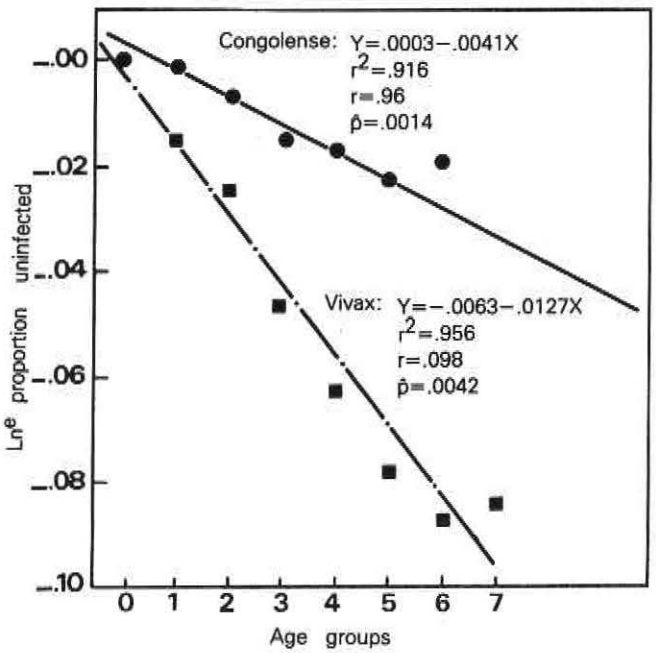

Figure 8. Ln (proportion of *G. pallidipes* uninfected with trypanosome) in relation to age of fly.

REPRODUCTIVE BIOLOGY OF *GLOSSINA PALLIDIPES*

M. F. B. Chaudhury, R. D. Dransfield, R. Brightwell

As part of a project on vector biology and population dynamics, the studies on the reproductive biology of *Glossina pallidipes* aim at determining the reproductive potential of the species and assessing various types of reproductive abnormalities and losses due to factors that contribute to overall mortality and population dynamics. Research was carried out in both the field and the laboratory.

Reproductive Status of Field-Caught Female *G. pallidipes* at Nguruman

Examination of field-caught female *G. pallidipes* at the Nguruman Escarpment, Rift Valley, Kenya, during 1986 showed that the lowest number (5%) of nulliparous females (both tenerals and non-tenerals) was caught in May and the highest number (50%) in March. The numbers of parous females caught were above 70% during most of the months. The numbers of teneral females caught varied from 2% in May to 16% in January and October to 27% in March. The number of parous females with empty uteri was significantly less than the number in the previous two years and varied from 0% in August to 7% in March, April and October, indicating an insignificant reproductive loss due to abortion. Non-teneral nulliparous females examined showed that 8% to 31% of the females were not inseminated and many of the females showed an underdeveloped first follicle, indicating a correlation between insemination and the developmental stage of the first oocyte, as suggested in the TRP report in the *ICIPE 1985 Annual Report*.

In Utero Larval Development

Out of 2361 parous females examined during the first ten months, 275 females were pregnant with either late second-instar larvae or third-instar larvae. Measurement of these larvae showed that an average of 32% of the larvae (ranging from 25% in June to 69% in March) were underdeveloped for their age, as determined by the corresponding follicle stage. Results of laboratory studies reveal that the females at this stage would have already ceased to take any more blood meal. Therefore, it is unlikely that these larvae would have gained any more weight during the final days of the pregnancy cycle and likely that they would suffer mortality due to abortion or due to the production of low-weight pupae.

Laboratory studies on the larval development, pupal production and adult emergence were initiated in the latter part of 1985. These preliminary studies are already yielding interesting results. Reduction in frequency and/or size of the blood meal resulted in retarded development of *in utero* larva without any visible retardation in the development of the first follicle. The retarded larvae

were sometimes deposited prematurely or retained in the uterus for longer than normal. Furthermore, the normally deposited larvae sometimes failed to pupate normally and this frequently caused wrinkled 'pseudo pupae', which did not produce adults. In many cases low-weight pupae—ranging from 15 to 22 mg—were produced. More than 50% of these pupae were not viable and did not produce adults. Other pupae produced adults with crumpled wings, malformed proboscises and other deformities; these eventually died. A few low-weight pupae produced diminutive but normal-looking adults. These adults took significantly longer to emerge than did normal flies emerging from normal-weight pupae. They were weak and could not take a blood meal successfully, probably because of their weak proboscises.

It is most likely that nutritional stresses such as those being simulated in the laboratory occur in the field and cause mortality in a considerable proportion of larvae, pupae and teneral adult populations of tsetse, but an assessment of the numbers of tsetse dying from nutritional stresses is difficult to make.

TSETSE TRAPPING

M. L. Owaga, A. Hassanali

In the *ICIPE 1985 Annual Report*, TRP reported that a blend of 7 phenols, which we named "buffinol", was identified in the active chromatographic fraction of an extract of buffalo urine. These included phenol itself, 3 and 4-cresols, 3 and 4-ethylphenols and 3 and 4-n-propylphenols. Recently we carried out a series of field tests using different blends of the constituent phenols to determine the relative importance of each phenol in the blend. Our results suggest that a mixture of 4-cresol and 3-n-propylphenol is responsible for most of the attractancy of buffinol. We are now extending these studies to include simultaneous release of buffinol and other tsetse attractants, such as acetone and 1-octen-3-ol, to see if the overall efficiency of odour-baited traps can be substantially enhanced.

STUDIES ON *GLOSSINA PALLIDIPES* APPARENT DENSITY IN RELATION TO TRYPANOSOME INFECTION IN LAMBWE VALLEY, WESTERN KENYA

L. H. Otieno, N. Darji

For the last year, regular ground spraying of dieldrin and cypermethrin in Lambwe Valley, western Kenya (by the Tsetse Control Section of the Ministry of Livestock Development of the Kenya Government) has kept the *Glossina pallidipes* population density at a low level. The effect of spraying has been most effective in the Riamakanga study area, where the fly density has been reduced during the first six months of the year to less than 1 fly per biconical trap per day. During the second half of the year, the densities rose slightly, possibly due to relaxation in the spraying operations. On the other hand, these operations were not as effective in the Ruma study area as in Riamakanga, with the result that during the second half of the year fly densities rose to over 20 flies per trap per day.

It is important to note that during the year no *Trypanosoma brucei* infections were detected in the flies from the study areas. The transmission of *T. congolense* and *T. vivax* was not, however, interrupted. The transmission of *T. vivax* was not interrupted even when the fly density was reduced below 1 fly per trap per day. This species of trypanosome is known to be transmitted by other biting flies, so it is not surprising that the transmission continues even when the fly density falls below apparent density <1. These observations suggest that it is relatively easy to interrupt the transmission of *T. brucei* if the fly density can be kept below a certain density level.

A survey of the *G. pallidipes* population and of cattle trypanosomiasis was carried out around the Ruri Hills–God Jope area to the northeast of the Ruma National Park. No flies were caught in this area throughout the year. For the first six months of the year the prevalence of cattle trypanosomiasis was below 2%. However, in the month of July there was a sudden increase (6%) in cattle trypanosomiasis, which coincided with an increase in the density of *G. pallidipes* (20 flies/trap/day). During the year, cattle trypanosomiasis caused by *T. brucei* was virtually non-existent, suggesting that there was reduced cattle-tsetse contact. On the other hand, infections caused by *T. vivax* were observed throughout the year. Although no flies were caught in Ruri Hills–God Jope area, it was clear from trypanosome infections in cattle that transmission was going on. It is possible that cattle trypanosomiasis was maintained by a few flies coming directly from the Ruma thicket, although their numbers were too low to be sampled by biconical trap.

ISOENZYME ANALYSIS OF TRYPANOSOMES

Isoenzyme Analysis of Cattle Stocks from Lambwe Valley

N. Darji, L. H. Otieno

This study analysed *Trypanosoma brucei* stocks isolated from cattle in the Lambwe Valley, western Kenya, at the third study site (God Jope) within a settlement area. This sampling area was chosen because it was suspected that the fly population might have split over from its natural habitat in the Lambwe Valley and established itself in the human settlement area. (See the TRP chapter in the *ICIPE 1985 Annual Report*).

As well as trapping tsetse in this area, a survey for cattle trypanosomiasis was carried out. A total of ten *T. brucei* stocks were isolated from the cattle this year and were characterized by the isoenzyme techniques described by Gibson and Wellde.* The isoenzyme results revealed that the cattle stocks displayed distinct

homogeneity. Only two zymodemes were identified: IC Z_{13} and IC Z_{14}. These have been described previously in cattle and fly by Gibson and Wellde (Table 2). Surprisingly, these zymodemes have not been isolated from the fly stocks collected from our two sampling areas, Riamakanga and Ruma thickets. The fly population in these areas has been very low due to insecticidal spraying. Only one *T. brucei* fly stock was collected during the year. There is no doubt, however, that any infected animal in the domestic environment poses a serious risk if the vectors are present. All such animals, as well as human cases, should be treated for trypanosomiasis if an outbreak is to be avoided. Such animals may also disseminate the disease in the other areas if the animals are herded to other areas or if they are transported for sale.

* *Gibson, W. C. and B. T. Wellde, 1985. Characterization of Trypanozoon stocks from South Nyanza sleeping sickness focus in western Kenya.* Trans. Roy Soc. Trop. Med & Hyg *79:671–676.*

Characterization by Isoenzyme Analysis of *Trypanosoma congolense* Collected from Two Geographically Isolated Areas in Kenya

U. Mustafa, L. H. Otieno, T. Dhadialla*

During field studies at the Nguruman Escarpment, Rift Valley, Kenya, and the Lambwe Valley, western Kenya, on the epidemiology of African trypanosomiasis, a large number of trypanosome isolates were collected for the purpose of discerning similarities and differences among these organisms. Isoenzyme profiles of 20 stocks of *Trypanosoma congolense* collected from *Glossina pallidipes* from the Lambwe Valley and Nguruman were compared using starch-gel electrophoresis.

Among the 20 stocks examined there was one zymodeme that was common to one stock from Nguruman and one from Lambwe and another zymodeme that was common to two stocks from Nguruman. The differences among the other 16 stocks were minor; they differed only in one or two enzyme profiles, which suggests that trypanosomes from those 16 stocks might be hybrids of each other and that *T. congolense*, like *T. brucei*, undergoes genetic exchange.

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Electrophoretic Studies on Isoenzymes of the Tsetse Fly, *Glossina pallidipes* Austen, in Kenya

T. Agatsuma, L. H. Otieno*

Enzyme electrophoresis has proved to be a useful tool for differentiating tsetse species and strains. The objectives of this study are to examine genetic structures of natural tsetse populations from various areas in Kenya, including Lambwe Valley, in western Kenya, which is the only area of Kenya endemic for human trypanosomiasis, and to estimate the genetic relationships among the populations. The isozymes were separated by horizontal starch-gel electrophoresis.

The following 14 enzymes were examined: malate dehydrogenase, malic enzyme, lactate dehydrogenase, glucose-6-phosphate dehydrogenase, phospo-6-gluconate dehydrogenase, *a*-glycerophosphate dehydrogenase, glucosephosphate isomerase, phosphoglucomutase, esterase, hexokinase, glutamic-oxaloacetic transaminase, isocitrate dehydrogenase, adenylate kinase and leucine aminopeptidase.

Out of the 14 enzymes examined, lactate dehydrogenase and leucine aminopeptidase showed no activity on the gel. The remaining 12 enzymes showed clear enzyme patterns. Only two enzymes, glucosephosphate isomers (GPI) and phosphoglucomutase (PGM), showed polymorphism in a population from Lambwe

Table 2. Variable isoenzyme patterns for cattle stocks

Area of Isolation	Stock no.	ALAT*	ASAT†	PGM§	ICD¶	ME‖	PEP_1#	Zymodemes
God Jope Farm	C_1	I	VIII	I	III	I	VII	Z_{14}**
God Jope Farm	C_2	II	I	I	III	I	VI	Z_{13}††
Ruri Hills	C_3	II	I	I	III	I	VI	Z_{13}
Ruri Hills	C_4	II	I	I	III	I	VI	Z_{13}
Ruri Hills	C_5	II	I	I	III	I	VI	Z_{13}
Ruri Hills	C_7	II	I	I	III	I	VI	Z_{13}
God Jope	C_8	II	I	I	III	I	VI	Z_{13}
Ruri Hills	C_9	II	I	I	III	I	VI	Z_{13}
Ruri Hills	C_{10}	II	I	I	III	I	VI	Z_{13}
God Jope	C_{11}	I	VII	I	III	I	VII	Z_{14}

Patterns for glucose phosphate isomerase (GPI), nucleoside hydrolase (NH), malate dehydrogenase (MDH), threonine dehydrogenase (TDH) and peptidase$_2$ (PEP_2) were invariant.

* ALAT: alanine aminotransferase.
† ASAT: aspartate aminotransferase.
§ PGM: phosphoglucomutase.
¶ ICD: isolitric dehydrogenase.
‖ ME: malic enzyme.
PEP_1: peptidase.
** IC Z_{14} is the same as Z_{85} (Gibson & Wellde, 1985 [see footnote to this paper]).
†† IC Z_{13} is the same as Z_{78} (Gibson & Wellde, 1985 [see footnote to this paper]).

Valley. Both of the two were highly polymorphic. For GPI, three types of pattern appeared: a slow-migrating band, a fast-migrating band and a three-banded pattern. The single band seems to be a homozygote and the three bands a heterozygote. For PGM, a slow-migrating, fast-migrating and double-banded pattern were detected. Here again, the single band appears to be a homozygote and the double band a heterozygote.

This is the first instance of polymorphism of the two enzymes GPI and PGM in a natural population of *Glossina pallidipes*.

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STUDIES USING RECOMBINANT DNA TECHNOLOGY TO DISCRIMINATE *T. BRUCEI* FROM *T. BRUCEI RHODESIENSE*

L. W. Irungu, N. N. Massamba, L. H. Otieno

A major restraint to the understanding of the epidemiology of human trypanosomiasis in Africa has been the difficulty of distinguishing the species and subspecies of trypanosomes belonging to the *T. brucei* group, these being morphologically identical. The taxonomic relationships among *T. b. brucei*, which is non-infective to man, and *T. b. rhodesiense* and *T. b. gambiense* are still poorly understood. Until recently, the only methods of determining the specific identity of these species have been the direct infectivity test, using human volunteers, and the blood incubation infectivity test, which is based on the observation that human serum is trypanocidal for *T. b. brucei* but not for *T. b. gambiense* or *T. b. rhodesiense*.

Two important questions remain unanswered: first, how to determine whether a trypanosome is man-infective (this information is essential for identifying animal reservoirs and vectors of the disease); and second, how to differentiate one pathogenic trypanosome strain from another in order to trace the origin and spread of new outbreaks of sleeping sickness. It is clear that specific strain markers are necessary to elucidate further the epidemiology of sleeping sickness. Various approaches have been taken to develop simple and reliable diagnostic tests. Some approaches rely on electrophoretic patterns based on interspecific enzyme and isoenzyme polymorphism. Other approaches have applied restriction endonuclease analysis of mitochondrial DNA (kDNA) to characterize the related species of the *T.b. brucei* group.

Initial studies by TRP include preparing clones from nine *T. brucei* stocks isolated from Lambwe Valley, in western Kenya. Populations from these clones have been prepared and are being analysed serologically to determine their homogeneity. DNA extracts from the parent stocks and clone populations are currently being prepared. Using the southern blotting analysis, we intend to examine the linkages between genes in the various stocks.

HUMORAL IMMUNITY IN *GLOSSINA MORSITANS MORSITANS*

G. P. Kaaya

TRP studies aimed at acquiring a better understanding of tsetse defence mechanisms were continued (see the *ICIPE 1985 Annual Report*). Inoculation of live *Escherichia coli* into *Glossina morsitans morsitans* tsetse flies induced a stronger antibacterial immune response (Attacin- and Cecropin-like factors) in females than in males and the response in both sexes increased with age from emergence to approximately two weeks and thereafter declined. Lysozyme response was also higher in females than in males, but was highest at emergence in both sexes and decreased with increasing age. Heat killed bacteria failed to stimulate production of antibacterial activity, but induced a lysozyme response that was weaker than that induced by live bacteria. Furthermore, inoculations of live *Trypanosoma brucei brucei* and *T. congolense* into tsetse failed to stimulate production of both antibacterial activity (Attacin- and Cecropin-like factors) and lysozyme. Although immunosuppression is a common feature in mammals infected with African trypanosomes, no evidence of immunosuppression was observed in tsetse inoculated or naturally infected with *T. b. brucei* and *T. congolense* when challenged with live *E. coli*.

Various species of bacteria stimulated different levels of antibacterial activity when inoculated into tsetse. *Enterobacter cloacae* stimulated the highest level of antibacterial immune response, followed by *E. coli, Acenetobacter calcoaceticus, Bacillus subtilis* and *Micrococcus luteus*. On the other hand, *E. coli* stimulated the highest lysozyme response, followed by *E. cloacae*, while the rest of the bacteria (10^3/fly) failed to stimulate lysozyme production. Levels of antibacterial immune factors in tsetse haemolymph increased progressively with increasing doses of live *E. coli* and reached a peak at a dose of 10^5 per fly. The immune factors retained their antibacterial activity when heated at 100° C for up to 25 minutes. Female tsetse inoculated with live *E. coli* prior to their first larviposition had significantly decreased fecundity, probably due to destruction of the gut symbionts by the induced antibacterial factors, while inoculations of live *T. b. brucei* and *T. congolense* had no effect on fecundity. However, tsetse infected in their mouthparts by *T. b. brucei* and *T. congolense* had significantly decreased fecundity and longevity.

Preincubation of tsetse immune haemolymph with Inhibitor A of *Bacillus thuringiensis*, followed by electrophoresis in acidic polyacrylamide gels, which were later overlaid with agar seeded with bacteria, revealed inactivation of both the Attacin- and Cecropin-like factors in tsetse immune haemolymph. Saline in which certain species of bacteria and *T. b. brucei* were incubated also inactivated tsetse immune haemolymph to various degrees. While *E. coli* and *E. cloacae* caused no inactivation (0%), *Serratia marcescens* and *B. thuringiensis* caused 100%, *Bacillus cereus* 65% and *T. b. brucei* 44% inactivations.

PRODUCTION OF *GLOSSINA PALLIDIPES* AT THE ICIPE MBITA POINT FIELD STATION

R. S. Ochieng, L. H. Otieno

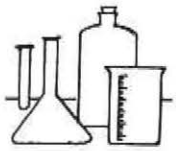
To rear *Glossina pallidipes*, a simple grass-thatched hut, constructed to allow a free flow of air, was built. The temperature and humidity inside this hut corresponds to that outside. Pupae used to start the colony originated from pregnant females collected from the Lambwe Valley, in western Kenya. Colony performance was evaluated on the basis of female survival numbers, weights of puparia produced and adult mortality rates (Table 3). The colony suffered a setback in October 1986 when the food used to feed the rabbits on which the flies fed was contaminated. This was quickly corrected and the tsetse mortality has been restored to its normal level.

A regular supply of *G. pallidipes* to TRP scientists for experimental purposes began during the year. The colony has now been handed over to ICIPE's Insect Mass-Rearing Unit for routine maintenance.

Table 3. Performance of the *Glossina pallidipes* colony, 1986, at the ICIPE Mbita Point Field Station

Mean female stock (no.)	4412
Mean daily female mortality (%)	1.5
Mean puparia per female per month (no.)	2.14
Mean weight of puparia (mg)	35
Puparia produced (no.)	81 793

Chemistry and Biochemistry



Chemistry and Biochemistry Research Unit

The primary role of the Chemistry and Biochemistry Research Unit (CBRU) is to carry out collaborative research with ICIPE's core programmes in areas of arthropod chemistry and biochemistry that are pertinent to the programmes' goals. The last three years, culminating in the unit's Second Triennial Review, in October 1986, saw the gradual crystallization of the unit's three major activities. First, CBRU conducts research on chemical ecology. This primarily involves an investigation of the pheromone, kairomone and allomone systems of ICIPE's target pests. The objective of this work is to contribute to efforts of core programmes to develop appropriate eco-technologies for the management of these pests. Second, CBRU conducts research on protein biochemistry in collaboration with ICIPE's Livestock Ticks Research Programme. The aim of this project is to identify tick antigens potentially useful for immunizing livestock against tick diseases. Third, CBRU screens anti-arthropod natural products from African plants. This work has a twofold aim: to identify new models for anti-insect activities and to explore the possibility of exploiting anti-arthropod plant products by developing simple methods—suitable for cottage-type or small-scale industries—to process such products.

ACCOMPLISHMENTS AND CURRENT ACTIVITIES

A. Hassanali

The 1986 research projects of CBRU were largely a continuation of those of the previous year. A synopsis of the unit's major accomplishments and current activities is given below.

Pheromone and Allelochemical Studies Relating to Crop Pests

The pheromone system of the African biotype of *Chilo partellus* has been shown to be more complex than the two-component blend reported by other investigators for the Indian population of the moth. In addition to (*Z*)-11-hexadecenal and (*Z*)-11-hexadecen-1-ol identified in the Indian biotype, a number of minor components have been shown to be present in the African biotype. Two of these have been identified as hexadecanal and hexadecan-1-ol. The identification currently under way of the other components will enable us to elucidate the roles of these components in the pheromone blend. This work is being carried out in collaboration with the University of Lund, Sweden.

As part of a comprehensive allelochemical study of sorghum, two new projects were initiated during the year: the study of volatile compounds emitted by whole sorghum plants and the identification of *Chilo* feeding allelochemics from sorghum cultivars. The latter is part of the Ph.D. work of a student in ICIPE's African Regional Postgraduate Programme in Insect Science (ARPPIS).

Volatile compounds trapped from 4-week-old seedlings of *Sorghum bicolor* (Serena cultivar) include toluene, hexanal, (*Z*)-3-hexen-1-ol, *m*-xylene, *o*-xylene, (*Z*)-3-hexen-1-ol acetate, nonanal and decanal. The role of these compounds in influencing pests' orientation to and recognition of sorghum plants will be undertaken in collaboration with ICIPE's Sensory Physiology Research Unit and Crop Pests Research Programme.

Feeding studies using third-instar *Chilo* larvae on cellulose acetate paper have shown that methanolic extracts of sorghum seedlings are the most effective in stimulating feeding, followed by ethyl-acetate extracts and hexane extracts. HPLC analysis of resistant (IS

2205) and susceptible (IS 18363) varieties indicate that component differences are largely quantitative. The main components of the ethyl-acetate extract have been shown to be *p*-hydroxybenzaldehyde and *p*-hydroxybenzoic acid. Both stimulate the feeding of third-instar *Chilo* larvae. They have also been shown by other workers to deter feeding in locusts and in a sorghum-feeding aphid. Identification of the minor components in ethyl-acetate extracts and those in methanolic extracts is under way.

Studies on the identification of *Maruca* larvae feeding deterrents from a resistant cowpea variety (TVu 946), and on a sorghum shootfly oviposition stimulant complex from a susceptible sorghum cultivar, were continued at a modest pace determined by the rate of bioassay work. The behaviour of the insects in both cases appears to be affected by a blend of chemicals (including the compounds reported by CBRU in the *1985 ICIPE Annual Report*), the activity of which is lost or substantially reduced on fractionation. This appears to be a fairly general semiochemical phenomenon and we are now using a new approach in screening for important components where each fraction or subfraction is excluded one at a time in reconstituted blends for bioassays. Details of the *Maruca* antifeedant and sorghum shootfly work will be reported in next year's *Annual Report*.

Tsetse Kairomone Studies

Several collaborative projects were undertaken on tsetse attractants during the year. Structure-activity studies on 1-octen-3-ol analogues have demonstrated the dependence of activity on the chain length and the relative positions of the two functionalities, as well as the nature of the functional groups. Dose response studies currently under way suggest that some of the analogues may be as active as or more active than 1-octen-3-ol. A detailed description of this work is given in the Sensory Physiology Research Unit chapter of this *Report*.

Last year we reported the identification of a blend of seven phenols, which we named buffinol, from a chromatographic fraction of dichloromethane extract of buffalo urine. This blend was responsible for about a sevenfold increase in *G. pallidipes* catches in the field. Field tests using different combinations of the constituent phenols have shown that the two most important components are *p*-cresol and *m*-propylphenol (see the Tsetse Research Programme chapter of this *Report* for a detailed description). We are currently preparing various analogues of these compounds for a detailed structure-activity study in the hope of improving the potency of the natural phenolic blend.

The demonstration during the year that buffinol components are formed as a result of microbial activity on water-soluble precursors has provided a potentially useful model for the controlled release of the attractants. Identification of the precursors is now at an advanced stage and will be reported next year. Meanwhile, the culturing of bacteria present in buffalo urine samples has started.

Tick Antigen Studies

During the last two years, the main focus of the CBRU collaborative research work with the Livestock Ticks Research Programme has been on tick gut antigens. The primary objective of this work has been to disrupt the tick midgut wall and digestion.

The carboxyl proteinase isolated earlier from the gut of *Rhipicephalus appendiculatus* has been shown to be a mixture of two components. These have now been separated by FPLC and are being characterized biochemically. Antisera to the enzymes are now being raised and their potential for disrupting digestion will be evaluated.

Fractionation studies were initiated on the soluble and Triton X-100 solublized midgut protein extracts of *R. appendiculatus* that were shown last year to give antisera that adversely affected the feeding of the tick.

The soluble extract was separated into several crude fractions by gel permeation chromatography. Immunoblots of SDS-PAGE of the fractions, however, revealed complex bands of proteins. The use of Native-PAGE, on the other hand, revealed a simpler pattern, with two readily discernible antigens with molecular weights of 140 000 and 110 000 in an undissociated state. Isolation and purification of these proteins is in hand. Similar studies on the separation and identification of antigens from Triton X-100 solublized protein fraction is under way and an account of the progress made is included in this report.

Anti-Arthropod Compounds from African Plants

A number of new isobutylamides were identified from a mosquito larvicidal extract of the flowers of *Spilanthes mauritiana*. Studies on the relative activities of these compounds are in progress. CBRU plans to study the practicality of using the plant, either in extract or in powder form, in small-scale mosquito control methods.

A novel limonoid with potent antifeedant properties against the larvae of *Eldana saccharina* and *Maruca testulalis* was isolated from the root-bark of *Harrisonia abyssinica*. It has a spiro ring A-B system and an oxidatively cleaved ring D unit and may provide useful insights for our structure-activity studies on limonoids. In view of the relative success of using crude limonoid extracts of the neem tree as unconventional pesticides, we are currently extending our present study to limonoids of Meliacea species indigenous to African ecologies.

Publications of the Unit

The Second Triennial Review, held in October 1986, provided CBRU with an opportunity to review its publication performance in recent years. Figure 1 shows a three-year moving average of the unit's publications for the period 1976–86. The unit's performance during the 1984–6 strategic plan period compares favourably with its performance during the years ICIPE had Visiting Directors of Research (1972–1979).

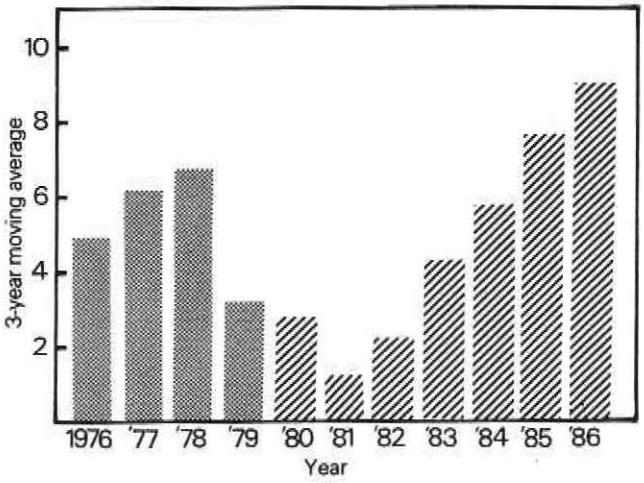


Figure 1. Histogram showing a three-year moving average of Chemistry and Biochemisty Research Unit publications for the period 1976–1986.

REINVESTIGATION OF THE SEX PHEROMONE SYSTEM OF *CHILO PARTELLUS**

P. G. McDowell

One area of research undertaken by the Crop Pests Research Programme of ICIPE is the study of moths (Lepidoptera) that cause damage to food crops. Sex pheromones are used in one of the methods developed to control such moths. Work of the Crop Pests Research Programme has shown, for example, that *Chilo partellus* males may be trapped successfully using virgin females as a pheromone source in a trapping device. Such use of sex pheromones has helped to control many pests throughout the world. Because using live females as an odour source is inconvenient and impractical on a large scale, the pheromone blends from a species under study must be identified if attempts to use pheromones for prognosis and/or control are to succeed. CBRU is identifying effective pheromone blends for field use by the Crop Pests Research Programme and for the development of monitoring and control methods.

Of the several moth species being investigated by the Crop Pests Research Programme, the spotted stalk borer, *Chilo partellus*, was chosen by CBRU as the first species for study. While two compounds have been isolated from this species by other investigators, using populations of the moth obtained in India, these known components—(*Z*)-11-hexadecenal (Z11-16:Ald) and (*Z*)-11-hexadecen-1-ol (Z11-16:Ald)—have been shown to be relatively ineffective in attracting male moths on the African continent. Thus, any attempt in Africa to use the pheromones of this species requires a new, in-depth study of the species' pheromone chemistry and behaviour. This study is well under way by the Crop Pests Research Programme.

The following two methods have been used to determine the content of female *C. partellus* pheromone glands: (1) solvent extraction of single, dissected glands and (2) trapping airborne volatiles from single females, followed by extracting the trapped volatiles with hexane. In each method, samples were analysed by capillary gas chromatography with splitless injection. Columns were either fused silica, bonded-phase DB-Wax or Superox and were 30 m in length, with a 0.25-mm inner diameter. Hydrogen was used as the carrier gas at approximately 40 cm/sec linear velocity. A flame ionization detector was employed, and the analyses were performed on an HP 5880A chromatograph or a Packard 438 chromatograph. Gas chromatography–mass spectrometry (GC-MS) analyses were also performed on extracts using a VG 12-250 quadrupole spectrometer.

Preliminary analyses of female *C. partellus* from Kenya were performed by extracting glands and collecting and extracting airborne volatiles three to four hours after the start of the scotophase on the first day following emergence. These analyses indicate the presence of both of the two known compounds, Z11-16:Ald and Z11-16:OH, with the aldehyde as the major component in most cases. The quantity of the major aldehyde ranged from less than 1 ng to approximately 20 ng per female, while the ratio of the aldehyde to the alcohol was variable. (Determinations of these two compounds in the Indian populations of *C. partellus* gave a ratio of aldehyde:alcohol of 7:1, with the aldehyde present at the 20 ng/female level.) Since the maximum activity of the insect in the field at Mbita Point Field Station, at Lake Victoria, western Kenya, is between 2300 and 0300 hours, analyses of female glands were undertaken at various times after the beginning of the scotophase, that is, at 1, 3, 5, 6, 7, 8 and 9 hours into the scotophase. Determination of the quantities of Z11-16:Ald at these times indicate that maximum production of components occurred during the 6- to 8-hour period of the scotophase, which is in line with the period of maximum activity in the field. Figure 2 shows a chromatogram of a single female gland at 8 hours into the first scotophase following emergence, the flame-ionization-detector response indicating approximately 80 ng of Z11-16:Ald.

The chromatogram shows that, in addition to the two known components, a number of other minor components are present in gland extracts. These components are also apparent in analyses of airborne volatile collections, as shown in the chromatogram depicted in Figure 3. On the basis of retention time and comparison with authentic samples, two of these components have been identified as saturated hexadecanal (16:Ald) and hexadecan-1-ol (16:OH). Saturated hexadecanal was identified also by mass spectrometry, as were the two major unsaturated compounds. Another very minor component—or pair of components—has been tentatively identified as (*Z*)-7-hexadecenal (Z7-16:Ald) and/or (*Z*)-9-hexadecenal (Z9-16:Ald). Other components remain to be identified and those of importance will be pinpointed by the use of gas chromatography–electroantennography (GC-EAG).

As an aid to identifying minor components in the gland that may be critically important to the activity of a pheromone blend, it has generally been found useful to identify the fatty acyl moieties in the gland from which the actual pheromone molecules are produced. These

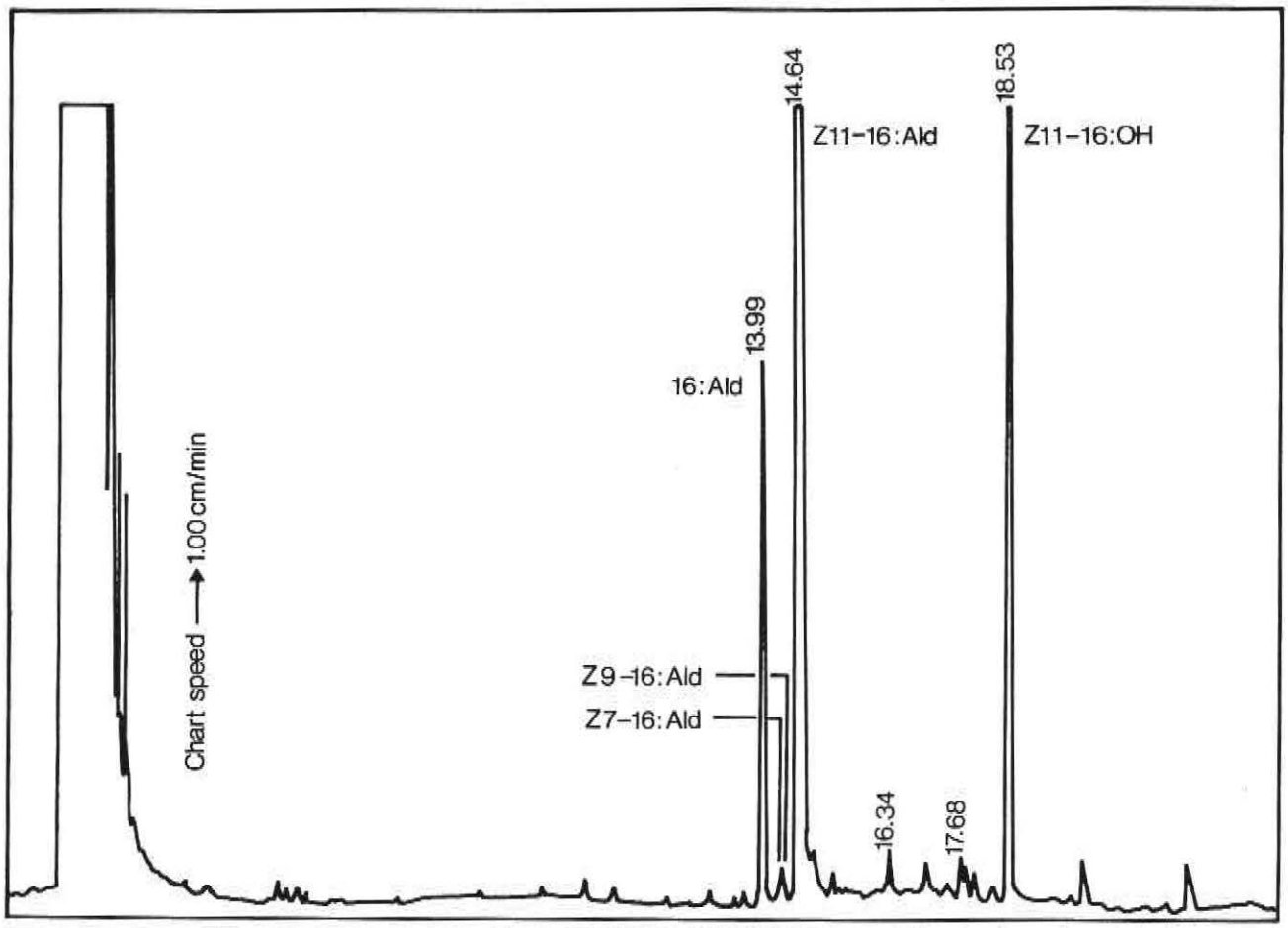


Figure 2. Gas chromatogram of extract from a single female *Chilo partellus* pheromone gland. The gland was dissected at 8 hours into the first scotophase following adult emergence. Gas chromatography conditions (Packard 438 instrument): 60° C for 2 min from injection, then set to 100° C. From 4 min after injection, the temperature was programmed to 180° C at 5° C/min.

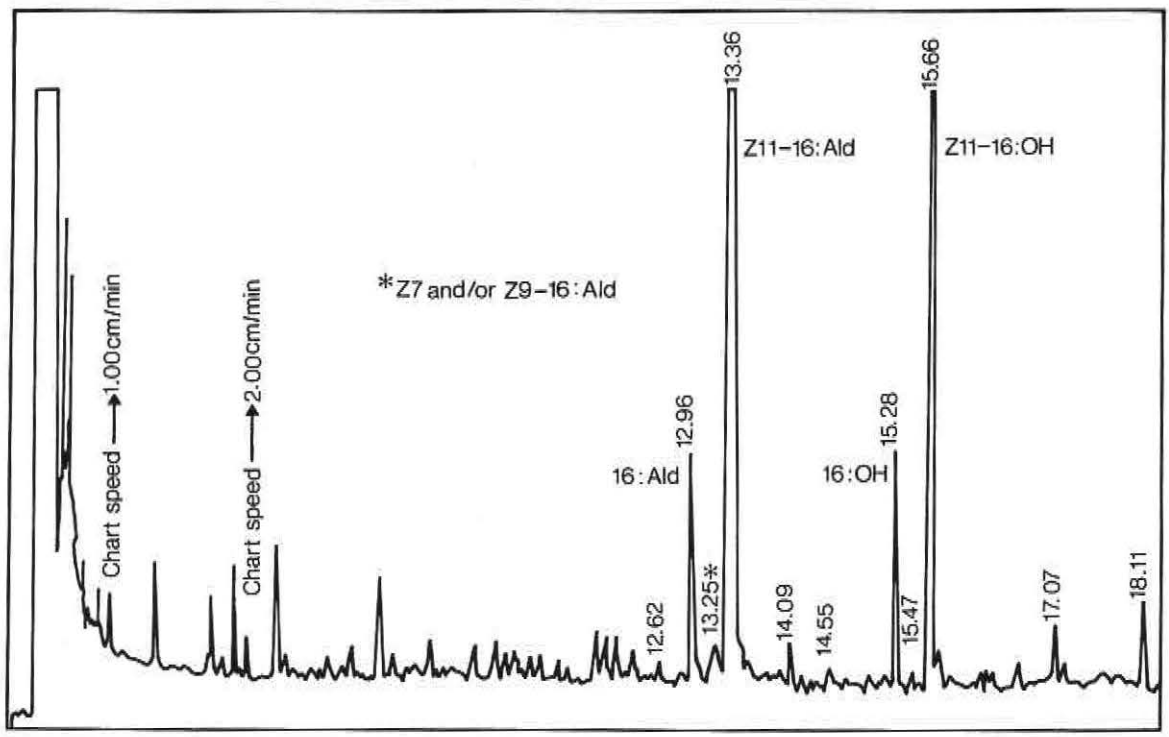


Figure 3. Gas chromatogram of extract of trapped volatiles from a single *Chilo partellus* female. The collection from the female was made at 4 hours into the first scotophase following adult emergence. Gas chromatographic conditions (Hewlett Packard 5880A instrument): 80° C for 2 min from injection, then programmed to 230° C at 10° C/min.

precursors are usually present in much greater quantities than the pheromones themselves. Such analyses are conveniently carried out by extracting the fatty acyl complexes from the gland using a chloroform/methanol mixture (2:1). The fatty acyl moieties are then converted to the methyl esters by base methanolysis and determined by GC (see Figure 4).

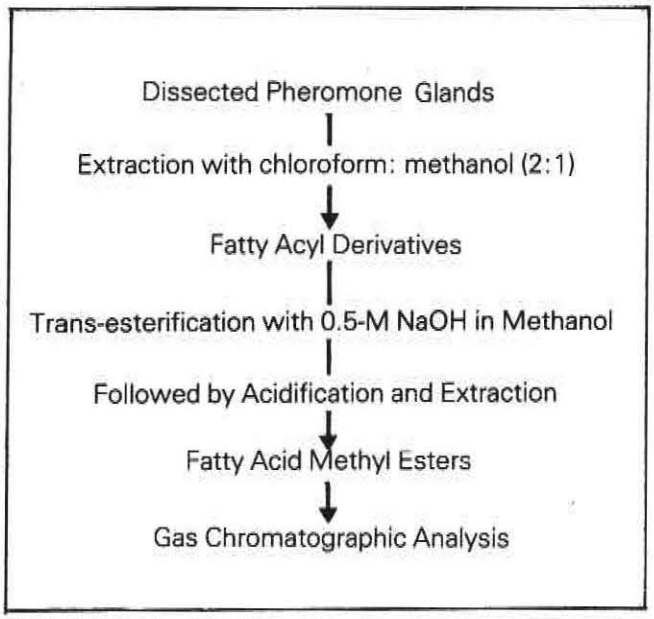


Figure 4. Procedure for extracting fatty acyl derivatives from *C. partellus* sex pheromone glands and converting them to fatty acid methyl esters.

Such an analysis of a number of female glands of *C. partellus* dissected at 6 hours into the scotophase is shown in Figure 5. The chromatogram clearly shows the presence of large quantities of saturated 16:Me and some saturated 18:Me. Minor quantities of 12:Me and 14:Me were also observed. The major unsaturated methyl ester was delta–9-18:Me (based on retention time). Two unsaturated 16:Me components were clearly observed and appear to be the delta-9 and delta–11-16:Me compounds. A couple of minor unsaturated 14:Me components were also observed, whilst di- and triunsaturated 18:Me components were also present. Double-bond positions have been assigned only on the basis of retention times in comparison to a number of known standards that were available. Further evidence for double-bond position will be obtained by derivatizing the compounds with dimethyl disulphide followed by GC-MS analysis.

It is evident that the pheromone system of *C. partellus* is more complex than the two-component system reported for the Indian population of this insect, particularly in view of the poor field responses to the two known components and also poor responses in wind tunnel studies being performed at the University of Lund, Sweden. Progress is being made towards identifying important minor components of the pheromone system, two of which—16:Ald and 16:OH—have been identified already.

* *The work on* Chilo partellus *pheromone is being jointly conducted by ICIPE and the Pheromone Groups at the Universities of Lund and Uppsala, Sweden.*

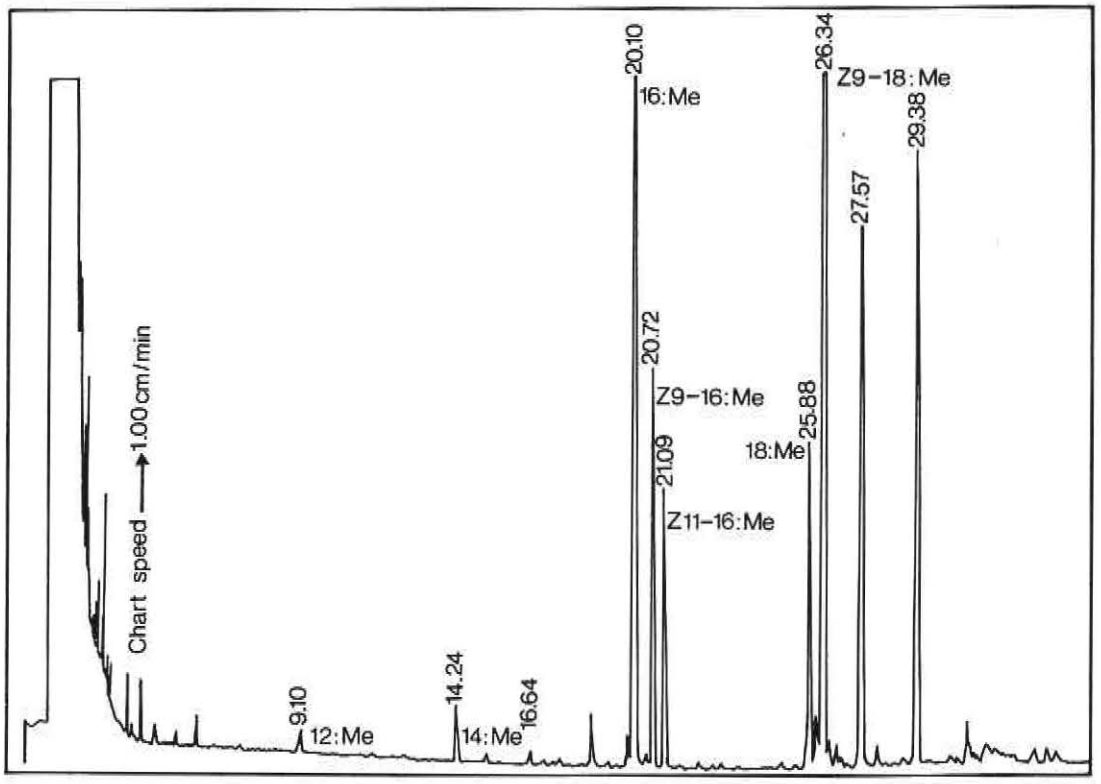


Figure 5. Gas chromatogram of fatty acid methyl esters obtained by trans-esterification of fatty acyl lipids extracted from pheromone glands of female *Chilo partellus*. The glands were dissected at 6 hours into the first scotophase following adult emergence. Gas chromatographic conditions (Packard 438 instrument): 60° C for 2 min from injection, then set to 100° C. From 4 min after injection, the temperature was programmed to 180° C at 3° C/min.

VOLATILES OF SERENA *SORGHUM BICOLOR* SEEDLINGS

W. Lwande

Odours emanating from *Sorghum bicolor* plants may play a role in the orientation of its insect pests to find and recognize the plants on which they will feed and oviposit. Thus, knowledge of the volatile compounds of sorghum may be useful in studying insect pest–sorghum plant relationships. Presently there is no report in the literature on the volatiles of *S. bicolor*. In the present study, airborne volatiles of 4-week-old *S. bicolor* (Serena cultivar) seedlings were trapped on Tenax-TA adsorbent and identified by gas chromatography–mass spectrometry (GC-MS). This volatile collection technique may yield a better picture of what the insects perceive in the environment around the sorghum plant. Traditional techniques such as solvent extraction, steam distillation and distillation under reduced pressure damages the plant, which results in a relatively large amount of enzyme-catalyzed oxidation products that are normally not present in the intact plant and that can completely mask the original volatiles. Enzyme action may also degrade some of the active components that emanate from intact healthy plants.

In the present study, charcoal-filtered air was swept over 100 seedlings of *S. bicolor* Serena cultivar in a glass chamber and then through a Tenax trap at a flow rate of 120 ml/min for 6 hours by applying a regulated vacuum. The Tenax trap consisted of a glass tube (7.8-cm × 0.6-cm outer diameter × 0.4-cm inner diameter) packed with Tenax TA (70 mg, 60/80 mesh, Alltech Associates, Inc.) previously preconditioned at 350° C with helium flow for two hours.

The trapped volatiles were released directly into a capillary GC-MS by heating the Tenax trap in the GC-MS injection port. Figure 6 shows the GC-MS trace of the volatiles in the column effluent. The identities of the components were confirmed by comparing their mass spectra and gas chromatographic retention times with those of authentic samples. A list of the identified volatiles is shown in Table 1. The minor components are being identified. Authentic samples of the identified compounds will be evaluated against some *S. bicolor* insect pests by behavioural tests and sensory physiology.

Table 1. Airborne volatiles trapped from four-week-old seedlings of *S. bicolor* (Serena cultivar)

Peak number	Compound	Relative %
1	Toluene	3.86
2	Hexanal	5.24
3	(*Z*)-3-Hexen-1-ol	14.04
4	*m*-Xylene	4.72
5	*o*-Xylene	2.05
6	(*Z*)-3-Hexen-1-ol acetate	64.93
7	Nonanal	3.81
8	Decanal	1.35

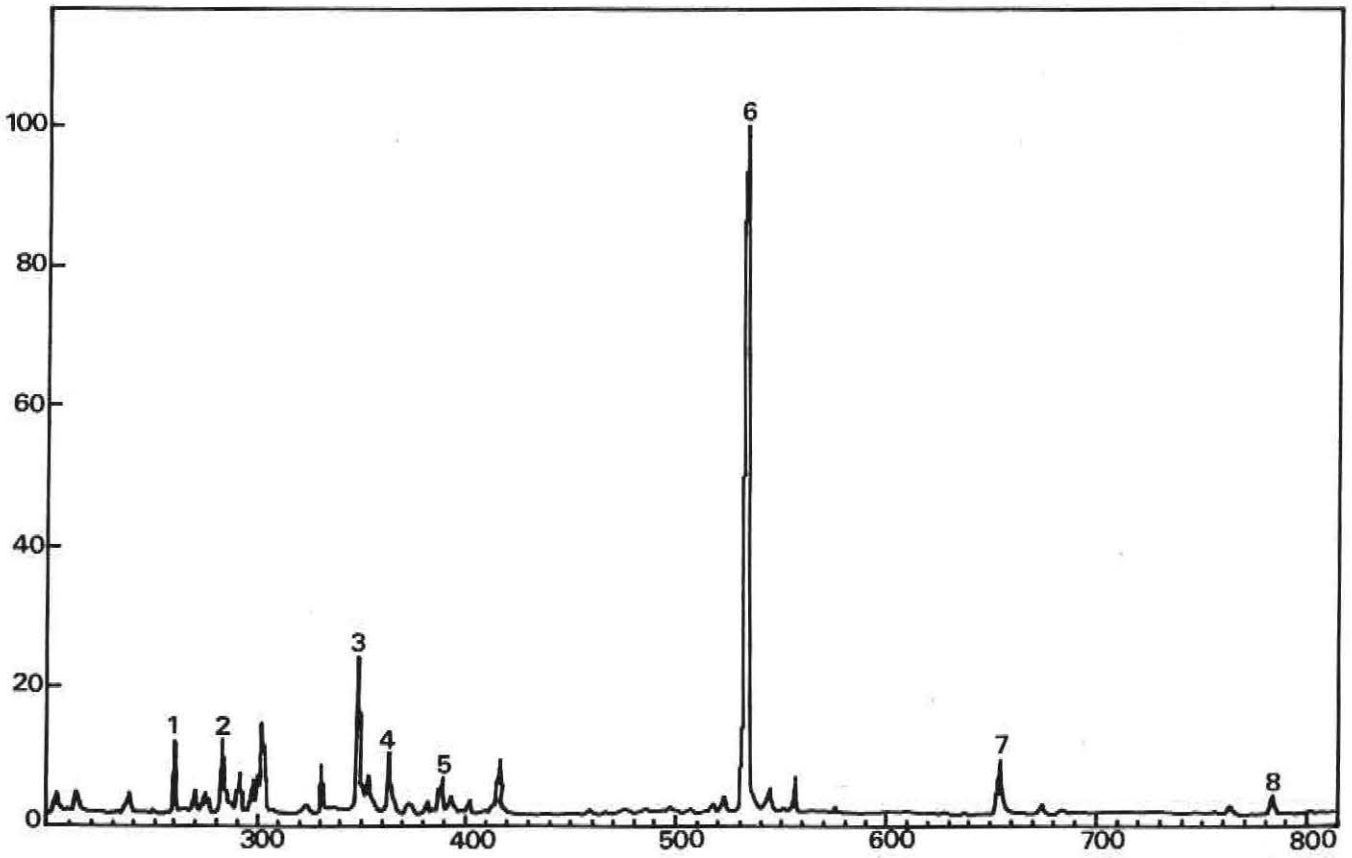


Figure 6. Gas chromatographic–mass spectrometric chromatogram of volatiles trapped from Serena (*Sorghum bicolor*) seedlings.

SORGHUM FEEDING ALLELOCHEMICS FOR *CHILO PARTELLUS*

*B. Torto**

It has been reported that the sorghum cultivar IS 18363 is susceptible to *Chilo partellus* and that the IS 2205 cultivar is resistant (*ICIPE Annual Reports*, 1983, 1985). The principles determining the resistance or susceptibility to *Chilo* of these two cultivars, as well as that of other cultivars of sorghum, have been established by behavioural work at the ICIPE Mbita Point Field Station. Larval feeding was found to be high on the leaves of IS 18363 but average on the leaves of IS 2205. As part of a comprehensive allelochemical study of sorghum, we are investigating the chemical basis of the differential feeding behaviour of the third-instar larvae of *Chilo partellus* on the whorls of these two cultivars.

At two growth stages, about 3 weeks and 6 weeks after the two cultivars emerged, the whorls were extracted successively with hexane, ethyl acetate and methanol and the extracts tested for *Chilo* larval feeding response. Extracts were loaded onto cellulose acetate disks and feeding tests were conducted in both choice and no-choice situations.

The results show that in both choice and no-choice situations, of the three sets of extracts tested, the methanol extracts were the most stimulatory to the larvae, followed by ethyl acetate and hexane extracts (Figure 7). In separate tests, larvae fed more on test disks loaded with extracts of cultivar IS 18363 than on disks loaded with extracts of cultivar IS 2205. For each cultivar, extracts of the 3-week-old whorls were more stimulatory to larvae than extracts of the 6-week-old whorls (Figure 8).

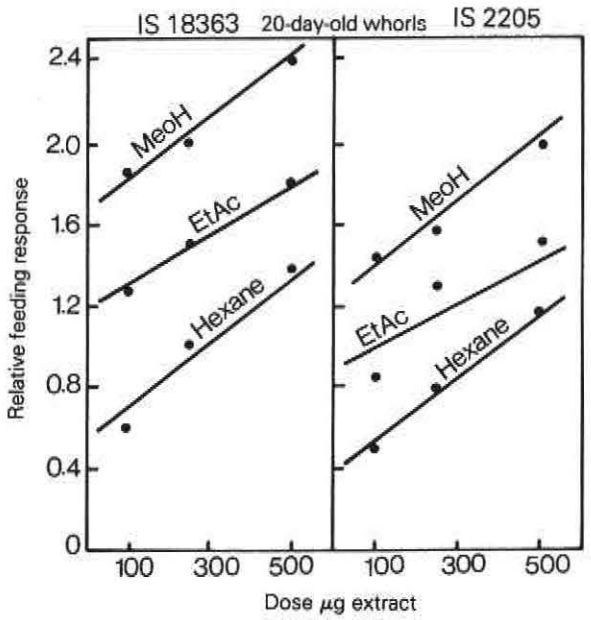


Figure 7. Feeding responses of *Chilo partellus* larvae (L_3) to leaf-whorl extracts of *Sorghum bicolor* (3 weeks old) in a no-choice bioassay. Relative feeding response = log $\frac{\text{mean wt treated disk consumed}}{\text{mean wt control disk consumed}}$

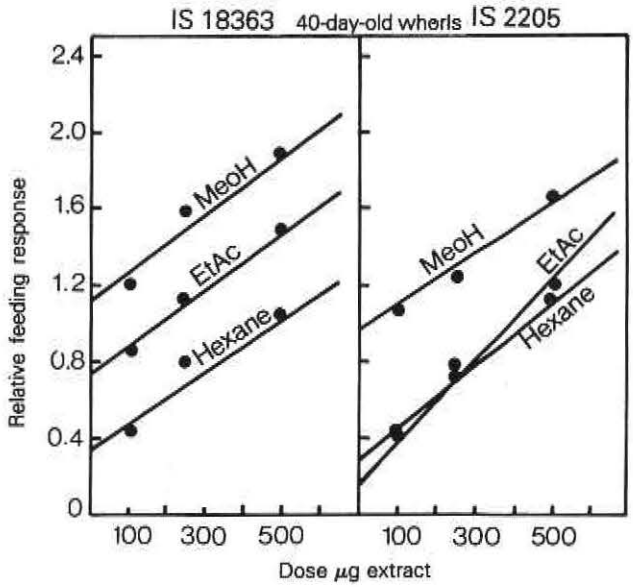


Figure 8. Feeding responses of *Chilo partellus* larvae (L_3) to leaf-whorl extracts of *Sorghum bicolor* (6 weeks old) in a no-choice bioassay. Relative feeding response = log $\frac{\text{mean wt treated disk consumed}}{\text{mean wt control disk consumed}}$

Analysis of the crude extracts by gas chromatography and high performance liquid chromatography (HPLC) showed that differences between the two cultivars appeared to be quantitative rather than qualitative. Quantitative differences were also found between extracts of the 3-week-old and 6-week-old whorls for each cultivar. Figures 9 and 10 show the HPLC chromatogram of the ethyl-acetate extracts of the whorls of the two cultivars at the two growth stages. The major components were identified as *p*-hydroxybenzoic acid and *p*-hydroxybenzaldehyde by comparison with authentic samples (coinjection on a reverse-phase HPLC, mass spectrometry). A purified synthetic sample of each of the two components was tested for larval feeding response. The results show that both *p*-hydroxybenzoic acid and *p*-hydroxybenzaldehyde stimulated the feeding of the larvae. Work on the active components in the methanol extract is in hand.

**Postgraduate scholar in ICIPE's African Regional Postgraduate Programme in Insect Science (ARPPIS).*

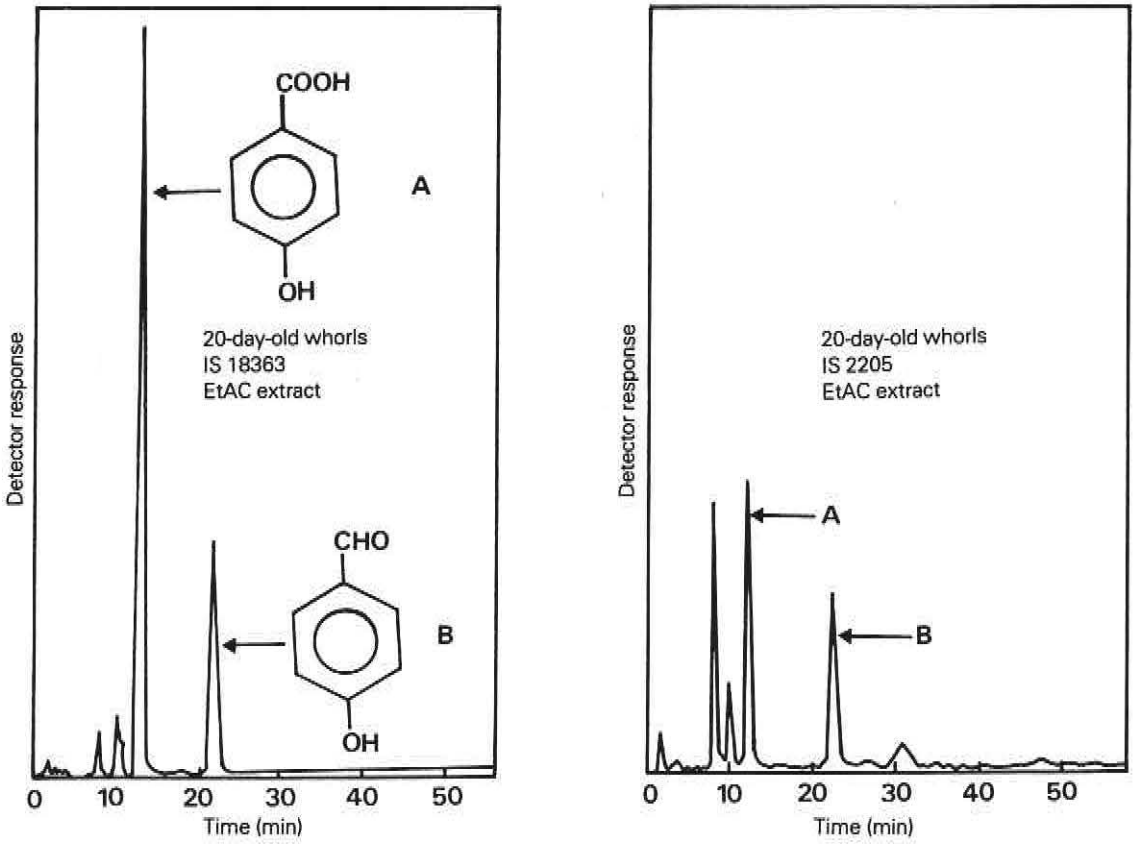


Figure 9. HPLC profiles of the extracts of the young leaf whorls of sorghum cultivars. Column: Zorbax ODS (reverse phase). Mobile phase 20% aqueous methanol. Detection: UV, 240 nm.

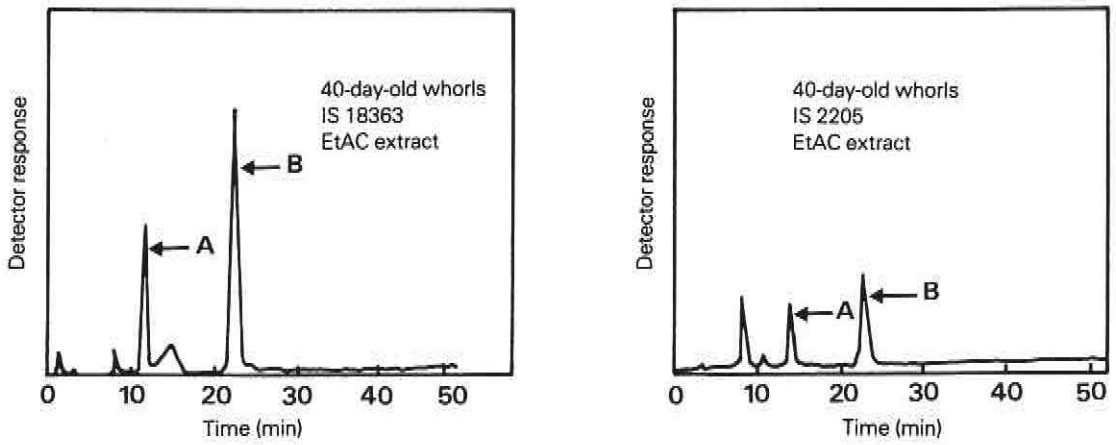


Figure 10. HPLC profiles of the extracts of the mature leaf whorls of sorghum cultivars. Column: Zorbax ODS (reverse phase). Mobile phase 20% aqueous methanol. Detection: UV, 240 nm.

STUDIES ON THE ORIGIN OF PHENOLIC TSETSE ATTRACTANTS FROM THE URINE OF BUFFALO, *SYNCERUS CAFFER*

A. Hassanali, P. G. McDowell, M. Owaga

In last year's *ICIPE Annual Report* (1985) we reported having identified a blend of seven phenolic compounds, which we named buffinol, from a chromatographic fraction of dichloromethane extract of buffalo urine that was responsible for about a sevenfold increase in the numbers of tsetse trapped in the field from that trapped in control traps. In the Tsetse Research Programme chapter of this *Annual Report* are described the results obtained from field tests on various combinations of the constituent phenols.

The good performance of buffalo urine in tsetse field traps provided the impetus for the present study, which we initiated early in 1986. Samples of buffalo urine placed near biconical traps showed more or less constant

tsetse activity for periods of 4 to 6 weeks, suggesting a continuous release of the attractants from precursors probably present in the urine. To test this hypothesis, we divided a freshly collected sample of buffalo urine into two equal parts, one part being kept at ±20°C to suppress any chemical activity and the other part left at room temperature to allow any ageing process to take place. After 14 days dichloromethane extracts of the two parts were examined by gas chromatography. Our results show a marked difference between the two parts, with a virtual absence of buffinol components in the frozen half (Figure 11).

We next compared the build-up of buffinol components among four equal parts (*A–D*) of a freshly collected sample of urine treated as follows:

(*A*) Stored at room temperature without any pretreatment.

(*B*) Autoclaved at 121° C and then cooled and stored at room temperature under sterile conditions.

(*C*) Passed through a 0.22-μM micropore filter and then stored at room temperature under sterile conditions.

(*D*) Stored at −20° C.

After 16 days, equal volumes of *A–D* were extracted with dichloromethane and analysed by reverse phase

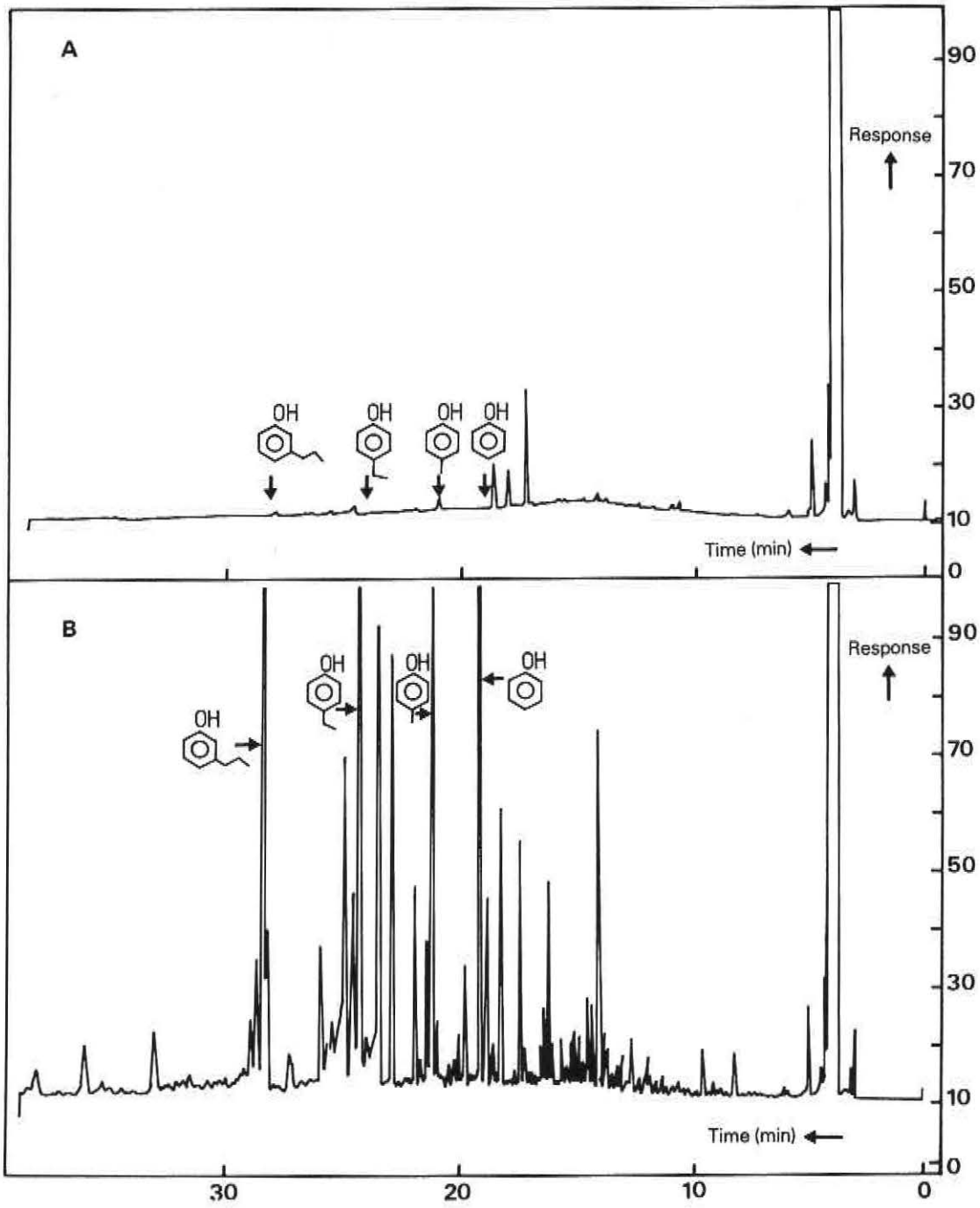


Figure 11. Gas chromatography profiles of CH_2Cl_2 extracts of (*A*) buffalo urine kept at −20° C, (*B*) buffalo urine kept at room temperature for 16 days. Column: 50-m Sil 5 fused silica. Temperature programme: 50° C (isothermal for 5 min) programmed to 180° C at 10°/min.

HPLC under identical conditions (Figure 12). Only *A* showed evidence of appreciable accumulation of degradation products, including buffinol components, indicating that these compounds are formed as a result of microbial activity.

The microbial breakdown of buffinol precursors represents a built-in mechanism for the controlled release of the phenols and provides a potentially useful model for dispensing the attractants for extended periods in remote areas. Accordingly, we are trying to isolate and identify both the precursors and the microbes involved in the precursors' breakdown.

DIGESTIVE ENZYMES OF THE BROWN EAR TICK *RHIPICEPHALUS APPENDICULATUS* NEUMANN: FURTHER FRACTIONATION AND PURIFICATION STUDIES

R. M. W. Vundla, V. L. Labongo

In previous *ICIPE Annual Reports* (1984, 1985) we described some immunological and biochemical properties of a carboxyl proteinase that we had partially purified from the gut of partly engorged female *Rhipicephalus appendiculatus*. In 1985 some properties of the enzyme, particularly its behaviour with the substrates haemoglobin and bovine serum albumin (BSA), suggested that we were dealing with more than one component. We have now shown that there are in fact two carboxyl proteinases. In the present report we outline the separation and purification of the two carboxyl proteinases.

The preparation of homogenates and the results of the gel filtration, which is the first step in our purification procedure, were as those described in the *ICIPE 1985 Annual Report*. The enzyme-active fractions from the gel filtration column were pooled, concentrated and chromatographed on an FPLC Mono Q column using a linear NaCl gradient. On assaying the eluted fractions for carboxyl proteinase activity, two distinct enzyme peaks, *A* and *B*, were realized (Figure 13). Enzymes *A* and *B* were each chromatographed further on the Mono Q column using appropriate NaCl gradients. Both enzymes were well separated from contaminating proteins, and the proteinase activity patterns of each

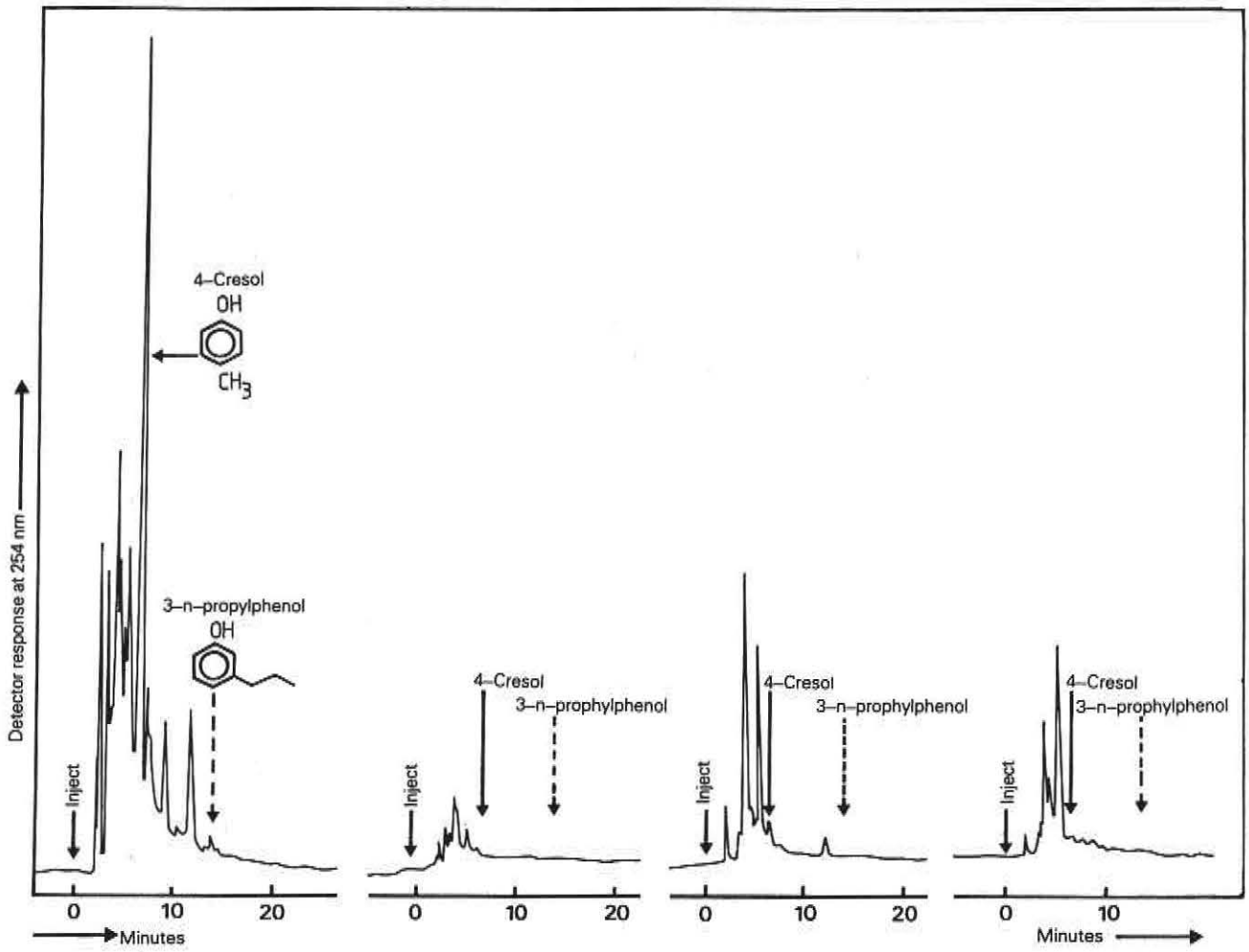


Figure 12. HPLC chromatograms of CH_2Cl_2 extracts of buffalo urine portions *A, B, C* and *D* (see text for explanation) on a Zorbax ODS reversed-phase column (25 × 0.46 cm) using 60% aqueous methanol as the mobile phase.

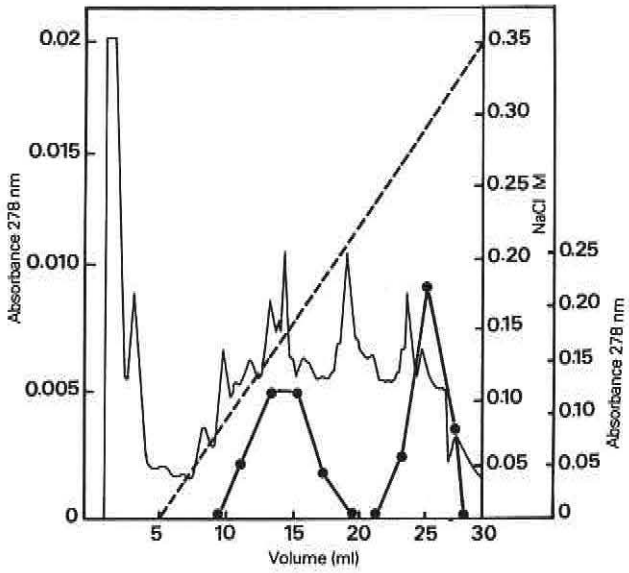


Figure 13. Anion exchange chromatography of ex-G100 fraction on a Mono Q column. Eluent: 0.02 m TRIS-HCl pH 7.5; 0.02 AUFS; flow rate: 1 ml min^{-1}; chart speed 0.5 cm min^{-1}. Elution: linear NaCl gradient, 0.0035–0.35 M.

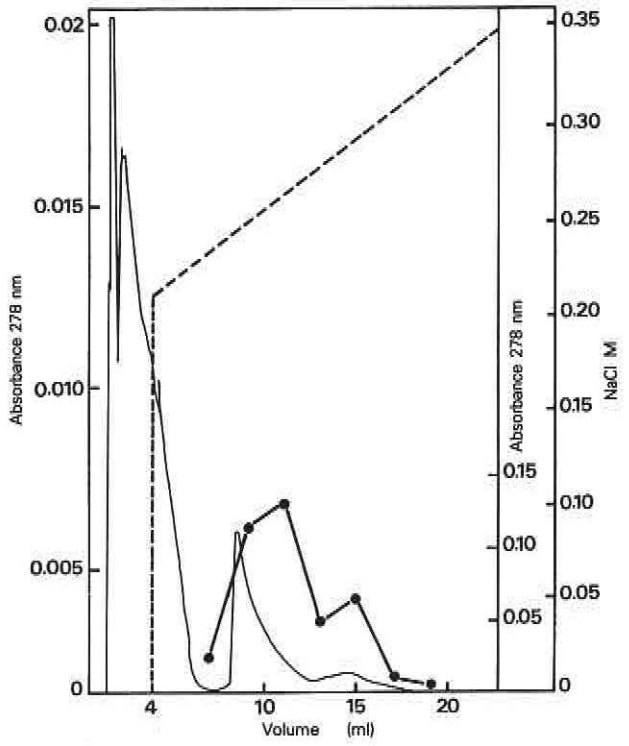


Figure 14. Anion exchange chromatography of enzyme fraction *B* from the Mono Q, on the same column. Eluent: 0.02 m TRIS-HCl pH 7.5; 0.02 AUFS; flow rate: 0.5 ml min^{-1}; chart speed: 0.5 cm min^{-1}. Elution: linear NaCl gradient 0.21–0.35 M.

enzyme peak suggested multiple forms of both enzymes (Figure 14).

Polyacrylamide gel electrophoresis (PAGE) on native gradient gels containing a substrate (either haemoglobin or BSA) showed that the two enzymes were well separated from each other and, as expected, each of them was made up of three major forms. Native PAGE of the two enzymes on gradient gels stained with silver showed that the two enzymes were very pure, and that the molecular weight of enzyme *A* was 47 000 and that of enzyme *B* was 25 000.

The two enzymes are being characterized biochemically. At the same time, antibodies to the pure enzymes are being raised in rabbits and their potential in disrupting digestion in ticks will be evaluated.

STUDIES ON THE IDENTIFICATION OF TICK MIDGUT ANTIGENS INVOLVED IN INDUCING HOST-RESISTANCE TO *RHIPICEPHALUS APPENDICULATUS*

S. Essuman, T. S. Dhadialla

In the *ICIPE 1985 Annual Report*, we reported our results of tick challenge on rabbits immunized with soluble and solubilized membrane protein extracts from the midgut of 6-day-old, partially engorged virgin (PEV-6) females. The results were encouraging in that adult ticks that fed on rabbits immunized with soluble or solubilized membrane protein extracts weighed 75% or 60%, respectively, of ticks that fed on non-immune control rabbits.

In an attempt to characterize antigens recognized by sera from rabbits that were more resistant than the others, we first extracted the soluble proteins from PEV-6 females. (The report following this one describes results of similar experiments on midgut solubilized membrane protein extracts.) The protein extract was fractionated by gel permeation on a Sephacryl-S-200 column equilibrated with 10-mM Na-phosphate, 0.1-M NaCl, 10-mM EDTA (PBSE). The elution profile is shown in Figure 15.

Four peak fractions (indicated by horizontal bars in Figure 16) were pooled and concentrated by ultrafilteration. Proteins in the pooled fractions were separated on 3%–15% polyacrylamide gels under denaturing conditions (SDS-PAGE). The separated proteins were blotted onto nitrocellulose papers and the blots probed with various immune and control sera. The results of one such immunoblot experiment are shown in Figure 16. In this experiment, replica protein blots were probed with sera from rabbits immunized with (1) soluble midgut protein extract (rabbit-6), (2) midgut membrane solubilized protein extract (rabbit-12), (3) protein extract of a fully engorged adult female (rabbit-500, supplied by Dr. A. O. Mongi) and (4) phosphate buffered saline plus adjuvant (control, rabbit-17). While proteins in fractions I and II separated into numerous protein subunits, blots of fraction I lighted up the greatest number of antigens with the immune sera. Although many common

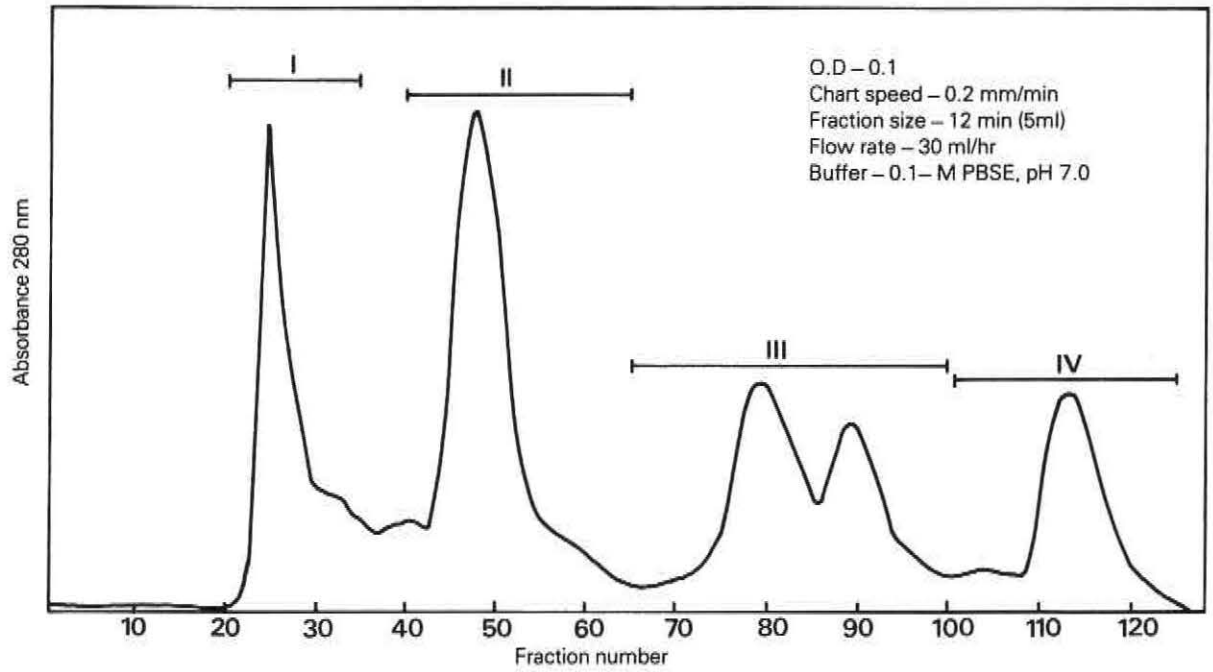


Figure 15. Elution profile of soluble protein extract from the midgut of a 6-day-old, partially engorged virgin female *R. appendiculatus* after gel permeation on Sephacryl S-200 (K26/90) column. Elution buffer: PBSE, absorbance: 0.1 outer diameter, flow rate: 30 ml/hr, fraction size: 12 min (6 ml), chart speed: 0.2 mm/min. Fractions under the horizontal bars were pooled, concentrated and used for immunoblotting experiments.

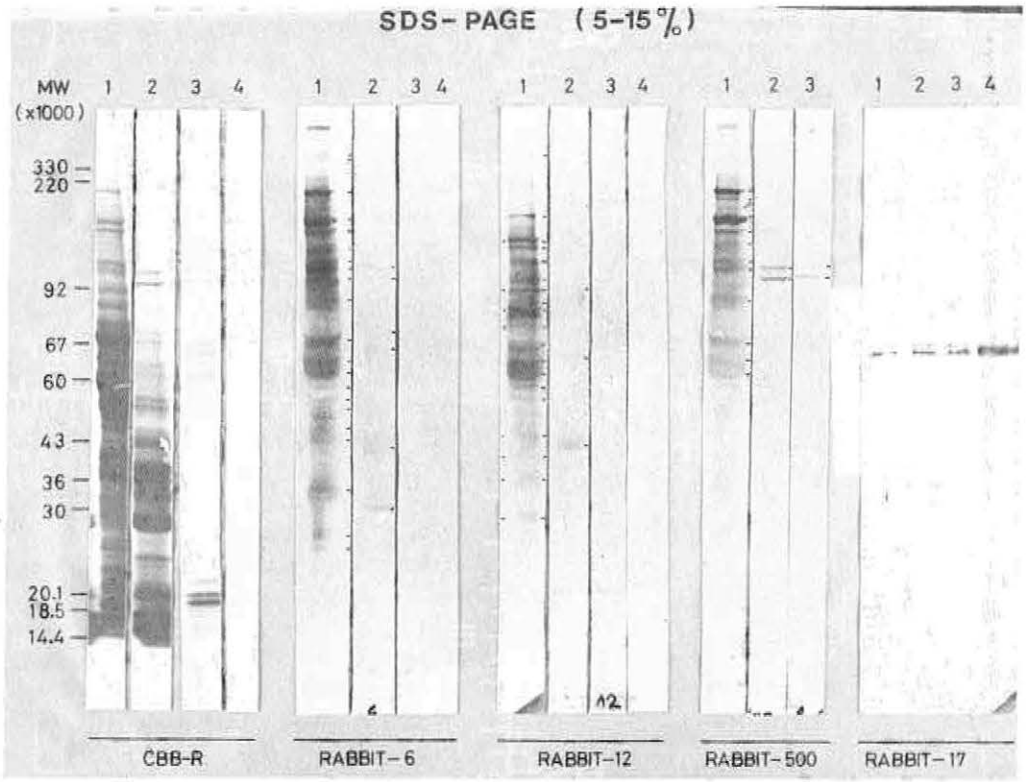


Figure 16. Electropherogram of pooled protein fractions on SDS-PAGE (3%–15% gradient) stained with coomassie brilliant blue-R (CBB-R). Protein blots of the same unstained gel were reacted with sera from three immune rabbits, numbers 6, 12 and 500, and a control, rabbit-17. The molecular weights of marker proteins are shown on the left of the electropherogram. Prominent bands on immunoblots are indicated with black marks on the right. Marks on the left of immunoblot of fraction I probed with immune sera from rabbit-12 indicate proteins recognized specifically with this sera.

antigens were recognized by the three immune sera, some antigens were specific to sera either from rabbit-6 and rabbit-500 or from rabbit-12. However, the protein patterns on immunoblots were very complex. Serum from rabbit-17 (control) recognized two protein bands (molecular weight around 67 000) in all four fractions.

Because of the complexity of the antigen subunit patterns obtained on immunoblots, we used a different approach. Proteins in the pooled fractions were first electrophoresed under non-dissociating conditions (Native-PAGE) on 3%–15% polyacrylamide gels. Immunoblots of such gels have revealed at least two antigens that have molecular weights of about 140 000 and 110 000. Experiments are now in progress to purify these two antigens in their undissociated state.

MEMBRANE-BOUND PROTEINS OF THE MIDGUT OF *R. APPENDICULATUS*: STUDIES ON SOLUBILIZATION AND IDENTIFICATION BY IMMUNOBLOTTING

S. Essuman, T. S. Dhadialla

CBRU has shown that the feeding performance of ticks applied on rabbits immunized with Triton X-100 solubilized membrane-bound proteins of the midgut of *Rhipicephalus appendiculatus* was significantly lower than that of ticks fed on rabbits immunized with soluble midgut proteins (*ICIPE 1985 Annual Report*). We now report on the progress made on identifying these proteins.

To extract the membrane-bound proteins, the midgut was first homogenized in phosphate buffered saline (PBS) and centrifuged. The pallet was washed several times and then homogenized again in PBS with 1% Triton X-100. The homogenate was ultracentrifuged and the supernatant aliquoted and stored at −70° C.

The solubilized protein extract was chromatographed on a Sephadex G-100 column eluting with PBS. Three fractions were collected, as indicated in Figure 17. The three fractions were analysed by SDS-gel electrophoresis and the protein bands transferred onto a nitrocellulose membrane. A subsequent immunological identification using rabbit antiserum raised against the Triton X-100 solubilized membrane-bound proteins revealed two groups of protein subunits (Figure 18). The first group, which was present largely in fractions 1 and 2, contained protein subunits with molecular weights ranging from 110 Kd to 390 Kd. Of these, two proteins, with molecular weights of 140 Kd and 240 Kd, seemed specific to the solubilized extract when compared to those recognized by the same antiserum in the soluble extract of the midgut. A protein subunit with a molecular weight of about 110 Kd was found to be highly enriched in the first two fractions. The second group of protein subunits of molecular weights, ranging from 48 Kd–67 Kd, appeared to be present only in fraction 3 of the Sephadex column.

We are immunizing rabbits with fractions 1 and 2 pooled together and fraction 3. The feeding performance of the ticks fed on these rabbits will be evaluated. If the fractions are found to affect significantly the feeding performance of the ticks, the antisera will be used for further isolation and purification of target antigens.

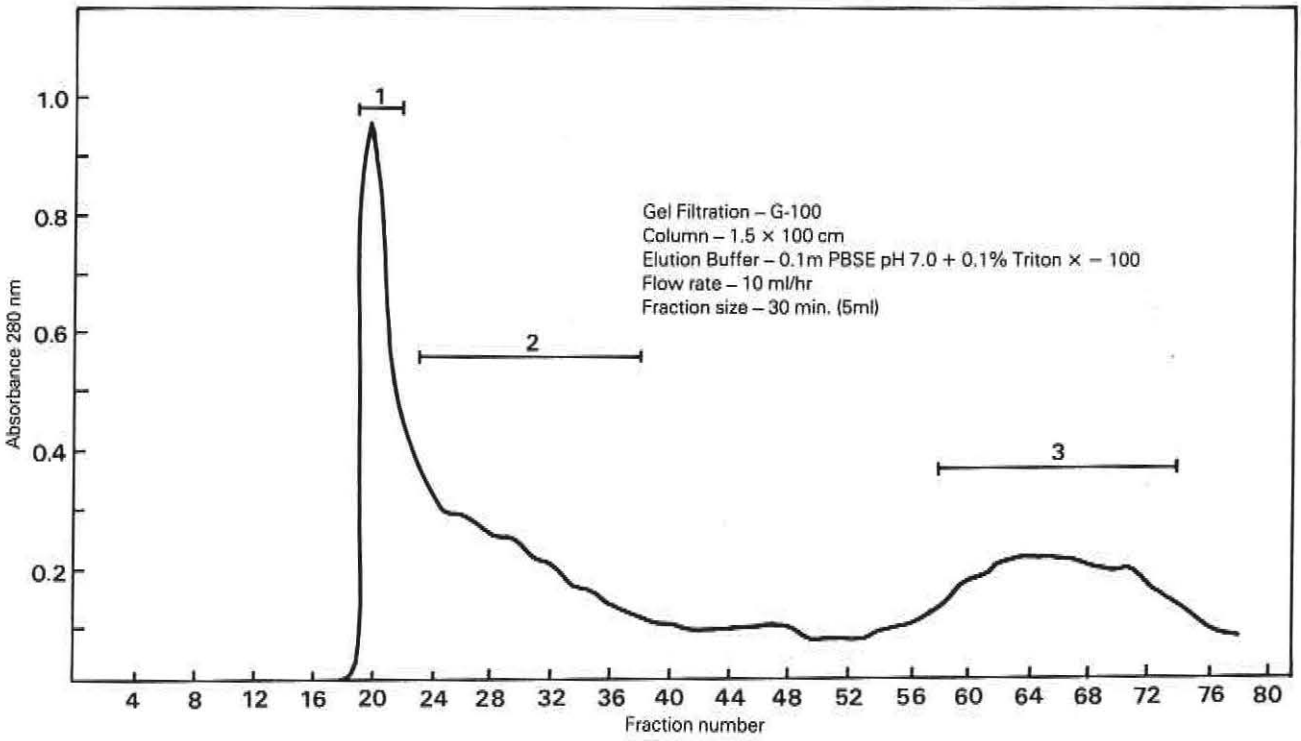


Figure 17. Gel filteration chromatography (Sephadex G-100) of Triton X-100 solubilized midgut membrane-bound proteins. Fractions were pooled as shown (bars).

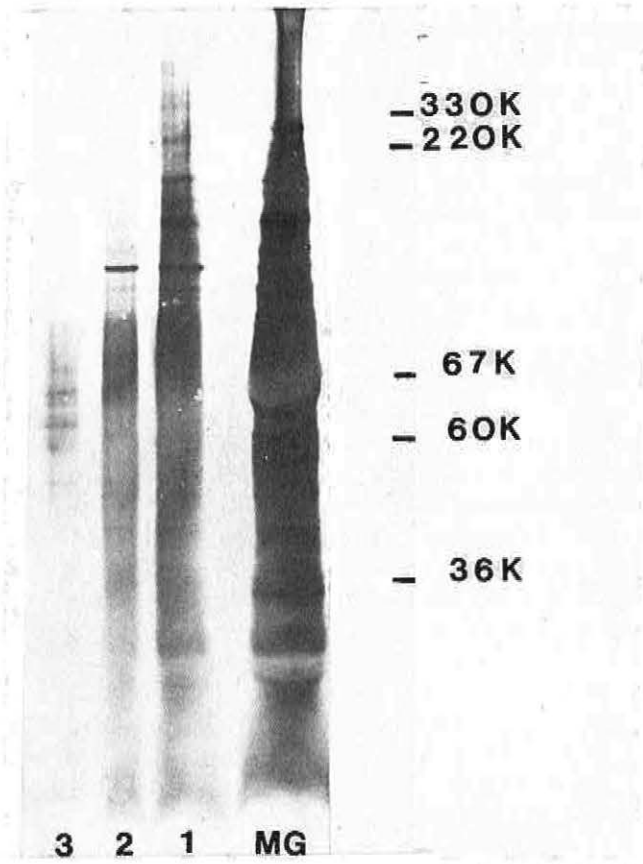


Figure 18. Immunoblots of pooled fractions 1, 2 and 3 and midgut soluble extract (MG). The fractions were analysed on gradient SDS-PAGE (5%–15%), transferred onto a nitrocellulose membrane and probed with rabbit antiserum.

MOSQUITO LARVICIDAL N-ISOBUTYLAMIDES AND A NOVEL INDOLE ALKALOID FROM *SPILANTHES MAURITIANA*

I. J. O. Jondiko, G. Achieng', G. Pattenden

In the *ICIPE 1985 Annual Report* we described the structure of a potent larvicidal N-isobutylamide *6* that we had isolated from a methanolic extract of wet vegetative aerial parts of *Spilanthes mauritiana*. Bioassay of the chloroform extract of the flower heads of *S. mauritiana* similarly showed high activities against third-instar larvae of *Aedes aegypti* (100% mortality at 10^{-3} mg/ml). In this report we describe the isolation and characterization of nine compounds that we isolated from an active fraction of this extract.

The chloroform extract was loaded on a silica gel column and eluted with 30% ethyl acetate in petrol (60°–80° C) to give several fractions, one of which gave a 100% larval mortality at 10^{-4} mg/ml. This fraction was further HPLC preparatively chromatographed on a reversed phase column to obtain ten fractions (see Figure 19). Nine pure components were subjected to spectroscopic analysis (ms, ^{1}Hnmr, uv, and ir), leading to structural determinations of four new N-isobutylamides, *1–4*; two known N-isobutylamides, *5–6*; a known N-ethylphenylamide, *7*; a known N-isopentylamide, *8*; and a novel indole alkaloid, *9* (see Figure 20).

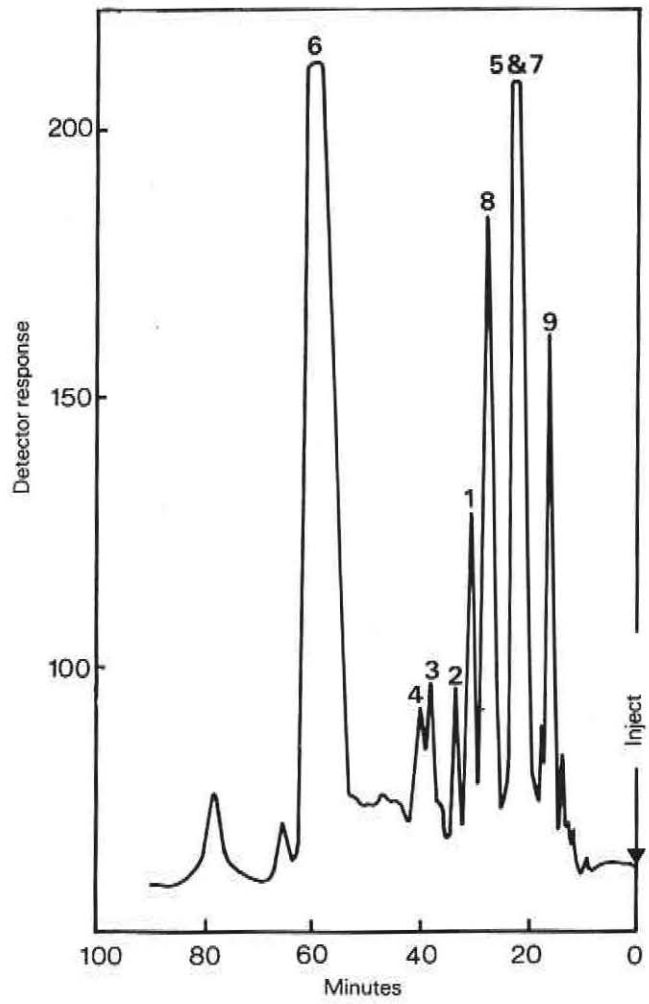


Figure 19. The HPLC chromatogram of fraction 4. Column: Zorbax ODS 250 × 46 mm, flow rate: 3.0 ml/min, solvent: 22.5% water in methanol, chart speed: 1 mm/min, loading: 250 ml of 2 mg/ml sample solution, detection: $UV_{254\ nm}$ and refractive index. Number on peaks corresponds to compounds in Figure 20.

Moreover, the high larvicidal activity of the crude chloroform extracts from which these compounds were isolated suggests that the flower heads of *S. mauritiana* may be useful in small-scale mosquito control programmes. Bioassays of individual components currently under way may throw some light on the structure-activity relationship in this class of larvicidal compounds.

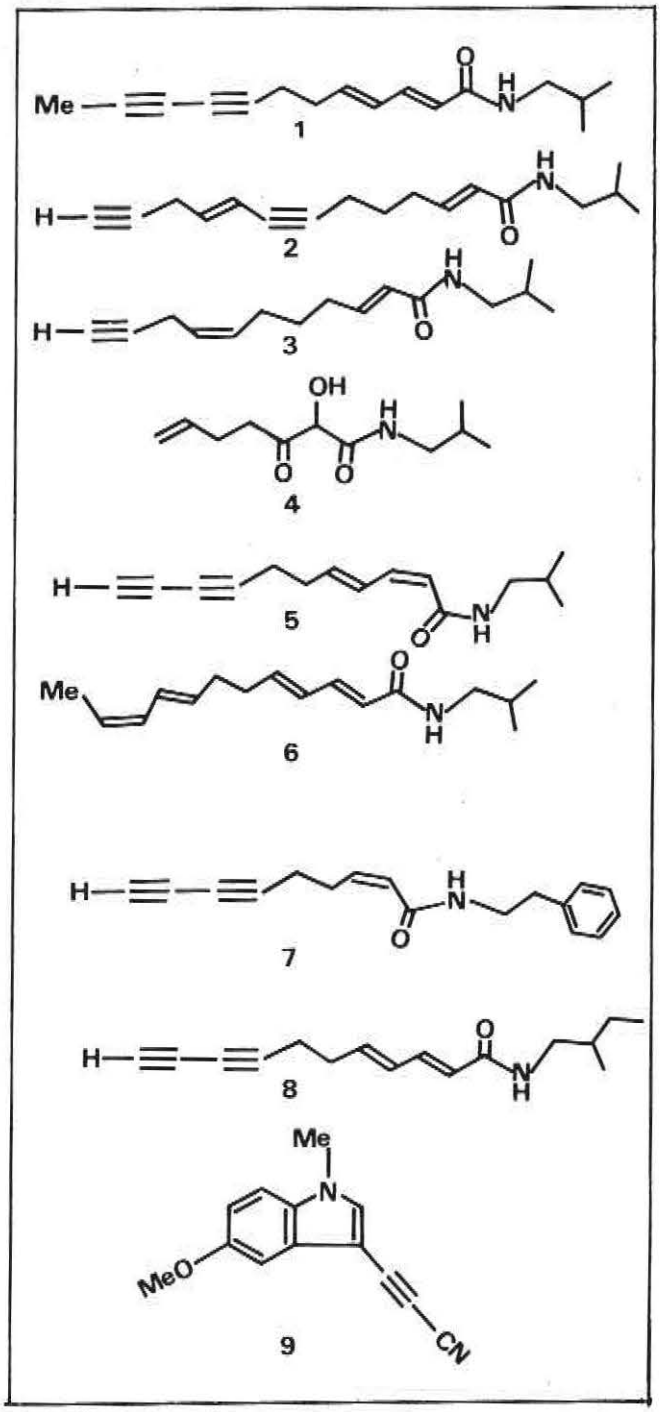


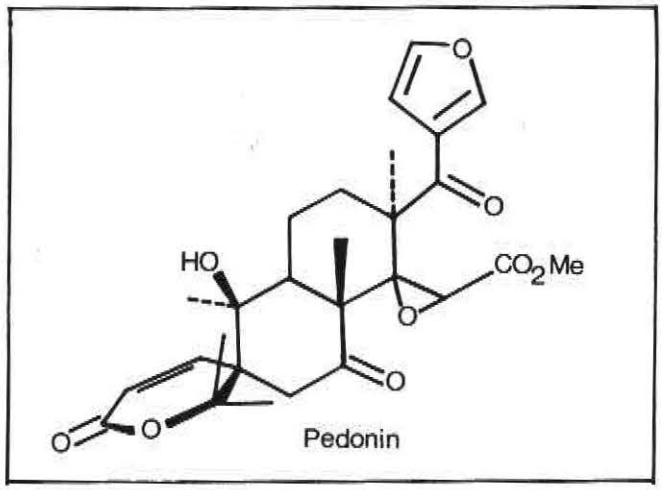
Figure 20. Structures of the compounds isolated from fraction 4.

A NOVEL TETRANORTRITERPENOID (LIMONOID) INSECT ANTIFEEDANT FROM *HARRISONIA ABYSSINICA*

A. Hassanali, M. D. Bentley, A. Chapya, E. Nyandat, L. Moreka*

Previous work at ICIPE on the root bark of the East African shrub *Harrisonia abyssinica* Oliv (Simaroubaceae) had yielded three limonoids with varying degrees of antifeedant activities against the larvae of *Spodoptera exempta, Maruca testulalis* and *Eldana saccharina (ICIPE 1984 Annual Report)*. Our interest in the comparative activities of these limonoids and the search for useful anti-insect model compounds led us to re-examine the extracts of *H. abyssinica*. In addition to the three previously described compounds, we have isolated a novel compound, which we have named pedonin.

The structure of pedonin was elucidated by ^{1}H and ^{13}C NMR spectroscopy, and by X-ray crystallographic analysis in collaboration with scientists at Imperial College, UK. Pedonin shows moderate feeding deterrent activity against the African armyworm (40% inhibition at 100 μg per 2-cm maize leaf disk), but it is very potent against *E. saccharina* (> 80% inhibition at 1 μg per 1.8-cm maize-leaf disk) and against *Maruca testulalis* (> 80% at 10 μg per 1.8-cm cowpea leaf disk). In view of its high activity relative to other limonoids, pedonin represents a useful addition to the CBRU growing collection of limonoid structural variants for ongoing structure-activity studies of this class of anti-insect compounds.



* *Chemistry Department, University of Maine at Toronto, USA.*

ISOLATION AND IDENTIFICATION OF MICRO-ORGANISMS FROM AFRICAN TERMITES FOR IMPROVED BIOMASS DEGRADATION

M. A. Okech, M. O. Koteng'o, P. O. Amoke

The goal of this special project has been to identify microbes associated with the higher African termites that may be used to upgrade waste lignocellulosic materials to a form that may be used directly for conversion to biogas or ethanol. Our objectives in the last year have been (1) to screen for ligninolytic activity in the isolated microbes, (2) to determine if microbe-producing ligninases can grow on lignocellulosic materials and (3) to study the abilities of these microbes to selectively break down lignin and demask cellulose.

All the isolates described previously (*ICIPE 1984 Annual Report*) were screened for the presence of the oxidative enzyme laccase as an indication of ligninolytic activity. The enzyme laccase has been implicated in the depolymerization of lignin biopolymer and has been found to be present in all white-rot fungi. Its presence

Table 2. Free sugars and accessible cellulose in the substrate before contact with organisms

Lignocellulose	Free Sugar (mg/g)	Accessible* cellulose (mg/g)
Maize straw	0.000	8.98
Sorghum straw	0.312	13.54
Wheat straw	0.000	4.68
Cassava stem	0.959	9.24

* Measured as the amount of cellulose that is depolymerized when in contact with added cellulase for an optimized period (48 hours).

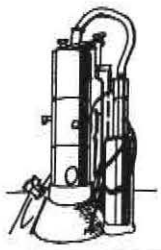
was therefore used as a basis for narrowing down the number of organisms for further work. Among the isolated organisms, only *Termitomyces* species and *Fusarium semitectum* were found to produce this enzyme.

To determine if microbes producing ligninases can grow on lignocellulosic materials, *Termitomyces* was grown on media containing ground maize straw, sorghum straw, wheat straw and cassava stem and the growth rates were then compared. Interestingly, the growth of *Termitomyces* on sorghum and cassava was better than its growth on maize and wheat straw. These results appear to correlate with the results of the analysis of these materials (Table 2), which show that sorghum and cassava had more free sugar and cellulose accessible to the enzyme cellulase than had maize and wheat.

In another set of experiments the effect of the growth of *Termitomyces* on ground maize straw in a liquid medium was studied by analysing the amount of cellulose accessible to externally added cellulase under standard conditions. Samples were analysed once every 10 days for 80 days. No accumulation of cellulose was evident, suggesting that lignin degradation occurred in a gradual, continuous fashion and that the demasked cellulose was being hydrolysed and used up by the proliferating fungus. Thus, contrary to our expectation, our observations suggest that unlike many other Basidiomycetes, *Termitomyces* does not behave like a white-rot fungus. Both lignin and cellulose are degraded more or less concurrently, which would not allow significant accumulation of cellulose for use in biogas plants.

Now in the last phase of this project, we are exploring the possibility of converting lignocellulosic materials to the *Termitomycess* fundal biomas and using this as a raw material for methane digestors.

Histology and Fine Structure



Histology and Fine Structure Research Unit

The major focus of the studies carried out in the Histology and Fine Structure Research Unit (HFSRU) has been to define cellular functional changes and associated mechanisms in important crop and livestock pests/disease vectors. HFSRU uses biochemical, immunological, immunocytochemical and autoradiographic techniques in the study of the structure and function of cellular and subcellular units of target pests and disease vectors.

The following were the main research activities in HFSRU in 1986.

- *Determining cellular changes associated with sexual maturation in the ejaculatory duct of the tsetse fly,* Glossina morsitans.
- *Characterizing changes and mechanisms associated with trypanosome and/or virus infection of the tsetse.*
- *Elucidating the morphological and functional basis of zonation (distal and proximal) in Malpighian tubules of the tsetse.*
- *Identifying,* in vitro, *factors controlling juvenile hormone biosynthesis in the tsetse corpus allatum.*
- *Undertaking studies on the synthesis and secretion of different components of the male accessory reproductive glands in tsetse and their transfer into the spermatophore.*

ACCOMPLISHMENTS

E. D. Kokwaro

Gonadal lesions associated with virus infection in both sexes of *Glossina pallidipes* have been examined and defined. Sterility of male *G. pallidipes* is due to severe spermatogenic arrest and degeneration. In the females, ovarioles manifest diffuse caseous necrosis of germarial cells associated with virogenic stromata. This strongly implies the transmission of virus particles from female to offspring through germ cells. More work is under way in this area to (1) determine the mechanisms underlying the gonadal damage, (2) establish generation-to-generation transmission and (3) produce immune serum to the virus particles in rabbits. Similar studies have also been started on *Glossina morsitans morsitans*.

Studies were conducted on the precise physiological roles of the secretory products of the accessory reproductive glands (ARC) of male tsetse, *G. morsitans*. The secretory products of the ARG form part of the wall of the spermatophore. Our previous histochemical and ultrastructural studies localized ARG components in the compartments of the spermatophore wall. This strongly implies that in its fully differentiated state, the ARG of *G. morsitans* synthesize carbohydrate-proteinaceous products, which serve as an indispensable substrate for sperm transfer to the female. Antibodies to homogenates of ARG and the spermatophore have been produced in rabbits. When these antibodies were applied in immunodiffusion, the results indicated that these ARG and spermatophore are antigenically similar. This study has successfully demonstrated an immunological relation between ARG and spermatophore. Further experiments are planned to unravel the salient features of some of the molecules present in these selected tissues.

In the course of sexual maturation, the epithelium of the ejaculatory duct of *G. morsitans* undergoes considerable structural modifications typical of sexually mature adults. At emergence, glycogen-like granules accumulate in the cytoplasm. These break down quickly as fly activity increases. Large intercellular spaces develop for 1–7 days, indicating specialization of the ejaculatory duct for water and/or ion transport. These

features may be connected with the modification of accessory gland components during spermatophore formation.

Studies carried out on tsetse Malpighian tubules depicted a structural distinction between the proximal and distal parts and also showed a greater uptake of tritiated glucose in the distal portion, which suggests greater metabolic activity and thus functional differences. These investigations will be extended to excretory tissues of tsetse and other target pests.

GONADAL LESIONS IN VIRUS-INFECTED MALE AND FEMALE TSETSE, *GLOSSINA PALLIDIPES* (DIPTERA: GLOSSINIDAE)

W. G. Z. O. Jura, T. R. Odhiambo, L. H. Otieno, N. O. Tabu

Ovaries and testes collected from wild *Glossina pallidipes* with virus-infected, hypertrophied salivary glands (HSG) were processed for routine electron microscopy and examined to determine the distribution of virus particles and the pathological changes within the tissues.

An examination of the germaria of ovarioles of normal *G. pallidipes* females depicted typical syncytial clusters of normal cells (Figure 1). In female *G. pallidipes* with virus-infected HSG, most of the germaria were affected by degeneration and diffuse caseous necrosis and showed foci of virogenic stromata within the nuclei or cytoplasm of germarial cells (Figure 2).

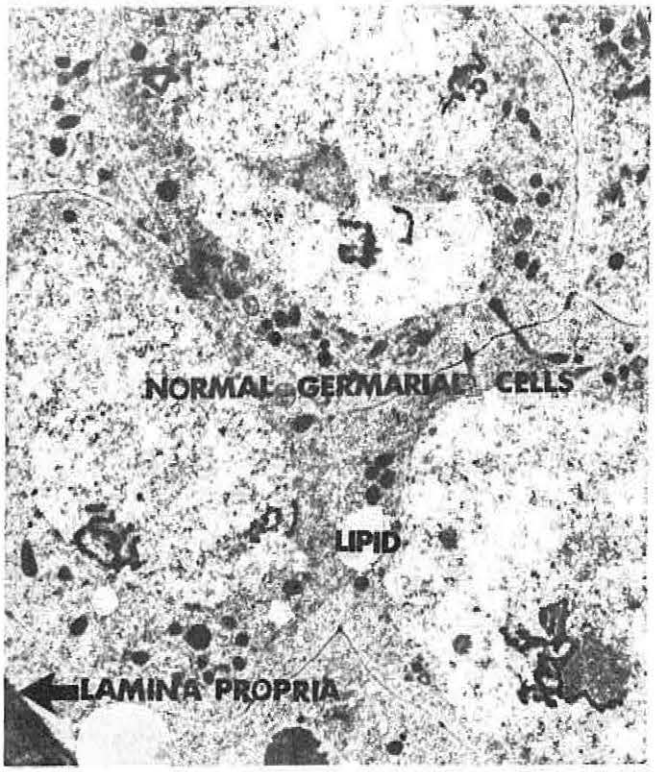


Figure 1. A cluster of normal oogonial cytoblasts within the germarium of non-infected *G. pallidipes*, showing normal cellular organelles.

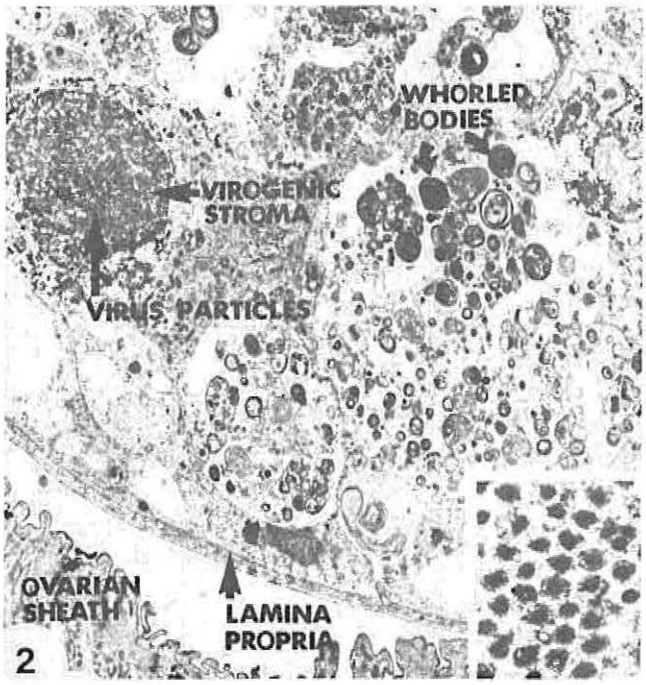


Figure 2. A germarium of a female *G. pallidipes* with virus-infected HSG, showing loss of cell architecture due to severe caseous necrosis. A focus of virus proliferation and assembly (virogenic stroma) is depicted within the nucleus of one of the cells.

The severe necrosis observed in the germarium of the ovarioles of females with HSG would eventually wipe out a whole germarium and cause disorderly ovarian cycles or, in extreme cases, where all four germaria are effaced, lead to female sterility. The demonstration of virogenic stromata within female germ cells proves the presence of perpetual foci of virions within the ovarian tissue. This suggests that the virus particles are transmitted to offspring through the germ cells during synchronous divisions of the oogonial cytoblasts.

Convoluted testes follicles of normal adult male *G. pallidipes* showed swarms of entangled spermatozoa (Figure 3), some in distinct cysts, the rest tightly packed but freely disposed within the lumen. The cystic stage (Figure 4) was permeated by processes of follicle (or sustentacular) cells (Figure 5), while the free forms (Figure 6), although still held within follicular epithelium, were no longer penetrated by the cytoplasmic processes.

In contradistinction to the situation in normal males, sections of testes follicles of adult male *G. pallidipes* with HSG (Figures 7 and 8) contained only sheets of undifferentiated, pre-meiotic spermatogenic cells, such as spermatogonia and primary spermatocytes. In some testes, degeneration, characterized by diffuse vacuolation (Figure 9) and exfoliation of degenerate cells (Figures 10 and 11), leading to empty lumina (Figure 12), was superimposed on the lack of differentiation. The lesion in the testes follicles of all male *G. pallidipes* with HSG is, therefore, a total bilateral arrest of spermatogenesis associated with degeneration and exfoliation of the undifferentiated degenerate cells, and thus causes complete sterility. These observations indicate that the virus has great potential as an effective microbial pathogen for the biological control of *Glossina pallidipes*.

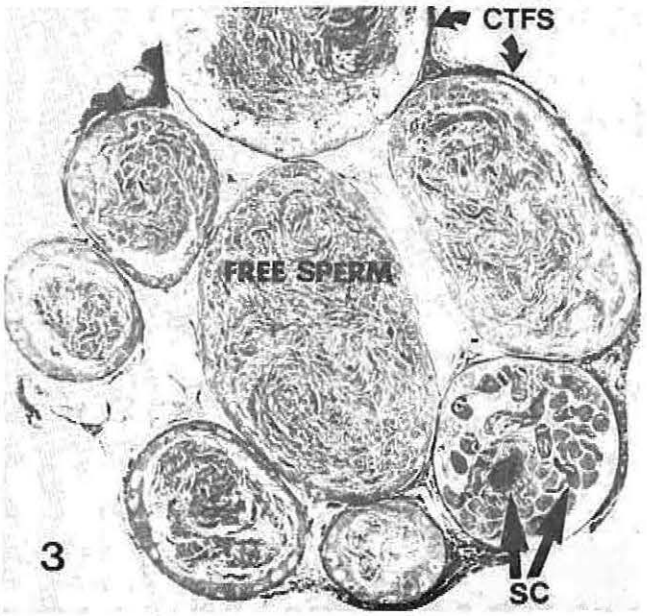


Figure 3. Section of a testis follical of a normal adult male *G. pallidipes* distended with spermatozoa. CTFS: convoluted testis follicle sections, SC: sperm cysts.

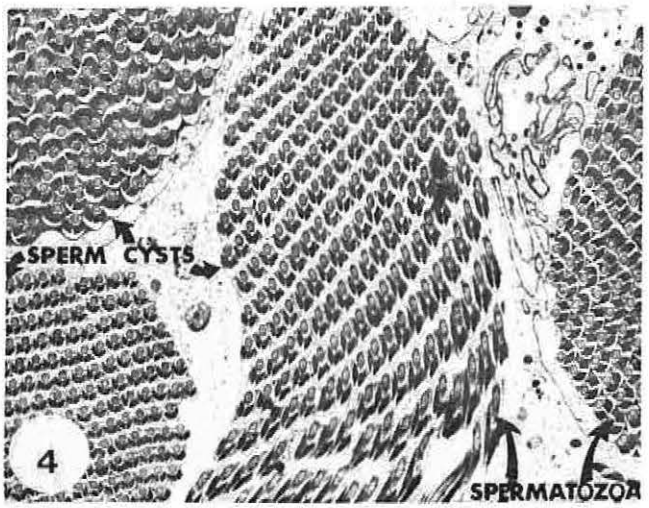


Figure 4. An electron micrograph of sperm cysts.

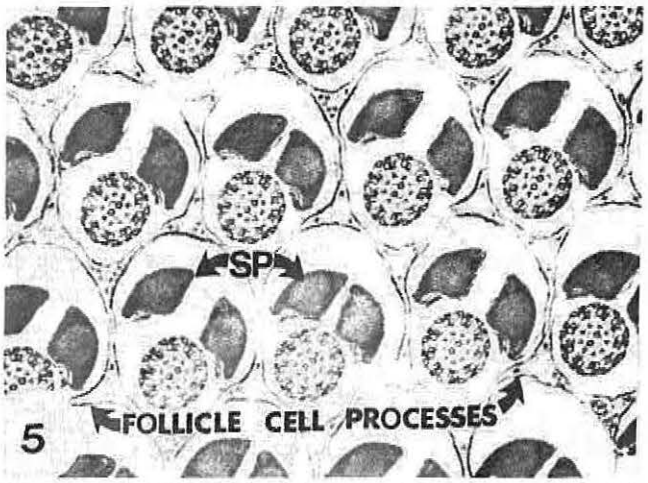


Figure 5. A higher magnification of a sperm cyst, depicting spermatozoa (SP) separated by follicle cell processes.

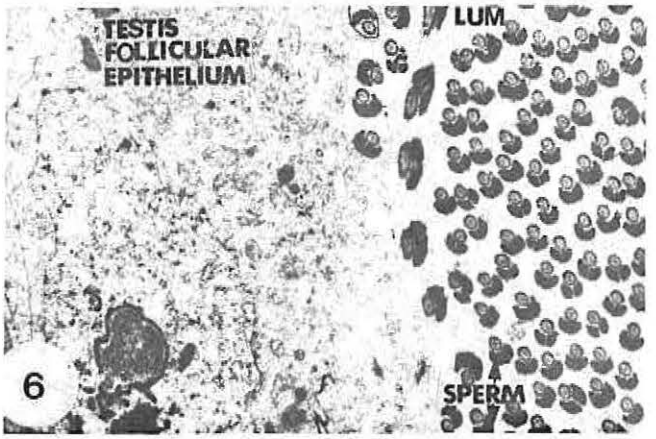


Figure 6. Section of a testis follicle of a normal *G. pallidipes*, showing spermatozoa not permeated by sustentacular processes. LUM: lumen.

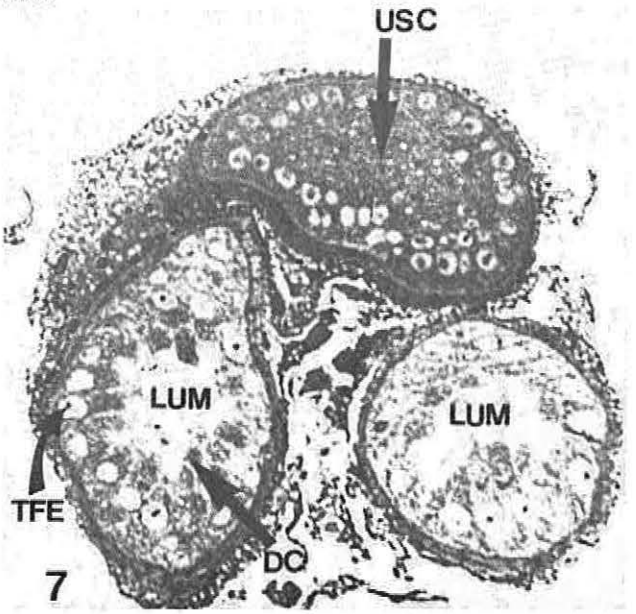


Figure 7. A photomicrograph of a section of a testis follicle of an adult male *G. pallidipes* with virus-infected HSG. USC: undifferentiated spermatogenic cells, DC: degenerate cells, TFE: testis follicular epithelium, LUM: lumen.

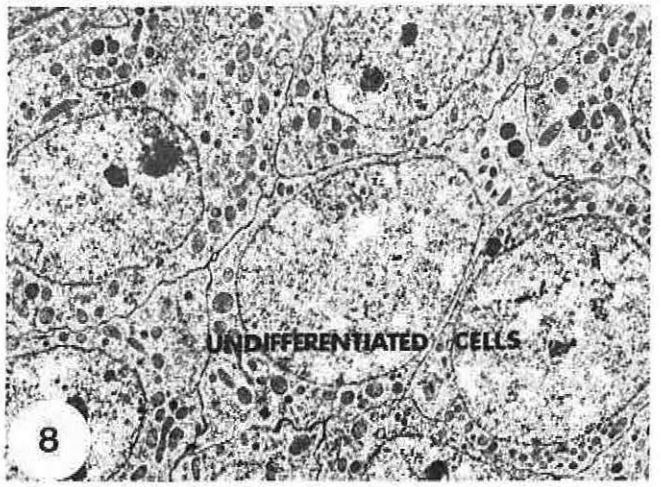


Figure 8. An electron micrograph of a testis follicle of an adult male *G. pallidipes* with HSG, showing a sheet of pre-meiotic undifferentiated spermatogenic cells.

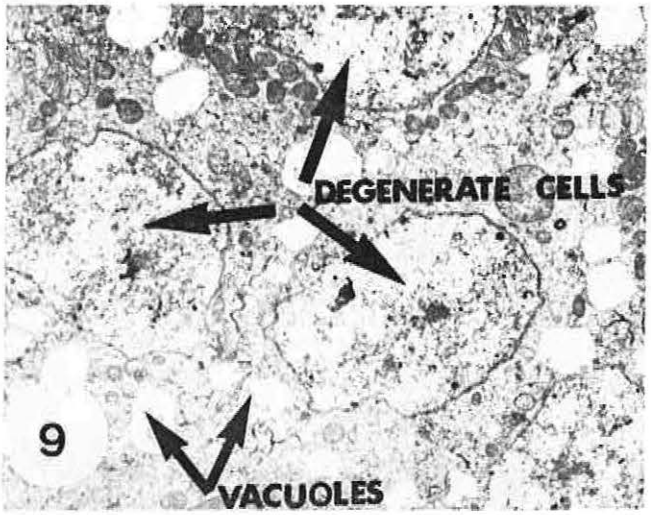


Figure 9. An electron micrograph of a testis follicle of an adult male *G. pallidipes* with HSG, showing diffuse vacuolation of undifferentiated spermatogenic cells.

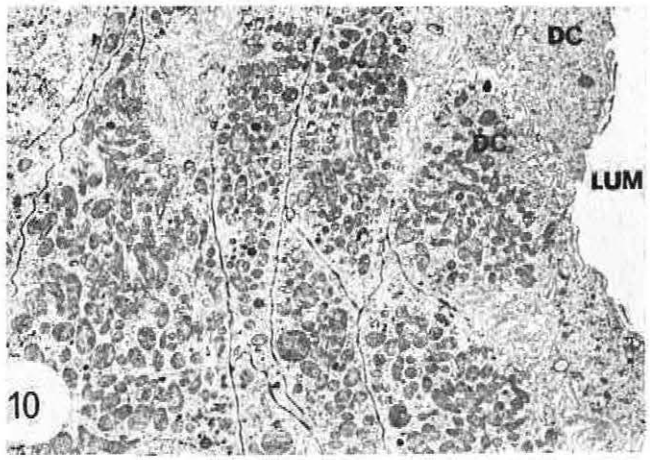


Figure 10. Section of a testis follicle of an adult male *G. pallidipes* with HSG, depicting the initial stages of exfoliation of undifferentiated degenerate cells (DC). LUM: lumen.

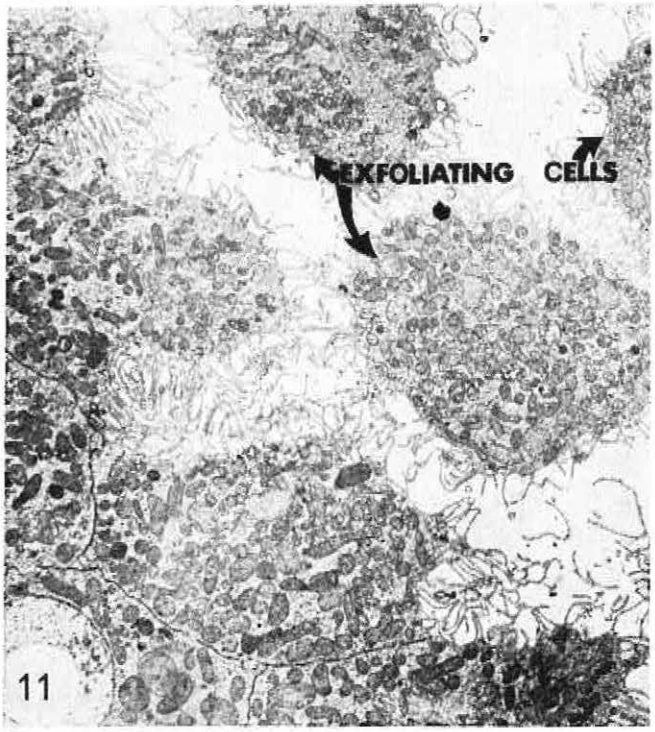


Figure 11. Advanced exfoliation of degenerate spermatogenic cells in a testis follicle of an adult male *G. pallidipes* with HSG.

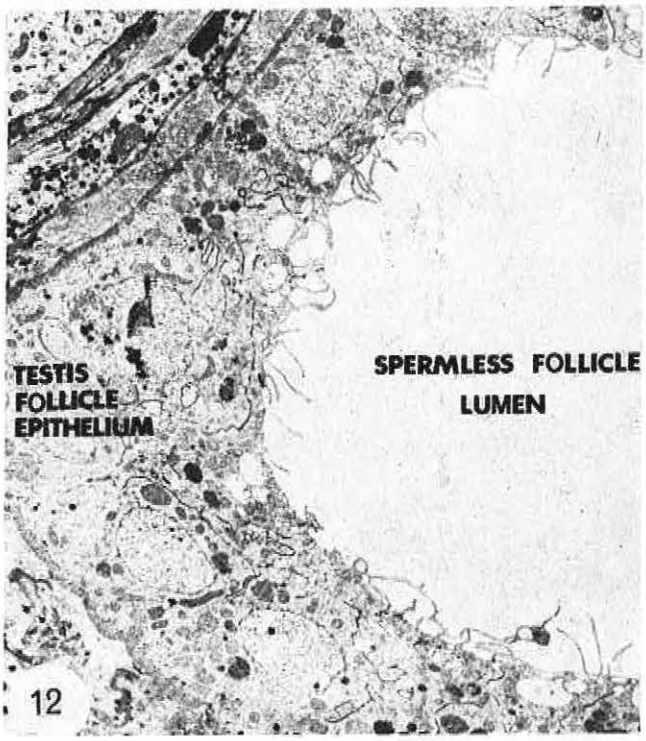


Figure 12. Spermless testis follicle of an adult male *G. pallidipes* with HSG.

OCCURRENCE OF VIRUS-INDUCED SALIVARY GLAND HYPERTROPHY IN *GLOSSINA MORSITANS MORSITANS*

W. G. Z. O. Jura, J. A. Kongoro

Virus-like particles of diverse natures have been reported in various anatomical locations in several species of *Glossina*: (1) within cytoplasmic vesicles of normal-sized salivary glands of *G. morsitans centralis*, (2) restricted to nuclei of midgut epithelial cells of *G. fuscipes* and (3) intra- and extra-cellularly within salivary glands of *G. pallidipes* (the only *Glossina* species in which virus particles have been associated with extensive glandular epithelial proliferation and vacuolation). To date, however, no descriptions have been reported on the occurrence of virus particles in *G. morsitans morsitans*. This study reports preliminary ultrastructural observations on the hypertrophied salivary gland tissue of unfed teneral and one-day-old *G. m. morsitans*.

Examination of the affected salivary gland tissues showed marked enlargement and proliferation of the glandular epithelial cells (Figure 13). The lumen of the hypertrophied gland was filled with a mass of virus particles (Figure 14), which were detected not only intra- and extra-cellularly but also within the cellular interstices (Figure 15). Virus particles of *G. m. morsitans*, like

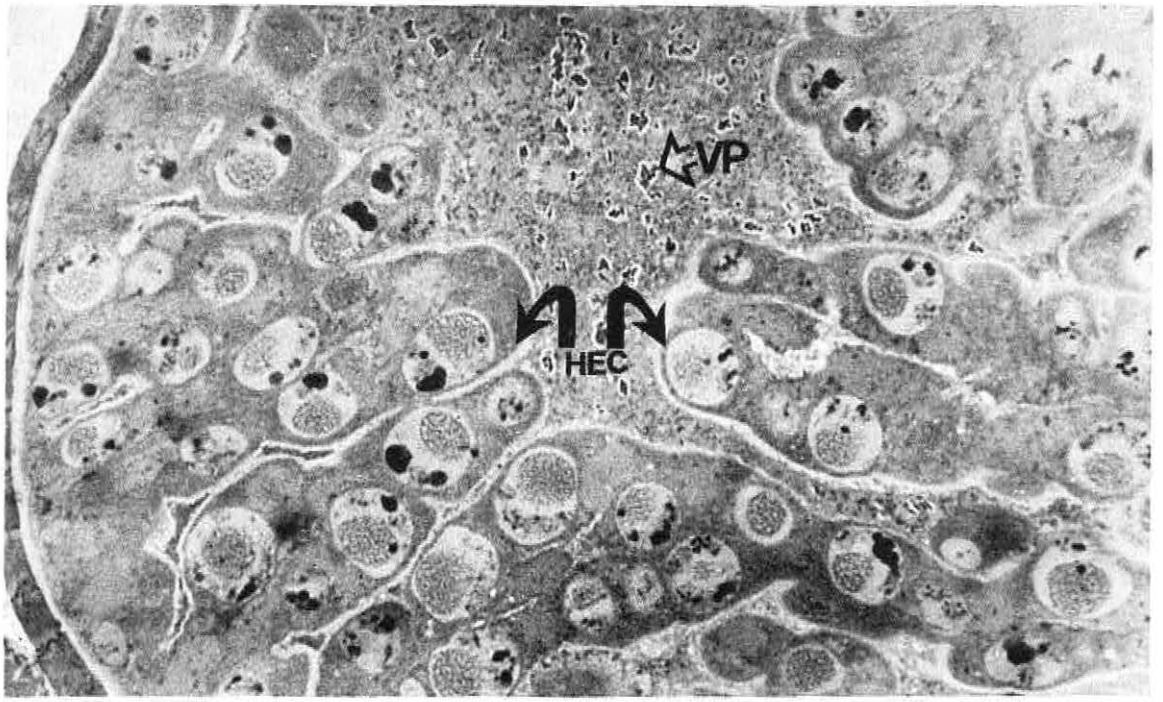


Figure 13. A hypertrophied salivary gland of *G. m. morsitans*, depicting hyperplastic epithelial cells (HEC) projecting into the glandular lumen containing virus particles (VP).

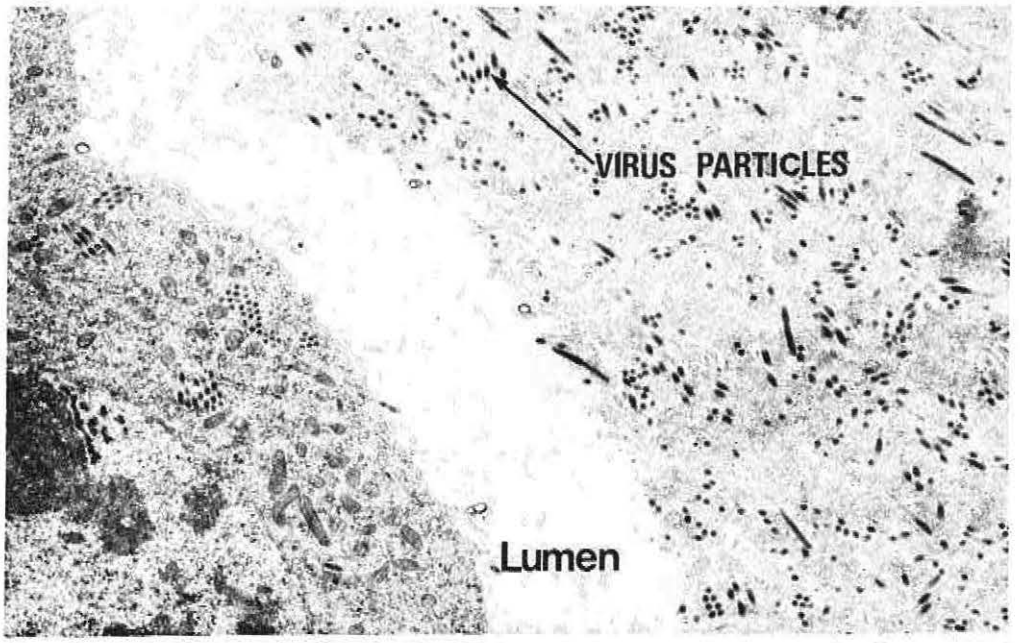


Figure 14. An electron micrograph of a hypertrophied salivary gland of *G. m. morsitans*, showing masses of virus particles within the glandular lumen. A portion of a hyperplastic epithelial cell is visible.

those of *Glossina pallidipes*, are not enveloped (Figure 16). The pathogenicity of virus particles to *Glossina* species other than *G. pallidipes* suggests great potential of the virus particles as microbial pathogens for the biological control of tsetse. The presence of masses of virus particles within the lumen of hypertrophied salivary glands suggests that affected tsetse transmit the viruses to animals and humans on which they feed and implies horizontal transmission of the microbes to the flies as a method of acquisition.

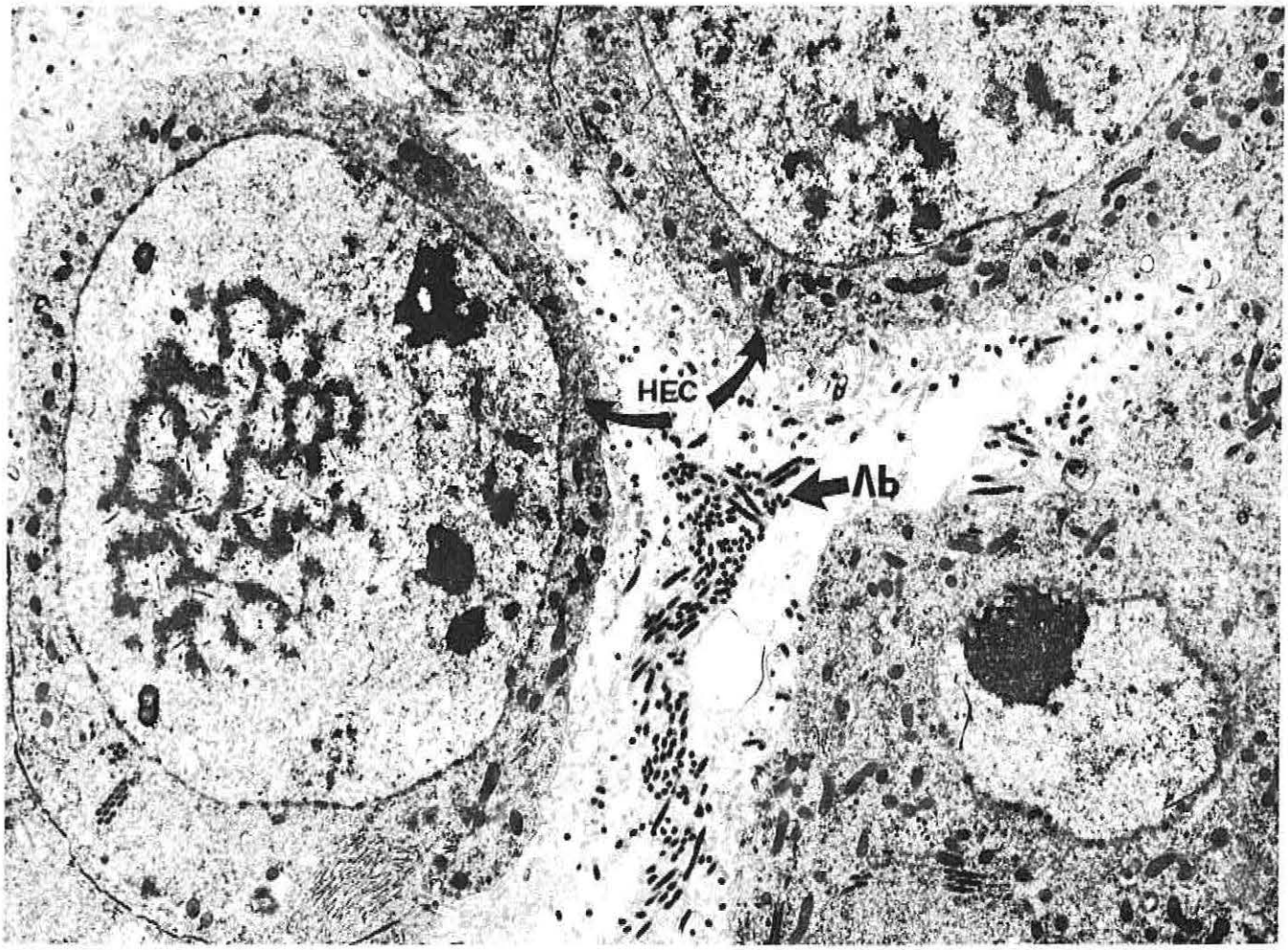


Figure 15. An electron micrograph showing virus particles (VP) within cellular interstices and within cytoplasm and nucleoplasm of hyperplastic epithelial cells (HEC) of a virus-infected *G. m. morsitans*.

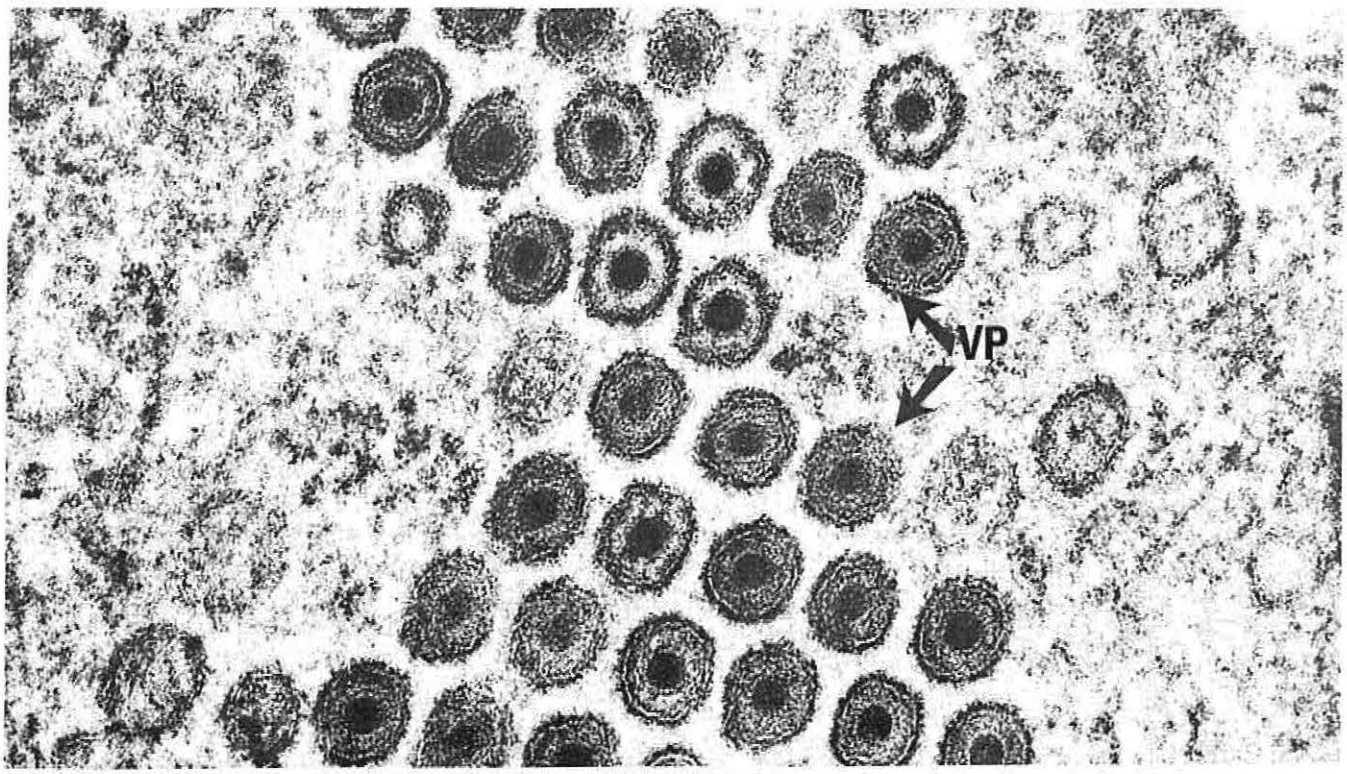


Figure 16. Unenveloped virus particles (VP) are depicted within the cytoplasm of a hyperplastic salivary gland epithelial cell.

ULTRASTRUCTURAL MODIFICATIONS IN THE EJACULATORY DUCT EPITHELIUM OF *GLOSSINA MORSITANS* DURING SEXUAL MATURATION

E. D. Kokwaro, J. Murithi

The ejaculatory duct is an important functional part of the male reproductive system of the tsetse fly, *Glossina morsitans*, and is responsible for the reception and transfer of sperm and accessory reproductive gland (ARG) secretions at the time of mating. The secretions from the ARG are used during mating to form several spermatophores, the formation of each comprising a brief period ranging from a few minutes to several hours.

As a first step towards a clear understanding of the spermatophore formation in this important pest, in 1982 HFSRU conducted a light- and electron-microscopic study of the ejaculatory duct from seven-day-old adult males (*ICIPE 1982 Annual Report*). The objective of the present study has been to extend this work and examine age-related changes in the ejaculatory duct and to relate structure to functional specialization. The ducts in teneral and 1- to 7-day-old male flies were used.

The ejaculatory duct is ectodermal and therefore lined with an intima on the luminal side. The cuticle-lined lumen is bordered by epithelial cells. These cells show age specialization with respect to the synthesis and accumulation of glycogen-like granules and the formation of intercellular spaces.

In teneral male flies, there are pockets of cisternae of smooth endoplasmic reticulum; associated with this are glycogen synthesis and storage (Figure 17). We specu-

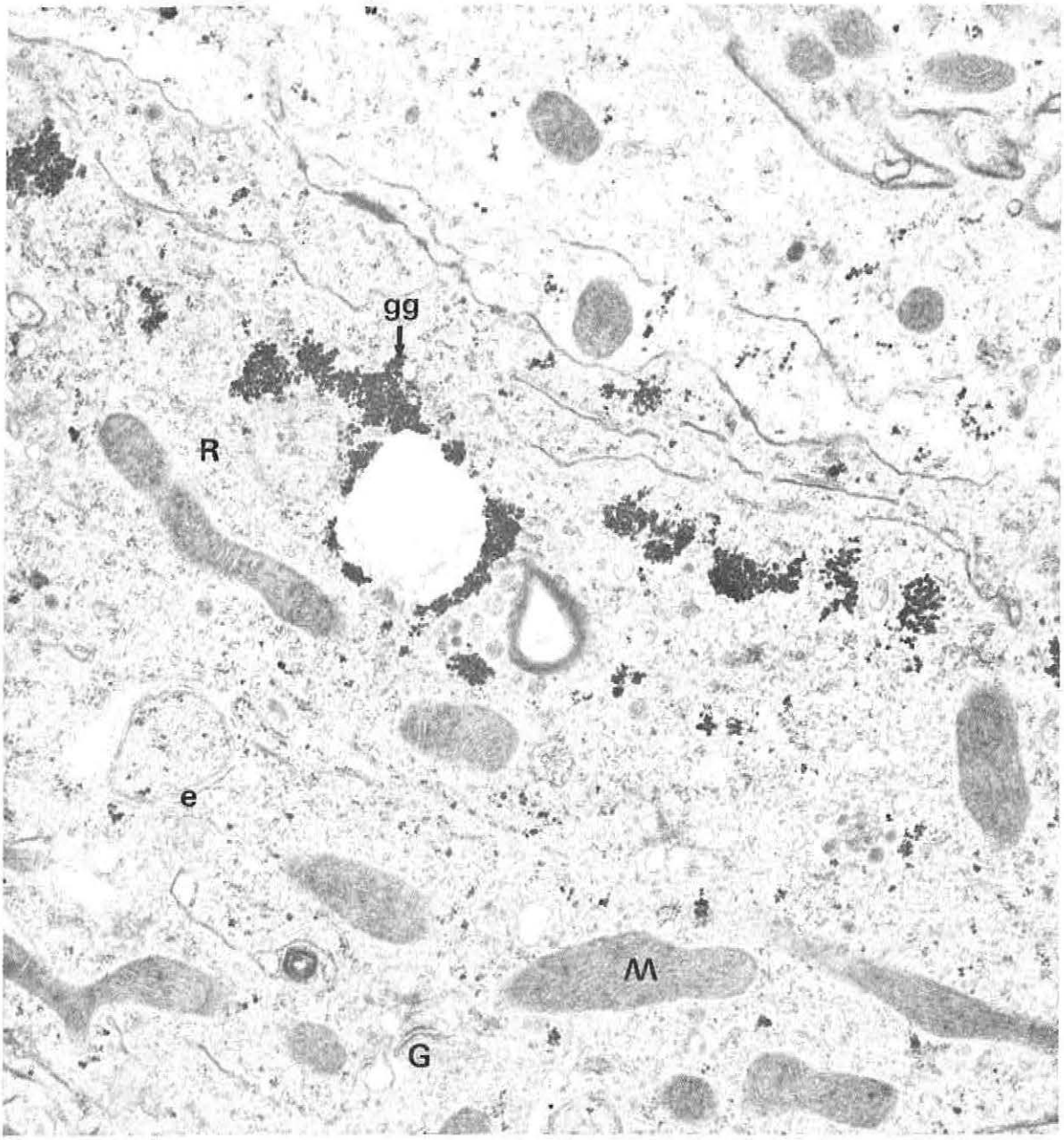


Figure 17. Micrograph of a cell from a teneral fly. In the cytoplasm there are numerous mitochondria (M), elements of smooth endoplasmic reticulum (e), free ribosomes (R), Golgi complexes (G) and clusters of glycogen granules (gg). Adjacent cells are tightly apposed.

late that the glycogen synthesis and storage may function as an energy source.

During sexual maturation (1–7 days), we have observed no storage of material comparable to that of glycogen granules (Figure 18). The intercellular spaces permeate most of the epithelium and connect to the infolded basal surface of the cells. Apically, there are numerous closely packed infoldings associated with mitochondria. This arrangement is quite similar to that observed in epithelial cells of teneral flies. These features, which characterize water- and/or ion-transporting epithelia, may be connected with a modification of accessory gland components during spermatophore formation. Also noteworthy are prominent channels towards the base of the cells, again reminiscent of the arrangement seen in some water and/or ion-transporting epithelia.

Other ultrastructural features include the numerous and often large mitochondria, distributed throughout the cytoplasm but most of them concentrated apically, polyribosomes being concentrated especially in the central and basal regions and microtubules. It seems probable that the microtubules are in some way related to the considerable shape changes that occur in the ejaculatory lumen and therefore the surrounding epithelium during spermatophore formation.

The duct is well tracheated, a feature presumably correlated with the existence of a thick layer of muscle. The muscle is strongly developed, presumably so as to be able to force the accessory gland secretions and sperm

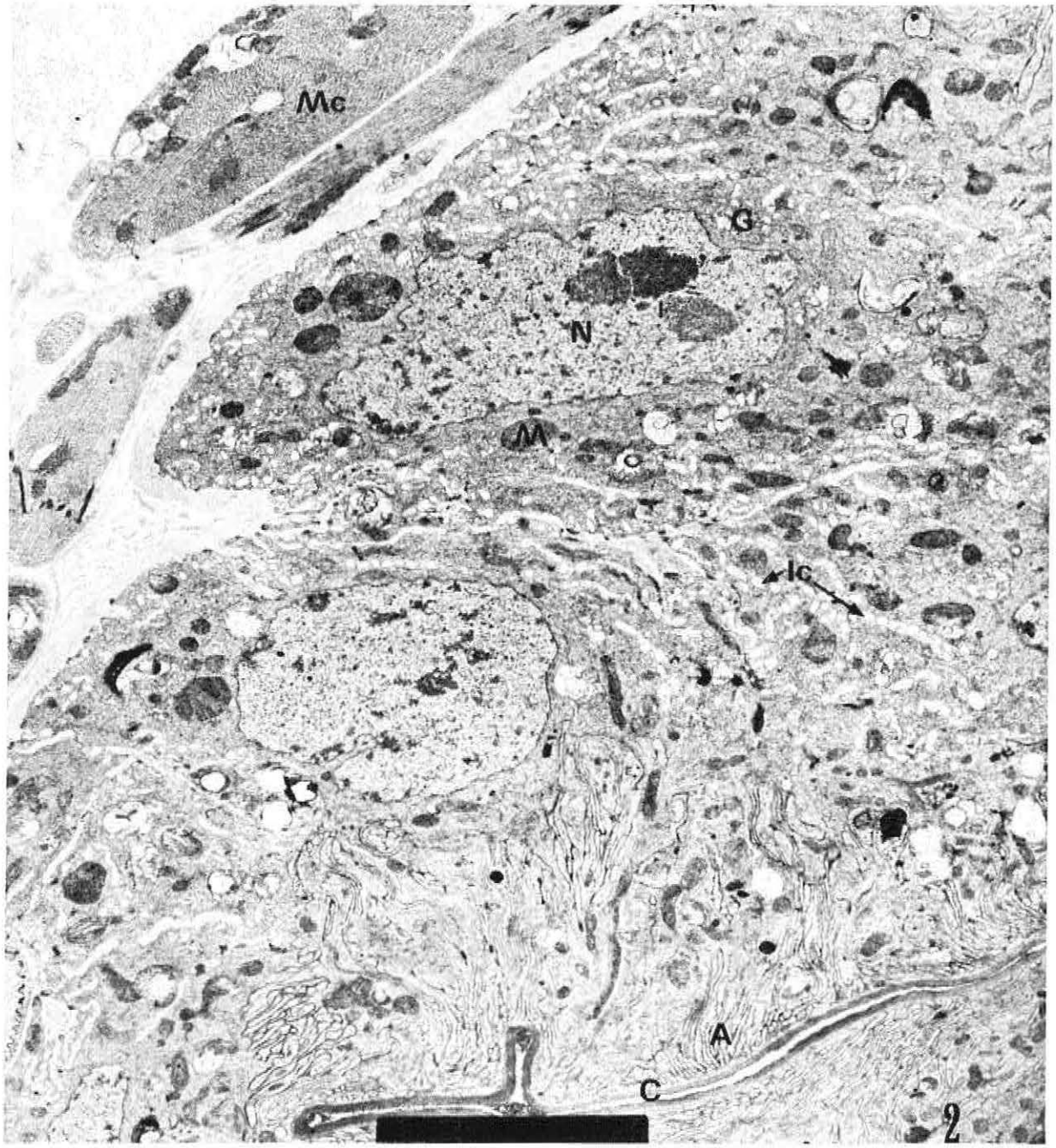


Figure 18. A 6-day-old adult. Cells with dense cytoplasm containing mitochondria (M), Golgi complexes (G), nucleus (N) and enveloped by thick muscle (Mc). Intercellular channels (Ic) develop beneath cell apex and open into large spaces at the basal surface (arrows). Note apical infoldings (*A*) and cuticle-lined lumen (*C*).

through a narrow cuticle-lined lumen during mating and spermatophore formation.

The present study has shown that while there is a general resemblance between the structure of the ejaculatory duct of teneral and 1- to 7-day-old flies, there are significant differences more noticeable in sexually mature flies. These are probably related to spermatophore formation.

STRUCTURAL AND FUNCTIONAL ZONATION IN THE MALPIGHIAN TUBULES OF *GLOSSINA MORSITANS MORSITANS*

J. A. Kongoro

The Malpighian tubules and rectum are the major excretory organs in insects. Tsetse Malpighian tubules, like those of other haematophagous insects, are of particular interest because they are specialized for very fast excretion of fluid after intake of a blood meal. The excess fluid ingested in the meal, if not discarded urgently, would upset the osmotic balance of the haemolymph; moreover, the excess weight would predispose the fly to predation. The Malpighian tubules, enabling the insect to adapt itself to its feeding habit, may provide a weak link to be exploited in long-term tsetse control measures.

In vitro observations indicate zonation in the functioning of the Malpighian tubules in some insects, but no substantial evidence has been provided to support these observations. The objective of this study was to elucidate structural and functional zonation in the Malpighian tubules of *Glossina morsitans morsitans* by electron microscopy and autoradiography, using tritiated glucose.

Ultrastructurally, the proximal and distal parts of the tubules were distinct (Figures 19 and 20). The cytoplasm

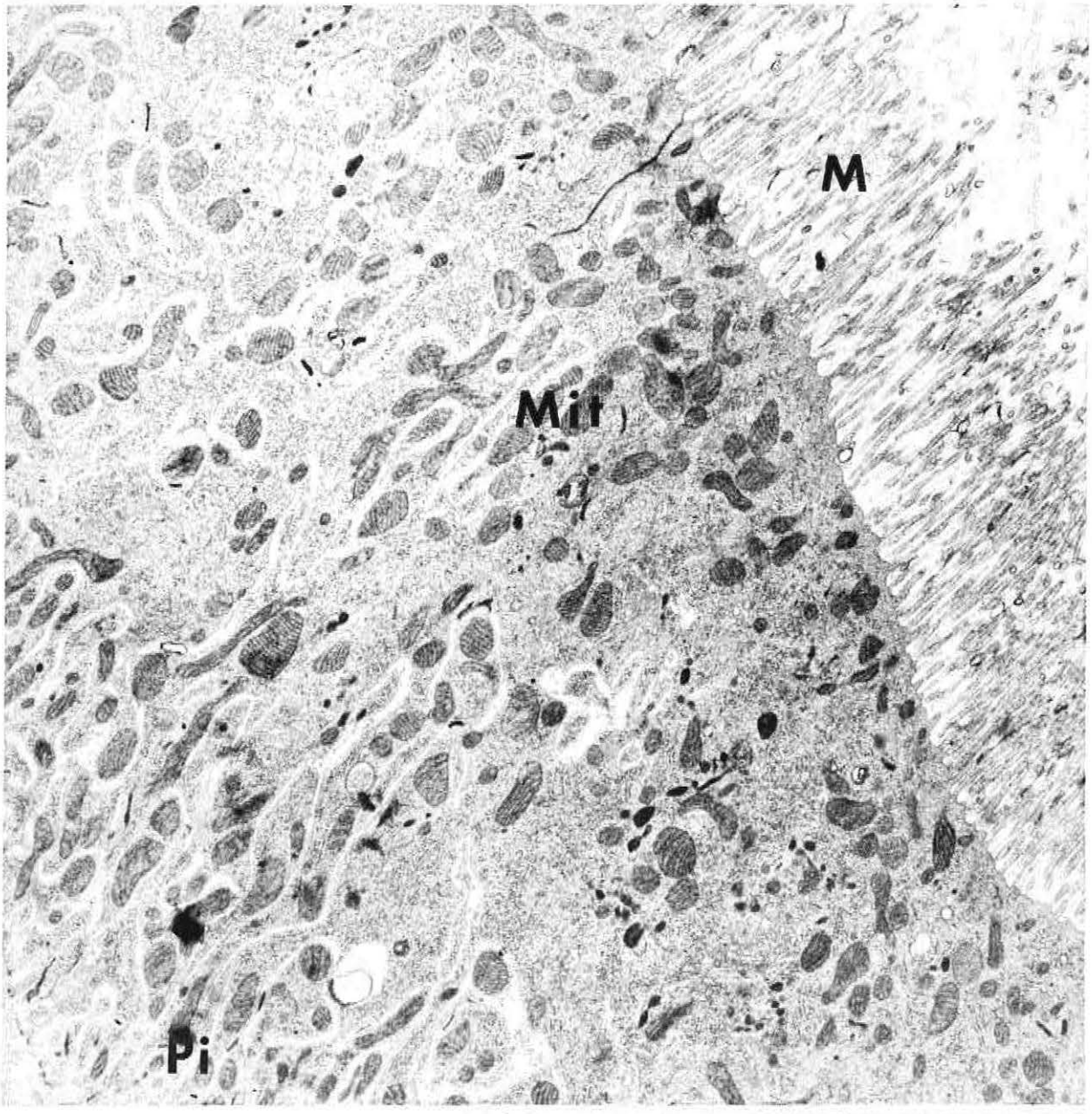


Figure 19. Part of a section of the proximal Malpighian tubule in *G. m. morsitans*. M: microvilli, Mit: mitochondria, Pi: plasmalemmal infolds.

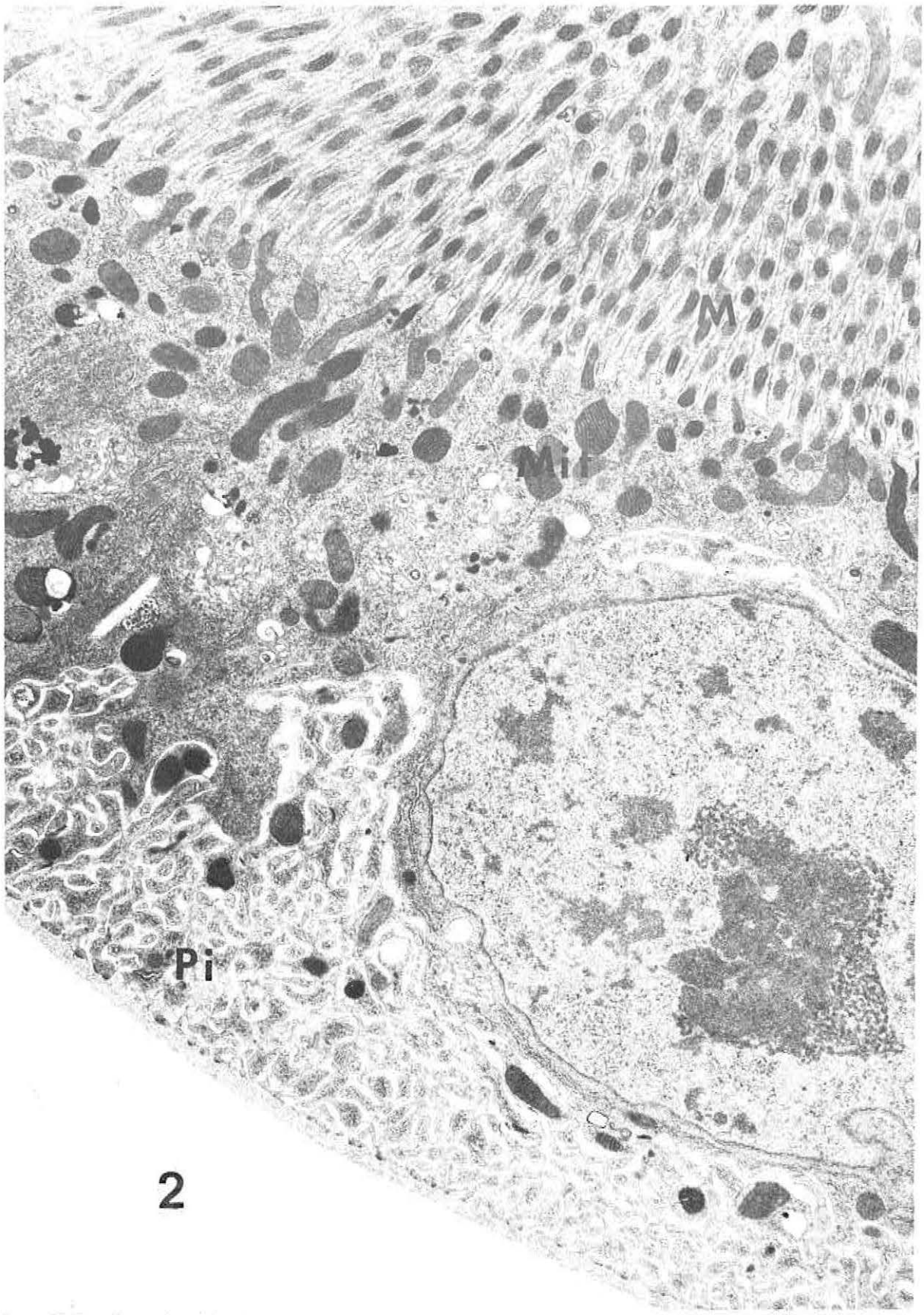


Figure 20. Part of a section of the distal region of *G. m. morsitans* Malpighian tubule. M: microvilli, Mit: mitochondria, Pi: plasmalemmal infolds.

of the epithelial cells was labelled, thus indicating synthetic activity in the tubules. Some of the silver grains seemed to be associated with mitochondria. Labelling density was greater in the distal than in the proximal parts of the tubules (Figures 21 and 22) and increased in tubule sections both with an increase in time following the injection and with concentration of triated glucose. These observations suggest that there is greater metabolic activity in the distal than in the proximal parts of the tubules.

Figure 21. LM autoradiograph of a section through the proximal regions of two *G. m. morsitans* Malpighian tubules. Tubules labelled with tritiated glucose.

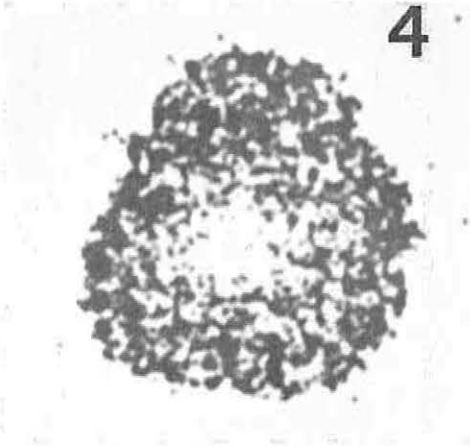


Figure 22. LM autoradiograph of a section through the distal *G. m. morsitans* Malpighian tubule. Tubules labelled with tritiated glucose.

Sensory Physiology

Sensory Physiology Research Unit

*The principal concern of the Sensory Physiology Research Unit (SPRU) is to identify and describe factors influencing insect pest responses to host and non-host stimuli. Emphasis is currently focused on crop pests, especially crop borers (*Chilo partellus, Maruca testulalis *and* Eldana saccharina*), and tsetse flies (*Glossina morsitans morsitans *and* G. pallidipes*). SPRU investigations employ both behavioural and electrophysiological methods.*

During 1986 SPRU work on crop borers continued to examine the chemical stimuli that cause differences in the palatability of susceptible and resistant host plants. An in vitro *feeding bioassay was established to examine the borer responses to host and non-host plant materials. Chemical factors involved in the tsetse host and mate selection were scrutinized and various synthetic and natural products were screened for the purpose of identifying chemicals of potential use in tsetse control. In the course of this work a behavioural bioassay based on tsetse antennal responses was consolidated; it is now the routine method used for screening compounds.*

The electrophysiological instrumentation and the gas liquid chromatograph have been interfaced with a data acquisition control and analysis facility run by an IBM PC XT computer. This new facility will provide reliable and rapid analysis of sensory-receptor responses to odour and taste stimuli. In addition to this, the system may be used to analyse insect behaviour when suitable computer software programmes become available. SPRU is now well equipped to undertake investigations on odours of biological significance, especially those of pheromones; such investigations will constitute much of the Unit's work in the future. In addition, investigations on interactions among pests and their hosts and predators will be intensified.

Facilities for conducting behavioural studies in the laboratory and field improved this year. A video system for observing and recording insect responses and movements was acquired and a system to support wind-tunnel experiments will be installed as soon as space becomes available. Experiments designed to observe tsetse fly behaviour around the host and larviposition sites are already in progress.

IN VITRO AND ELECTROPHYSIOLOGICAL BIOASSAY OF HOST MATERIALS (STEM BORERS)

S. M. Waladde, H. Kahoro, S. A. Ochieng

In this work, emphasis is put on the susceptible Inbred A and the resistant MP 704 maize varieties. The plants used were raised at the ICIPE Mbita Point Field Station, in western Kenya, and harvested five to six weeks after planting. The plant materials were collected and treated using the method described by SPRU in the *ICIPE 1985 Annual Report*. The objective of this work is to test the sensitivity of the *in vitro* feeding bioassay for *Chilo partellus* in particular.

The first bioassay was designed to find out whether the method used could demonstrate differences in the larval responses to Inbred A and MP 704 maize varieties. In this test the maize plant materials were divided into nodes and internodes and the larval feeding

response to each type was analysed. The second bioassay test was designed to show the effects of maize extract components on larvae feeding responses. In these tests the substrate used was invariably internodes of Inbred A. The third bioassay test was designed to let us observe the process of *C. partellus* burrowing into maize stem pieces.

Electrophysiological tests done on the maxillary styloconica sensilla were conducted to find out whether taste sensilla responses of *Chilo, Eldana saccharina* and *Spodoptera exempta* to the extracts can serve as useful indicators of stimuli differences in the maize varieties.

Feeding Bioassay

No overall significant difference occurred between the feeding activity on Inbred A and that on MP 704, though larvae on Inbred A internodes fed substantially more than those on MP 704. However, it was clear that larvae fed on Inbred A material gained far more weight than those fed on MP 704 material (Figure 1).

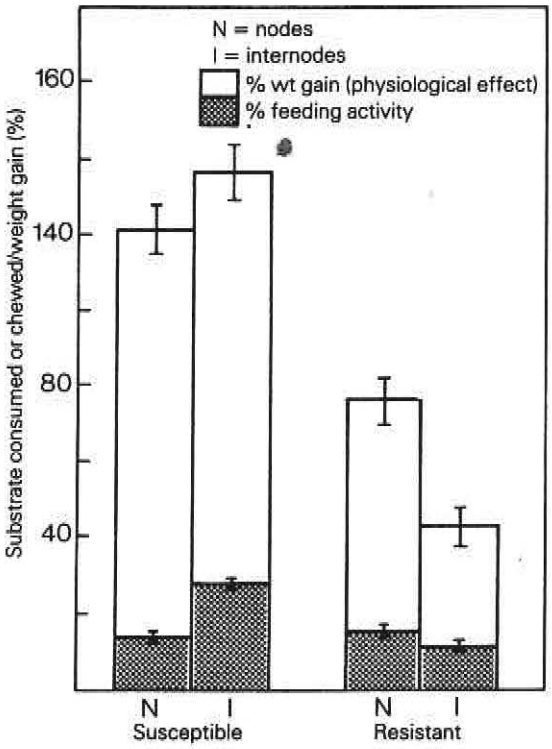


Figure 1. Histogram showing responses of *Chilo partellus* larvae to Inbred A (susceptible) and MP 704 (resistant) maize varieties. Shaded parts of the bars indicate the percentages of the substrate consumed or chewed (feeding activity), while the entire bar indicates the percentages of weight gained by the larvae.

Internodes impregnated with either Inbred A or MP 704 aqueous extracts had approximately the same level of feeding activity as the control. However, larval weight gain was significantly lower among those larvae that fed on the substrate treated with aqueous extracts from MP 704. Diethyl-ether extracts from the two maize varieties were equally effective in reducing feeding activity and larval weight gain. Chloroform-methanol extracts appear to affect both feeding activity and weight gains (Figure 2).

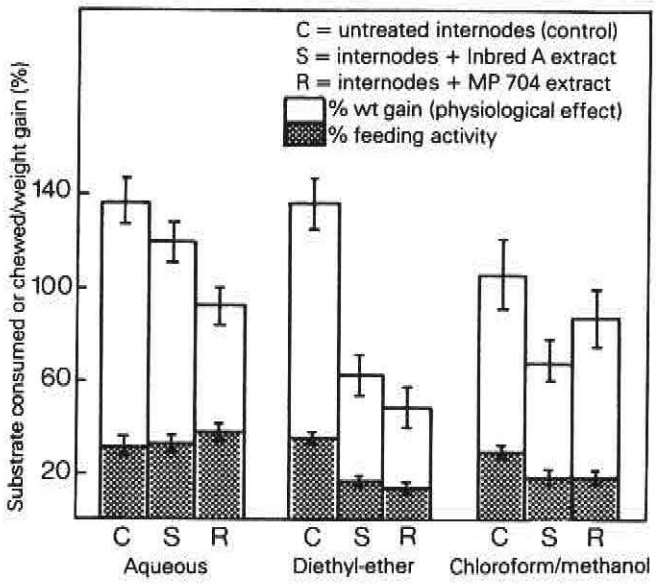


Figure 2. Histogram showing responses of *Chilo partellus* larvae to extracts of two maize varieties impregnated in the feeding substrates. Shaded parts of each bar indicate the percentages of the substrate consumed or chewed (feeding activity), while the entire bar indicates the percentages of weight gained by the larvae.

Electrophysiology

In *Eldana*, the lateral and medial sensilla were more sensitive to aqueous extract of MP 704 than to that of Inbred A. Furthermore, the stimulating components in the extracts evoked polyneuronal responses in both styloconica sensilla. However, in the lateral sensillum there was a mononeuronal response to sucrose. Response curves for pure sucrose and salt were different from those for the extracts; this was expected because the extracts contain a wide range of potential stimuli. It is obvious that the stimulatory effect in the extracts of the two varieties are different (Figure 3).

Burrowing Activity

Behavioural responses of *Chilo* larvae burrowing into pieces of susceptible and resistant maize stem varieties were observed in a dark-room lit with a red lamp. Third- to fourth-instar larvae previously starved for approximately 24 hours were used and the total weight of all the larvae used in each treatment was recorded at the beginning of each experiment. Then each individual larva was placed on a hydrated piece of maize stem (substrate), which was immediately covered with a glass vial. The activity of each larva was observed and recorded at ten-minute intervals during the first hour and thereafter at 2, 4, 8 and 24 hours. Activities recorded included crawling on the substrate, nibbling, four levels of burrowing activity and evasive movements. At the end of each experiment the larvae were collected and weighed again. All the frass produced by the larvae was collected, dried and weighed. With this data it was possible to estimate larval weight gain and frass produced per larva.

Within the first hour of these observations, burrowing activity was better on the susceptible variety than on the resistant variety. Furthermore, within the first two

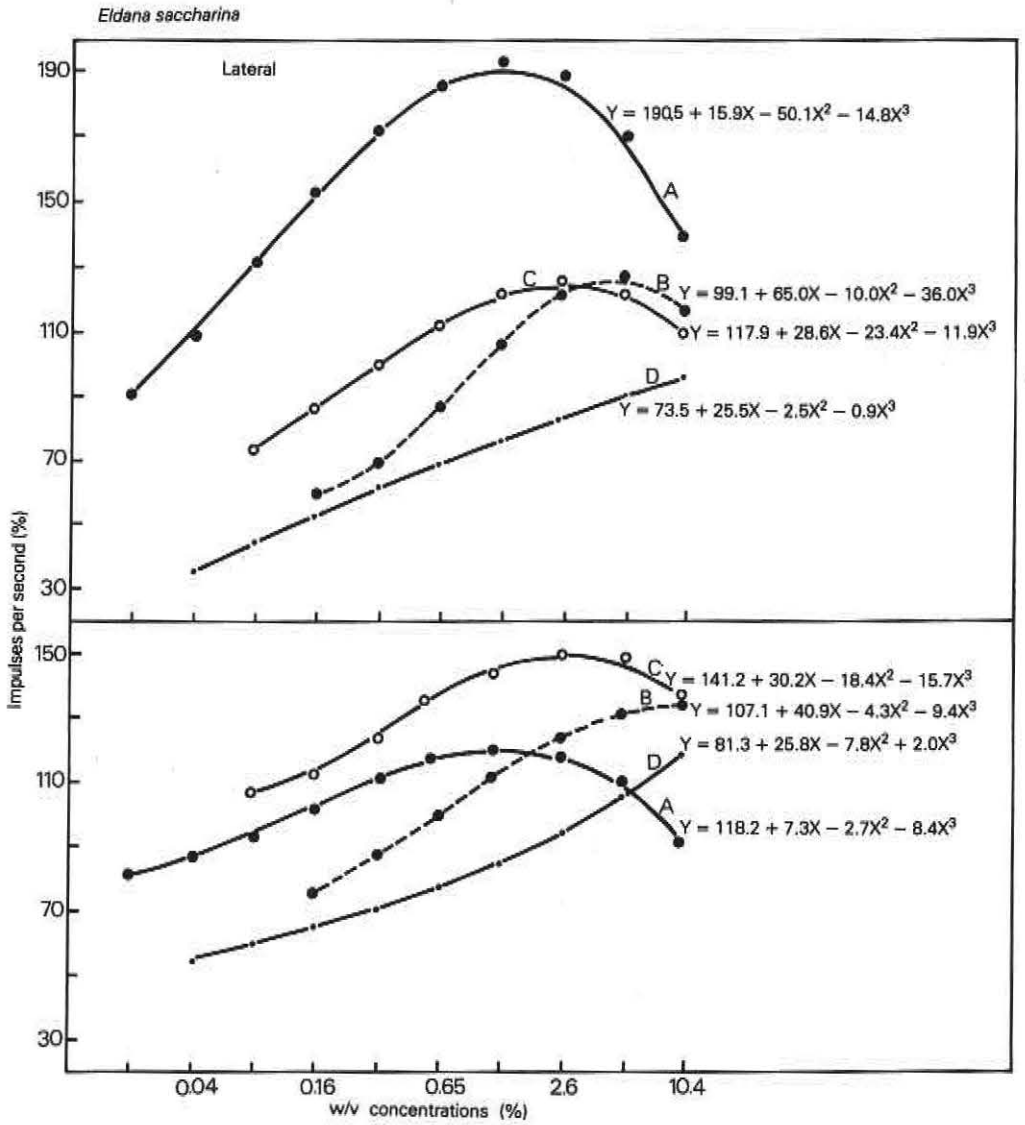


Figure 3. Dose-response curves for sucrose (*A*), aqueous maize extracts ([*B*] MP 704, [*C*] Inbred A) and NaCl (*D*), showing responses of *Eldana saccharina* styloconica sensilla. X and Y axes indicate the percentages of concentrations of stimuli and impulses per second, respectively.

hours, larvae that had burrowed half-way, or almost entirely into the substrates, followed a pattern similar to that mentioned above. Within 24 hours the number burrowed in the two varieties was about the same. The weight of the frass collected indicated that larval activity on the resistant variety generated twice as much frass as that on the susceptible variety. This suggests that *Chilo* larvae actively chewed their way into the resistant variety but did not ingest much of that substrate (Figure 4). This may explain why larvae fed on the resistant variety gained less weight than those fed on the susceptible variety.

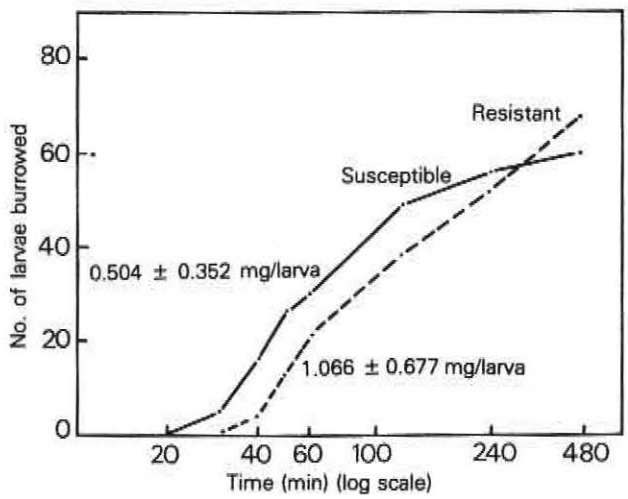


Figure 4: Burrowing activity of *Chilo partellus* larvae in susceptible and resistant maize substrates. The value appended to each curve indicates the amount of frass produced per larva in 24 hours.

RESPONSES OF *MARUCA TESTULALIS* SENSILLA TO HOST PLANT EXTRACTS

E. M. Hussain, S. M. Waladde

Maruca testulalis is an important pest of cowpea, causing major damage in the field. Among the cowpea varieties

studied so far, it has been reported that Vita I is the most susceptible while TVu 946 is the most resistant. It has been found that *M. testulalis* larvae show a preferential feeding response to the extracts of the two cultivars. The chemical factors responsible for susceptibility or resistance are not known.

The aim of this study is to find out whether taste sensilla can detect differences between the extracts from the two cultivars. We investigated electrophysiological responses of the medial and lateral sensilla styloconica to extracts of the two cowpea varieties. Other stimuli tested included sugars, salts and amino acids. These tests provided information about the response patterns of the sensilla.

Both varieties of cowpea—Vita I and TVu 946—were grown at ICIPE's Mbita Point Field Station, in western Kenya, and were harvested 30 days after planting. The fresh leaves and flowers of each variety were collected, separately chopped into small pieces and then passively extracted in methanol for 3 weeks at 4°–10° C. The extract was filtered, then concentrated using a rotar evaporator and finally freeze-dried to produce a powder. Various quantities of the dry extracts were weighed to make a series of solutions used in the electrophysiological tests.

In *M. testulalis*, both styloconica sensilla are sensitive to NaCl solutions. The threshold and optimal concentrations were 0.003 M and 0.081 M, respectively. The lateral sensillum generated two or three types of spikes, while the medial sensillum generated one type of spike amplitude. In addition to NaCl, both sensilla are sensitive to other mineral salts such as KCl, $MgCl_2$ and LiCl. Sucrose is a good stimulant of both sensilla and its threshold and optimal concentrations were 0.0001 M and 0.0081 M, respectively. However, the spike generation from the sensilla is almost inhibited by a 0.024-M sucrose concentration. It was observed that the lateral sensillum is more sensitive to salts and sucrose than the medial sensillum. On the other hand, some monocarboxylic amino acids, such as glycine and alanine, had a better stimulatory effect on the medial sensillum than on the lateral sensillum. Responses to these known compounds indicate that the styloconica sensilla are sensitive to many compounds likely to be found in the host plant tissues. The Lepidopteran styloconica sensilla are usually innervated by four taste neurons. This is most likely to be the case in *M. testulalis* larvae, but this remains to be verified by transmission electron microscopy.

Methanol extracts from cowpea flowers evoked responses in the lateral sensilla but not in the medial sensilla. It was observed that flower extract from TVu 946 elicited a better stimulatory effect than did a similar extract from Vita I (Figure 5), but behavioural studies showed that *M. testulalis* larvae feed better on Vita I than on TVu 946 plant tissues. Chemists have found that there are less sugars, amino acids and proteins in TVu 946 than in Vita I and more phenols and flavonoids in the stems of TVu 946 than in the stems of Vita I. The observed differences in electrophysiological responses may partly be due to differences in the chemical composition between the two cultivars.

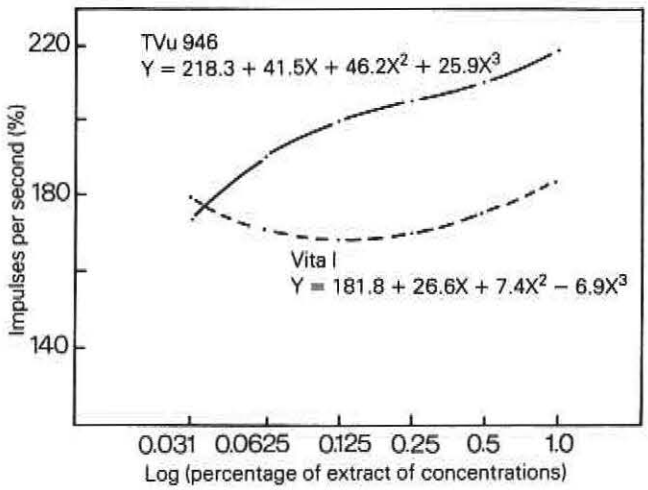


Figure 5. Response curves of the lateral styloconica sensilla of *M. testulalis* to cowpea flower extracts.

Methanol-leaf extracts of both varieties had no stimulatory effect on the styloconica sensilla. This was unexpected because it is known that *Maruca* larvae effectively feed on cowpea leaves. It was therefore necessary to find out how the leaf extract affects the responses of the two sensilla to known compounds. In this test a series of leaf-extract solutions dissolved in 0.0081-M sucrose were used. It was observed that the extract reduced the activity of the sucrose-sensitive cells and that this effect was strongly dependent on the concentration of the extract (Figure 6).

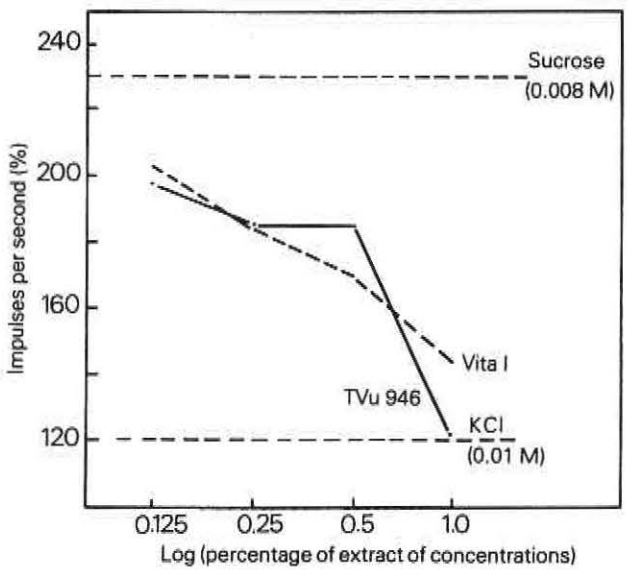


Figure 6. Response curves showing effects of cowpea-leaf extracts on sugar sensitive cells. Increasing extract level in 0.0081-M sucrose depresses response to this solution. Broken lines at the top and bottom of the figure represent average responses to 0.0081-M sucrose and 0.01-M KCl, respectively.

Work is in progress to test the responses of the sensilla to the different fractions of cowpea extracts from leaves, flowers and pods.

CHEMOCOMMUNICATION IN TSETSE FLIES

R. K. Saini

Tsetse Antennal Responses to Buffalo Urine

The behavioural bioassay based on antennal responses (reported in the *ICIPE 1985 Annual Report*) was used to investigate the responses of tsetse to buffalo urine. Tsetse flies rapidly raised their antennae upon stimulation with the odour of this olfactory attractant. The reponses of males to the urine odour as compared to the odour of filter paper and water (the control) were about five times more for the undiluted fresh urine, about four times more for the urine diluted ten times and about two times more for urine diluted 100, 1000, 10 000 and 100 000 times (Figure 7). Hence, flies showed a clear preference for the undiluted fresh buffalo urine and the responses, even at 100 000 dilution, were significantly different from the control, indicating the efficacy of the attractive compounds in the urine. Antennal responses to fresh, undiluted urine were two times more than those to acetone or 1-octen-3-ol.

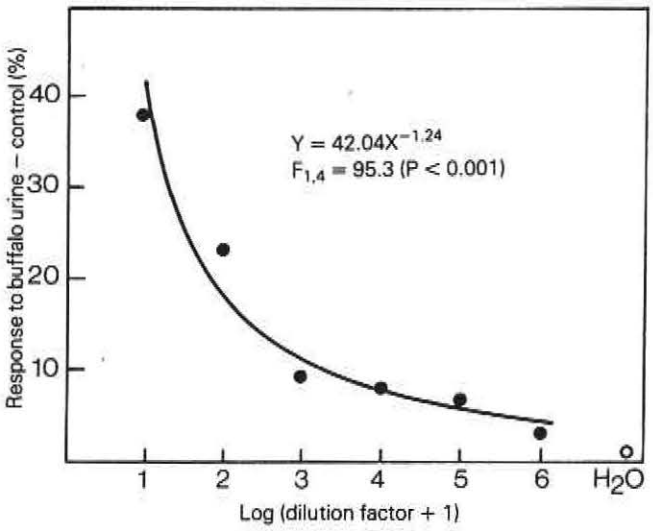


Figure 7. Dose response curve of the percentages of behavioural (antennal) responses of male *G. m. morsitans* to various doses (undiluted and diluted 10, 100, 1000, 10 000 and 100 000 times) of fresh buffalo urine. Open circle at the bottom right of the figure indicates the responses of the flies to the odour of clean filter paper and water (control).

Experiments undertaken to determine whether male responsiveness increased with increasing age of the urine (Figure 8) indicated that male responses to fresh undiluted urine were significantly more (about five times more than the control) than their responses to any dilutions either of fresh urine or of any doses of the 4- and 8-day-old urine tested (only 2–3 times more than the control). These results therefore indicate that though the efficacy of the urine persisted with age, the attractiveness did not increase with advancing age. These results also suggest that at the time of urination there may be additional volatile components in the urine that have not been detected in field studies because in the field the urine is left out for several hours.

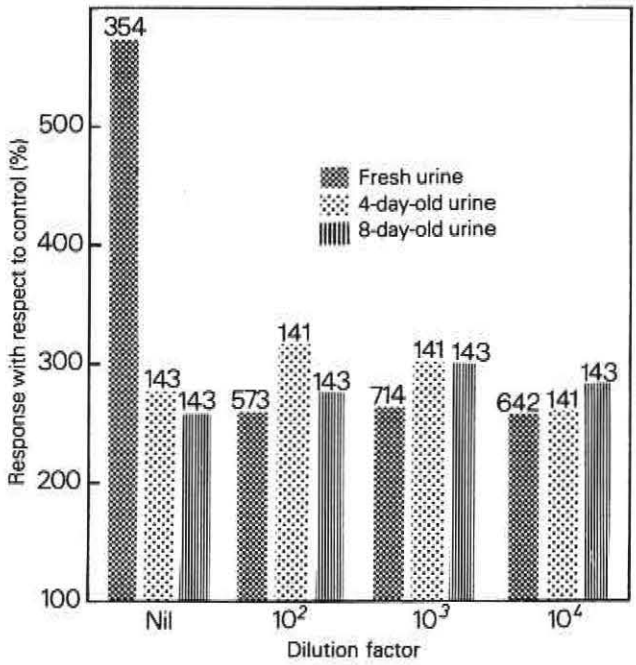


Figure 8. Behavioural (antennal) responses of 1-week-old *G. m. morsitans* to various doses (undiluted and diluted 100, 1000 and 10 000 times) of fresh, 4- and 8-day-old buffalo urine expressed as a percentage of responses to the odour of clean filter paper (control). Numbers above columns indicate numbers of flies tested.

Male responses to different doses of the dichloromethane extract and to its aqueous-layer extract when it was fresh and four days old (Figure 9) indicate

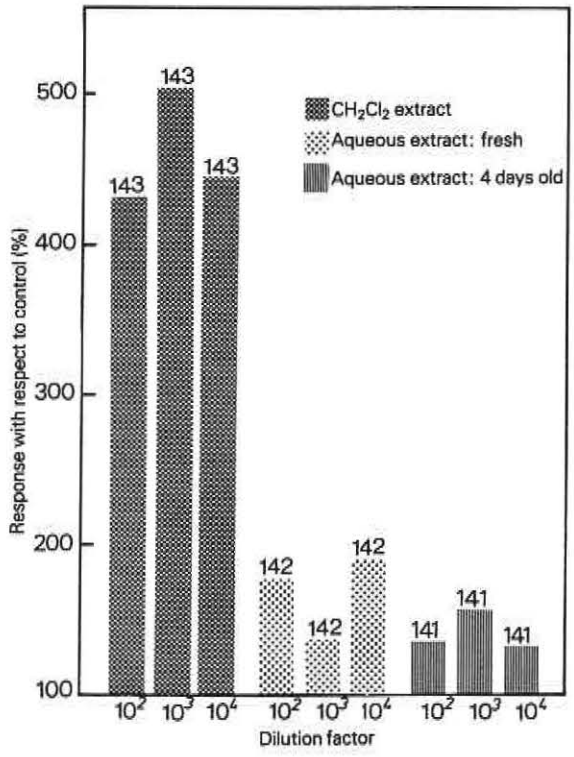


Figure 9. Behavioural (antennal) responses of 1-week-old *G. m. morsitans* males to various diluted doses (diluted 100, 1000, and 10 000 times) of dichloromethane extract of fresh urine and its aqueous-layer extracts (fresh and 4 days old). Responses are expressed as a percentage of responses to the odour of clean filter paper (control). Numbers above columns indicate numbers of flies tested.

that the attractive compounds were effectively extractable by dichloromethane. The responses to different doses of the dichloromethane extract were not only significantly greater than the responses to the control, but were also different from the responses to both the aqueous extracts.

Antennal responses of female *G. m. morsitans* (Figure 10), while indicating a trend similar to those of males, were significantly less (only about three times more than the control) than those of males (about five times more than the control).

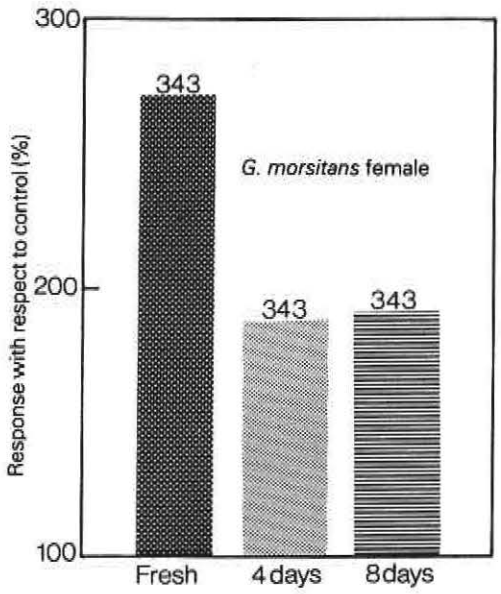


Figure 10. Behavioural (antennal) responses of 1-week-old *G. m. morsitans* females to fresh undiluted buffalo urine and 4- and 8-day-old urine expressed as a percentage of responses to the odour of clean filter paper (control). Numbers above columns indicate number of flies tested.

Observations on male and female *G. pallidipes* also indicate that the flies preferred fresh undiluted urine (responses were five times more than the control) as compared to 4- or 8-day-old urine (responses were 2–3 times more than the control).

Behavioural and Electrophysiological Responses of Tsetse to Various Phenols

R. K. Saini, A. Hassanali

The most active fraction of the dichloromethane extract of buffalo urine has been shown to be composed of seven phenolic compounds, which include phenol, 3- and 4-cresols, 3- and 4-ethylphenols and 3- and 4-*n* propylphenols. Behavioural and electrophysiological studies are in progress to determine the relative importance of these various phenols, used both alone and in various blends.

Antennal responses of *G. m. morsitans* to these phenols showed that of the two cresol isomers, the para (4-cresol) is more stimulatory. In fact, out of the seven phenols, para cresol was the most stimulating, eliciting antennal responses ranging from about 2.5 times more than the control at 0.5 and 1.0 μg concentrations to about five times more at 4, 8 and 16 μg concentrations. Both the ethylphenols elicited antennal responses that were about twice that of the control. Of the two isomers of the propyl phenols, the meta propyl phenol was more stimulatory, eliciting antennal responses more than two times that of the control at the various doses tested, as compared to para propyl phenol, which elicited antennal responses only about 1.5 times more than that of the control. Phenol itself appeared to be the least stimulatory, because it elicited antennal responses not significantly different from that of the control.

Electroantennograms (EAG) also provided an insight into the sensitivity of olfactory receptors to odours. EAG response spectra of *G. m. morsitans* to equimolar concentrations of these phenols indicated that, as in the behavioural studies, para cresol was the more stimulatory of the two isomers of the cresol. Meta propyl phenol was the most stimulatory among the propyl phenols, while the two ethylphenols were equally active. EAG responses to phenol itself, however, increased with increasing concentrations.

Similar behavioural and electrophysiological studies are in progress with *G. pallidipes* and preliminary results indicate that the responses of the two species to various phenols differ, suggesting that the two species are likely to respond to different compositions of the constituent phenols.

Structure Activity Relationships of 1-octen-3-ol Analogues

R. K. Saini, A. Hassanali

Behavioural and electrophysiological studies are in progress to investigate the structure-activity relationships of l-octen-3-ol analogues in order to optimize the activity and to identify more potent attractants in this class of tsetse kairomones. We have investigated the effect of (1) chain length, (2) substituting carbonyl and hydroxyl groups with other functionalities and (3) changing the relative positions of the two functional groups.

Results obtained from the series $CH_2 = CH - (CH_2)_nH$ show an interesting dependence on chain length, the activity dropping from 3-carbon homologue (allyl alcohol) to 7-carbon homologue (1-hepten-3-ol), rising to a maximum 8-carbon homologue (1-octen-3-ol) and then dropping again to 9-carbon homologue (1-nonen-3-ol).

Responses of *G. m. morsitans* to l-octene and 3-octanol were lower than that to l-octen-3-ol, indicating that both the π system and the oxygen functions were important for activity. Responses of flies to l-octyn-3-ol, l-octen-3-one and 3-acetoxy-l-octen suggest that the structural requirements for activity of the functional end of the molecule are not rigid. Thus, l-octyn-3-ol, l-octen-3-one and 3-acetoxy-l-octen, which have different π configurations and shapes, appear to be as active as l-octen-3-ol. However, dose-response studies may reveal some measurable differences among these four com-

pounds and such studies have been initiated. The results to date imply that other functional variants may have activity as high as or higher than that of l-octen-3-ol.

Lower responsiveness of flies to 3-buten-l-ol than to 3-buten-2-ol indicate that the presence of the two functional groups in the same relative position as in l-octen-3-ol was important. Field investigations to check the efficacy of these and other analogues are in progress. Preliminary field tests indicate that at certain dose ranges 3-buten-2-ol may be as active as l-octen-3-ol.

Biostatistics and Computer Services Unit

ACCOMPLISHMENTS

H. F. Magalit

The Biostatistics and Computer Services Unit (BCSU) helped 31 ICIPE researchers to use word processing, data processing and statistical computer programmes and to learn programming languages. BCSU developed and wrote computer programmes for the researchers that are efficient and easy to use.

The Unit continued to store large amounts of data on the disks of the VS 80 system for Tsetse, Crop Pests and Medical Vectors research programmes. Data for the other research programmes were also stored in this system.

A tsetse population model was developed and run on the VS 80 system. This model was regularly revised by the Tsetse Research Programme staff.

BCSU helped to prepare questionnaires for a social science survey conducted by Dr. A. Pala Okeyo, a Crop Pests Research Programme survey conducted by Prof. K. N. Saxena and a cassava mite survey conducted by Dr. G. W. Oloo.

Mrs. W. N. Ssebunnya and Mr. J. K. Maina designed and developed a financial system and Mr. Maina wrote computer programmes for the Finance Division.

Courses in computer programming, applications and biostatistics were offered to ICIPE staff, students in ICIPE's African Regional Postgraduate Programme in Insect Science (ARPPIS) and training groups at ICIPE. The following were offered:

- A two-hour lecture and demonstration that introduced computers to 12 participants of the Tick Management Course held at Chiromo in January 1986.
- Training in statistical analysis and data processing to 6 staff researchers at Chiromo, 20–31 January 1986.
- Training in statistical analysis and data processing to 12 staff researchers at Mbita Point Field Station, 3–8 March 1986.
- A three-hour demonstration on microcomputer applications to 20 participants of a University of Nairobi Microcomputers in Research Organizations Workshop, 20 March 1986.
- A two-hour demonstration in computer applications to 24 participants of a UNESCO Course in Information Technology in Libraries and Information Services conducted for Moi University, 14 April 1986.
- A three-hour lecture-demonstration to 12 participants of a European Economic Commission/ICIPE course, 14 July 1986.

  A one-hour lecture on the use of computers and on data analysis to 15 participants of the Ninth International Group Training Course, 18 August 1986.
- A ten-day biostatistics course for 8 students in ICIPE's African Regional Postgraduate Programme in Insect Science (ARPPIS), August 1986.

BCSU gave computer support to the International Conference on Tropical Entomology, held at the Kenyatta International Conference Centre in August 1986, and to conferences held at the Duduville International Guest Centre.

Software

BCSU made the following software programmes available.

VS 80 computer:

- A financial information and payroll system.

Microcomputers:

Wang PC:

- Graphics
- Word Processing
- Multiplan (spreadsheet)
- Lotus 1-2-3 (spreadsheet, graphics and information management)
- In-Magic (data base for bibliographies)
- D'Base II (data base)
- Mstat (statistics)
- In-house developed programmes in BASIC and FORTRAN languages

IBM PC:

- SMART (integration of data management, word processing, communications, graphics and spreadsheet)
- Word Perfect (word processing)
- Panacea (data base with some statistical programmes)
- Mstat (statistics)

Hardware

The following hardware was installed during the year.

- 3 Wang PCs: one each to the African Regional Postgraduate Programme in Insect Science (ARPPIS), Financial and Administrative Management of Research Projects in Eastern and Southern Africa (FAMESA), and Mbita Point Field Station
- 3 workstations of 2200 LVP at Mbita Point Field Station
- 2 IBM PC/XTs: one each to the Livestock Ticks Research Programme and the Sensory Physiology Research Unit

Communication was established between the Wang PCs and the VS 80 by installing appropriate software and hardware. Data and programmes may now be transferred between these two computers.

Outreach and Training

Outreach and Training Unit

The primary goal of the Outreach and Training Unit (OTU) is to strengthen the scientific leadership and technological capability of tropical developing countries in insect science through collaborative research and training programmes. To do this, OTU draws on the scientific output of the ICIPE programmes and units and strengthens their collaboration (1) with the international scientific community so as to develop new technology in insect science and (2) with the tropical scientific community so as to transfer relevant technology to resource-poor farmers (Figure 1). The various activities of OTU are linked with each other and with the ICIPE research programmes and units and administration in supportive and interactive capacities (Figure 2).

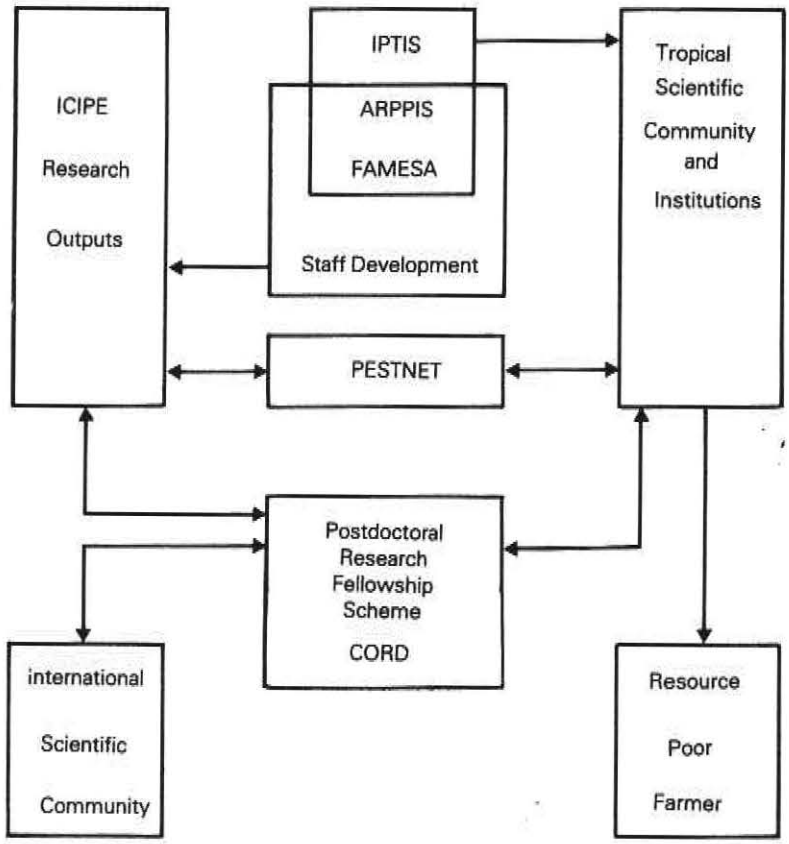


Figure 1. Links between OTU, ICIPE's research output and the international and tropical scientific communities.

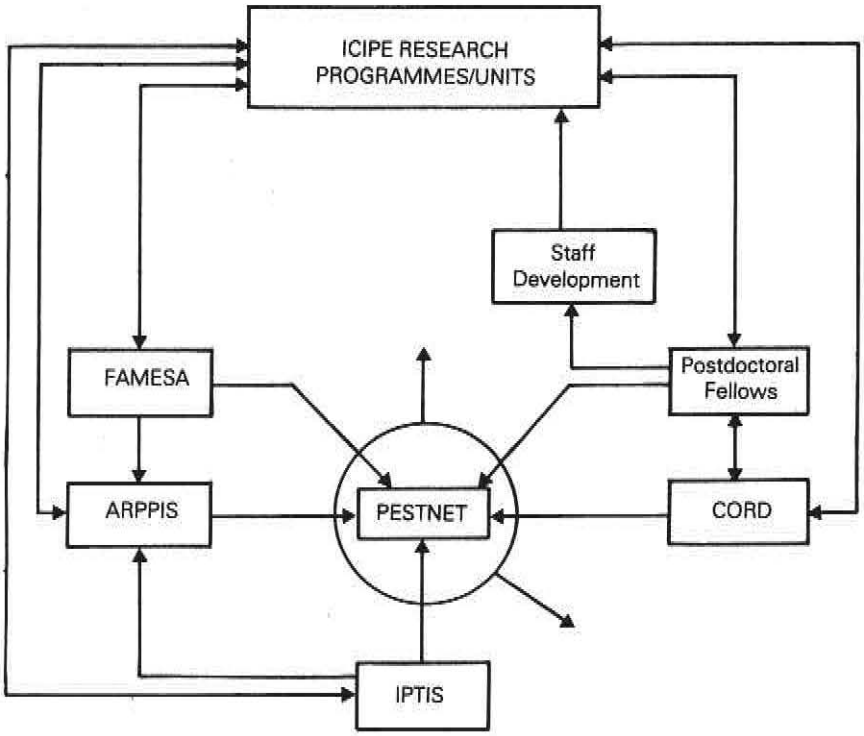


Figure 2. Links within OTU and between OTU and ICIPE's scientific programmes and units.

OUTREACH AND TRAINING PROGRAMMES

C. P. F. De Lima

PESTNET: THE AFRICAN REGIONAL PEST MANAGEMENT RESEARCH AND DEVELOPMENT NETWORK FOR INTEGRATED CONTROL OF CROP AND LIVESTOCK PESTS

At a PESTNET implementation meeting in Nairobi in June 1986, ICIPE was selected as the coordinating centre for PESTNET. The programme of work required of the coordinating centre—that is, publishing the proceedings of the implementation meeting, publishing a quarterly newsletter and circulating a draft project document to members—was completed on schedule. Representatives of national governments set the implementation date for PESTNET at 1 January 1987. ICIPE will take an active part in this implementation by helping to prepare project documents and by organizing annual PESTNET meetings to coincide with the ICIPE Annual Research Conference. The first annual PESTNET meeting will take place in April 1987.

CORD: COLLABORATIVE RESEARCH AND DEVELOPMENT

In 1986 ICIPE's programmes and units continued research work conducted under the following collaborations: the Crop Pests and Livestock Ticks research programmes with the Kenya Government, the Crop Pests Research Programme and Sensory Physiology Research Unit with the Ivory Coast Government and the Livestock Ticks Research Programme with the University of Neuchatel, Switzerland. In addition, collaborative work has started with the Biological Control Laboratory of the Chinese Academy of Sciences. Close collaboration has continued with the International Rice Research Institute, in the Philippines, and the International Institute of Tropical Agriculture, in Nigeria.

ARPPIS: THE AFRICAN REGIONAL POSTGRADUATE PROGRAMME IN INSECT SCIENCE

The Ph.D. programme received eight new students during the year. A Master of Philosophy programme was started in collaboration with Rivers State University, Nigeria, and two students began to do their M.Phil. thesis work at ICIPE. Progress was made towards establishing an ARPPIS scientific network. The first ARPPIS newsletter, *ARPPIS News*, was issued during the year.

IPTIS: INTERNATIONAL PROGRAMMES FOR SPECIALIZED SHORT-TERM TRAINING IN INSECT SCIENCE

The Ninth International Group Training Course in Components Essential for Ecologically Sound Pest and Vector Management Systems (ICIPE/International Development Research Centre) was conducted in August 1986 and the Second Training Course for Self-Reliance in Ecological Pest Management in the Tropics (ICIPE/United Nations Environment Programme) was held in November/December 1986 at the Centre Reg-

ional de Formation Phytosanitaire, in Yaounde, Cameroon. This latter course marked the first time that ICIPE conducted a course in French. In addition, the Second and Third Tick and Tsetse Management Courses (ICIPE/European Economic Community) were held in January/February and June/July 1986, respectively. Finally, a new specialized regional course on Biochemical Separation and Molecular Techniques was held in September 1986. An increasing number of specialized short-term courses are planned for 1987.

FAMESA: FINANCIAL AND ADMINISTRATIVE MANAGEMENT OF RESEARCH PROJECTS IN EASTERN AND SOUTHERN AFRICA

During 1986 FAMESA conducted one national training programme and two regional training courses. The national training programme, a workshop in research management, was held in Malawi. At the workshop trainers were taught the principles of research and development, strategic and project planning, and budgeting. The two regional workshops were on research and development facilities and materials management and on the research and development institute–constituency relationship. The FAMESA Secretariat has prepared manuals in these areas of research and development management.

PESTNET

THE AFRICAN REGIONAL PEST MANAGEMENT RESEARCH AND DEVELOPMENT NETWORK FOR INTEGRATED CONTROL OF CROP AND LIVESTOCK PESTS

C. P. F. De Lima

Following the 1985 workshop on PESTNET, an Implementation Meeting was held from 22–26 June 1986 that was attended by government representatives from nine countries in eastern and southern Africa. At this meeting a Framework of Cooperation was agreed upon regarding PESTNET's organization, linkages, research and development, training, and transfer of information. The delegates agreed that the PESTNET Secretariat, comprising a coordinator and supporting staff, should be based at ICIPE and be established by 1 September 1986 and that it should publish the proceedings of meetings and a quarterly newsletter and circulate a draft project document. This programme of work was completed on schedule. An implementation date of 1 January 1987 was set for PESTNET activities in research and development, training, and the transfer of information.

In research and development, collaboration was identified in three major areas: crop pests, with emphasis on maize and sorghum pests; livestock ticks of the genera *Rhipicephalus, Amblyomma, Boophilus and Hyalomma;* and tsetse flies *G. morsitans* and *G. pallidipes.*

In training and the transfer of information, it was agreed that short methodology courses in specialized areas and general integrated pest management courses should be held, that medium-term training should be conducted for a research associate scheme and for the Master of Science degree, and that long-term training should be conducted for the Ph.D. degree. Postdoctoral training was also considered necessary in special areas for the transfer of advanced skills. Further information exchange would be made through the publication of workshop manuals, field books, project reports and a newsletter.

Full details of these activities and the work programme are given in the proceedings of the June 1986 PESTNET meeting (*Proceedings of the International Working Group on the Implementation of the African Regional Pest Management and Development Network [PESTNET] for integrated Control of Crop and Livestock Pests, Nairobi, Kenya: 22–26 June 1986) and in the* first issue of the newsletter *PESTNET TODAY*, October 1986.

CORD

COLLABORATIVE RESEARCH AND DEVELOPMENT

C. P. F. De Lima

Collaborative research was undertaken during the year with research scientists from GERME, of the Ivory Coast, in the areas of crop pests and sensory physiology. In Kenya, collaborative work on crop borers and livestock ticks has continued. A special training project funded by the European Economic Commission on tsetse and livestock ticks was conducted in collaboration with Kenya, Zambia and Sudan.

Collaboration with international institutions involved substantial work with the University of Neuchatel, Switzerland, on livestock ticks; with the International Rice Research Institute, the Philippines, on the brown planthopper; with the International Institute of Tropical Agriculture, Nigeria, on biological control of the cassava green spider mite (research and training); and with the Economic Commission for Africa/Food and Agriculture Organization of the United Nations on reduction of food losses through integrated pest management.

Finally, collaboration in the area of biological control was established with the Biological Control Laboratory of the Chinese Academy of Agricultural Sciences, People's Republic of China, in the area of biological control of stem borers through research and training.

ARPPIS

THE AFRICAN REGIONAL POSTGRADUATE PROGRAMME IN INSECT SCIENCE

M. E. Smalley

The African Regional Postgraduate Programme in Insect Science (ARPPIS) was established in March 1983 as a collaborative postgraduate training venture be-

tween the ICIPE and a consortium of African universities. ARPPIS draws on the strengths of ICIPE and all its participating universities to train scientists for research and leadership in all areas of insect science. On graduation, the ARPPIS postgraduate scholars are expected to return to their home countries where they will contribute to building national scientific capabilities, particularly in pest and vector management.

ARPPIS currently comprises two programmes: a Ph.D. degree programme in the insect sciences and a newly introduced (1986) Master's degree programme specializing in the biological control of agricultural pests.

In February 1986 the eight Ph.D. scholars of the 1983 class completed their studies. By the end of the year two postgraduate scholars—Dr. Latif Ibrahim and Dr. Wadeeda Forawi—had successfully defended their theses; both were registered at the University of Khartoum. The remaining six postgraduate scholars had completed their work and four had submitted their theses for examination.

ARPPIS has therefore demonstrated the effectiveness of collaborative training between an international research centre and a network of universities. From 1986 onwards there will be a constant input of trained insect scientists into the national scientific and agricultural programmes of African countries.

In March 1986 the fourth ARPPIS class, comprising eight postgraduate scholars, began its studies. These postgraduate scholars, coming from Kenya, Nigeria, Tanzania and Uganda, brought the Ph.D. programme to a total of 31 participants from 9 countries (Table 1).

The 1986 class completed a six-month semester of six compulsory and examined courses, which present core areas of entomology at a higher degree level and orientate the postgraduate scholars to their research projects. Professor R. Kumar, Rivers State University of Science and Technology, Nigeria, taught "Insect Taxonomy"; Professor El Amin El Rayah, University of Khartoum, Sudan, taught "Insect Functional Morphology"; Dr. J. Allotey, Rivers State University of Science and Technology, and Dr. S. K. Firempong and Dr. C. Mutero, both of ICIPE, taught "Insect Ecology"; Dr. R. Dransfield, ICIPE, taught "Biostatistics"; Dr. W. Otieno, Dr. M. Odindo and Dr. G. P. Kaaya, ICIPE, taught "Insect Pathology"; and a team of ICIPE scientists coordinated by Dr. M. F. B. Chaudhury taught "Insect Physiology and Biochemistry".

Following the course work, the 1986 class members began their research projects. Together with members of the 1984 and 1985 classes, this resulted in 23 ARPPIS postgraduate scholars working in the ICIPE research programmes and units (Table 2). Members of ARPPIS have been well assimilated into ICIPE's research programmes and units and are regarded as scientists in their own right.

During the year ARPPIS welcomed visits to ICIPE by the university supervisors of ten postgraduate scholars: Professor M. Magzoub, University of Khartoum, supervisor of Dr. A. L. Ibrahim (1983 class) and Mrs. U. M. Elneima (1984); Professor C. W. Baliddawa, Makerere University, supervisor of Mr. S. Kyamanywa (1983) and Mr. M. Ogenga-Latigo (1984); Dr. J. M. Mueke, Kenyatta University, supervisor of Mr. J. H. Nderitu (1984); Professor R. Kumar, Rivers State University of Science and Technology, supervisor of Mr. I. Aniedu (1985) and Mr. M. Basimike (1985); Professor W. Z.

Table 1. Postgraduate scholars in the African Regional Postgraduate Programme in Insect Science (ARPPIS)

	1983	1984	1985	1986	Total
Ethiopia	—	—	1	—	1
Ghana	—	1	2	—	3
Kenya	3	3	2	4	12
Malawi	—	1	—	—	1
Nigeria	—	—	1	1	2
Sudan	2	1	—	—	3
Tanzania	1	—	—	2	3
Uganda	2	2	—	1	5
Zaire	—	—	1	—	1
Total	8	8	7	8	31

Table 2. 1984, 1985 and 1986 ARPPIS class members conducting research projects with ICIPE programmes and units

	1984	1985	1986	Total
Crop Pests Research Programme	5	—	7	12
Livestock Ticks Research Programme	1	1	—	2
Tsetse Research Programme	2	3	1	6
Medical Vectors Research Programme	—	2	—	2
Chemistry and Biochemistry Research Unit	—	1	—	1
Total	8	7	8	23

Coker, University of Ghana, supervisor of Miss D. A. Adabie (1984) and Mr. C. Kyorku (1985); and Dr V. Saka and Dr. D. Munthali, University of Malawi, supervisors of Mr. L. Kantiki (1984). Also during the year, ARPPIS postgraduate scholars were sent on study visits to their universities; members travelled to Makerere University and to the Universities of Dar es Salaam, Khartoum and Malawi.

During 1986 ARPPIS established a new graduate training programme as a component of a wider collaboration between ICIPE and the International Institute of Tropical Agriculture in the Africa-Wide Programme for the Biological Control of Cassava Mealy-Bug and Cassava Green Spider Mites (ABCP). ABCP is intended to develop biological control strategies for cassava pests, which will be appropriate for national programmes of cassava-growing countries to implement. To facilitate the implementation, ABCP is committed to training scientists from national programmes and institutes, and ICIPE is a partner in this endeavour. ABCP sponsored three members of the 1986 Ph.D. class and the establishment of a Master's programme.

ARPPIS is working in close collaboration with Rivers State University of Science and Technology, Nigeria, to produce an effective two-year Master's course for ABCP. Postgraduate scholars attend two semesters of course work at the university and then, provided they pass the examinations, travel to ICIPE to complete a one-year research project on some aspect of biological control. The university will award the Master of Philosophy degree to successful participants. Two members of the 1985–87 university class are doing research at ICIPE, and a group of four postgraduate scholars from Kenya, Uganda and Nigeria joined the 1986–88 ARPPIS class.

New developments in ARPPIS during 1986 included the purchase of visual-aid equipment and the publication of *ARPPIS News*. The visual-aid equipment, purchased with funds given by the Australian Government, includes projectors and a discussion stereo-microscope which will be used during the ARPPIS teaching semester. *ARPPIS News* will initially be published twice a year and will keep everyone within the ARPPIS network informed of news and developments.

Support for postgraduate scholars during 1986 came from the German Academic Exchange Programme, Studies in the Region Programme of the Netherlands Government, the Ford Foundation, the International Livestock Centre for Africa, the International Fund for Agricultural Development and the Organization of African Unity Scientific, Technical and Research Commission.

During the year, ARPPIS was joined by two new universities: Anambra State University of Technology, Nigeria, and Moi University, Kenya. The ARPPIS network now has a consortium of 13 African universities (Table 3).

Table 3. The participating universities of ARPPIS

Addis Ababa University	Ethiopia
Anambra State University of Technology	Nigeria
Makerere University	Uganda
Moi University	Kenya
Rivers State University of Science and Technology	Nigeria
University of Dar es Salaam	Tanzania
University of Ghana	Ghana
University of Ibadan	Nigeria
University of Khartoum	Sudan
University of Malawi	Malawi
University of Sierra Leone	Sierra Leone
University of Zambia	Zambia
University of Zimbabwe	Zimbabwe

The ARPPIS Academic Board met twice during 1986. In June the meeting was held at the ICIPE Mbita Point Field Station for the first time. The December meeting, in Nairobi, was of particular importance because it included a one-day scientific meeting and the Inaugural ARPPIS Lecture, given by Professor M. S. Ntamila, Regional Director of UNESCO, who also presented certificates to all members of the 1983 class.

During 1987 ARPPIS looks forward to the graduation of the 1984 Ph.D. and the 1985 M.Phil. classes. With that successfully achieved, 18 young scientists will have trained in ARPPIS and returned to their home countries. An ARPPIS Scientific Network of graduated scientists will have been established and will continue to offer intellectual and financial help so that the scientists are encouraged and supported to develop their careers in Africa rather than leave the continent.

POSTDOCTORAL RESEARCH FELLOWSHIP

During 1986 seven postdoctoral scientists from five countries were resident at ICIPE. Dr. S. A. Tarimo, from Tanzania, was attached to the Tsetse Research Programme; Dr. S. K. Firempong, from Ghana, and Dr. J. Bartkowski, from Poland, worked at Mbita Point Field Station with the Crop Pests Research Programme; Dr. J. Jondiko, from Kenya, and Dr. S. Essuman, from Ghana, were in the Chemistry and Biochemistry Research Unit; Dr. M. E. Hussein, from India, continued to work in the Sensory Physiology Research Unit; and Dr. W. Jura, from Kenya, joined the Histology and Fine Structure Research Unit.

IPTIS

INTERNATIONAL PROGRAMMES FOR SPECIALIZED SHORT-TERM TRAINING IN INSECT SCIENCE

J. F. Omange

International Group Training Course on Components Essential for Ecologically Sound Pest and Vector Management Systems

The ninth course in this series was conducted at ICIPE from 10 to 29 August 1986. Twenty-eight trainees from 12 tropical developing countries participated in the course. For the first time, the main sponsor for the course was the International Development Research

Table 4. Regional distribution of participants in the nine sessions of the International Group Training Course on Components Essential for Ecologically Sound Pest and Vector Management Systems

Tropical regions	Countries of origin	Participants per year									
		1977	1978	1979	1980	1981	1982	1984	1985	1986	Total
Africa	22	14	25	22	22	26	23	26	24	26	208
Asia	6	1	2	3	1	2	2	—	2	—	13
Middle East	5	—	4	1	1	2	1	1	—	—	10
Latin America	3	—	2	1	1	2	1	1	2	2	12
Total	36	15	33	27	25	32	27	28	28	28	243

Centre. To date 243 participants have benefitted from this course series (Table 4).

Training for Self-Reliance in Ecological Pest Management in the Tropics

Collaboration among ICIPE, the United Nations Environment Programme and the Regional Phytosanitary Training Centre, in Yaounde, Cameroon, continued this year and resulted in the staging of this course at Yaounde from 15 November to 5 December 1986. The course was conducted in French, and this marked the first time ICIPE had run a course in a language other than English. The twenty participants, who successfully completed the course, were from Cameroon, Guinea Bissau and Guinea. The course content was an improvement on the content of the 1985 Integrated Pest and Vector Management Course that had been offered in English at the same venue for participants from Ghana, Liberia, Sierra Leone and English-speaking Cameroon.

New places of interest visited during field excursions included the Louis Pasteur Institute, in Yaounde, and the Veterinary Research Station at Bambui, near Bamenda (Figures 3, 4, and 5).

ICIPE/European Economic Commission Courses on the Management of Vectors for the Control of Trypanosomiasis and East Coast Fever in Livestock Production

Three courses were conducted under this series during the year for participants from Kenya, Sudan and Zambia. The first of these was a Tick Management Course held from 12 January to 28 February. Eleven participants successfully completed this course, which was on all aspects of tick management and involved lectures, demonstrations, practicals and excursions.

From 28 June to 28 July two courses in the series were conducted concurrently, with emphasis on practical aspects of tsetse and tick management: Practical Tsetse Management Course and Practical Tick Management Course. Due to lack of space, each course was offered for only three participants, one from each of the participating countries.

This course series on tsetse and tick management has been so popular with participants that it has been recommended that it be continued and expanded so that it is open to people from other countries in Africa.

Figure 3. IPTIS course participants take benchmark examination at the beginning of the course.

Figure 4. IPTIS course participants examining specimens during a laboratory session.

Figure 5. Award of certificate of successful course completion to a participant during the closing dinner ceremony of an IPTIS course.

Joint ICIPE/Pharmacia Course on Biochemical Separation and Molecular Biology Techniques

This new course was held for the first time at ICIPE, at the Chiromo campus, from 8 to 13 September. It was presented jointly by scientists from Pharmacia Biotechnology Institute, Uppsala, Sweden, and from ICIPE.

Twenty-three participants from eastern and central Africa took part. The course covered both theory and practicals, with the practicals being conducted at the laboratories of the Biochemistry Department of the University of Nairobi.

The course content covered the following areas:

- *Column chromatography:* gel filtration, ion-exchange, chromofocusing, hydrophobic interaction and affinity techniques, fast protein liquid chromatography (FPLC), with practical work on manual and automated FPLC.
- *Electrophoresis*: polyacrylamide gel electrophoresis (PAGE), isoelectric focusing, with practicals on

PAGE gradient gels and electrophoretic titration curves.

- *Molecular biology:* practicals on restriction enzyme digestion of DNA, electrophoresis and hybridization with a radiolabelled probe.

STAFF DEVELOPMENT TRAINING

Specialized training was given to ICIPE staff members both locally and overseas. Table 5 shows the breakdown of those who undertook staff development training during the year.

Table 5. ICIPE staff members given specialized training

Scientists	7
Technicians	11
Administrators	5
Secretaries	1
Total	24

FAMESA

FINANCIAL AND ADMINISTRATIVE MANAGEMENT OF RESEARCH PROJECTS IN EASTERN AND SOUTHERN AFRICA

L. O. Abe

During 1986 FAMESA continued its activities on curriculum development and delivery of training courses under the FAMESA theme "Management for Productive Research and Development". Two curricula areas were chosen: (1) research and development institute facilities and materials management and (2) the research and development institute–constituency relationship.

Research and Development Institute Facilities and Materials Management

Following field work conducted in 1985 to assess the needs of research and development institutes in eastern and southern Africa for facilities and materials management, the project concentrated on preparing and validating basic curriculum.

Curriculum development

The basic curriculum and training manual were written in coliaboration with one international and four regional consultants. Among the topics covered in the training manual are strategic facilities and materials management, procurement, land, buildings, equipment and materials.

Validation workshop

From 21 July to 1 August FAMESA held a workshop to validate curriculum on Research and Development Institute Facilities and Materials Management. This curriculum constitutes series II of FAMESA's Management for Productive Research and Development.

A total of 15 people who work in supplies, maintenance and personnel administration departments in research and development institutes in eastern and southern Africa participated in the workshop. The participants included:

Mr. C. Chanda, Administrative Officer, National Council for Scientific Research, Zambia

Mr. Lucas O. Gongo, Research Officer, Kenya Industrial Research and Development Institute, Kenya

Mr. H. Inyundo, Senior Supplies Officer, Kenya Industrial Research and Development Institute, Kenya

Mr. J. Kiara, Senior Research Officer, Coffee Research Foundation, Kenya

Mr. G. K'Owino, Supplies Officer, Kenya Medical Research Institute, Kenya

Mr. B. Mariam, Head, Procurement and Supplies Officer, Institute of Agricultural Research, Ethiopia

Mr. S. Malililino, Administrative Secretary, Malawi Bureau of Standards, Malawi

Mr. C. Nyamadambo, Chief Technical Officer, National Council for Science and Technology, Zambia

Mr. D. Olalo, Storekeeper, ICIPE, Kenya

Mr. D. Waugh, Regional Controller, International Development Research Centre, Kenya

There were two resource persons as well:

Dr. J. Nollet, Ecole des Hautes Etudes Commerciales, University of Montreal, Canada

Mr. I. Temba, Lecturer, Institute of Development Management, Tanzania

Among the achievements of the workshop was an extensive review of the draft curriculum, on which a manual will now be based. The participants were also able to acquire more information on the subject of research and development institute facilities and materials management. It is hoped that these participants will eventually form the core of trainers required by FAMESA. In evaluating the impact a training programme using this manual could have on their research and development institutes, participants stated that training in the following areas would improve their service:

- Procuring supplies and keeping stores
- Reorganizing and restructuring supplies procedures
- Updating inventory of facilities, materials and equipment
- Preparing schedules of maintenance, including grounds and buildings
- Strengthening the audit sections of research and development institutes

The Research and Development Institute-Constituency Relationship

From 20 June to 10 July 1986, FAMESA held a workshop to validate curriculum on the research and development institute–constituency relationship. The workshop, sponsored by the Ford Foundation, was held at the ICIPE Duduville International Guest Centre, in Nairobi.

Participants at the workshop included:

Mr. G. Tibakweitira, Principal, Institute of Development Management, Tanzania

Dr. F. Banda, Director, Malawi Bureau of Standards,

Malawi

Mrs. E. Mede, Secretary, National Research Council, Malawi

Mr. M. K. Gao, Director, Tsetse and Trypanosomiasis Research Institute, Tanzania

Captain Ayele Haile, Manager, Ethiopian Management Institute, Ethiopia

Dr. D. Jones, Director, Agricultural Research Division, Crown Agents, United Kingdom

Dr. R. Arunga, Director, Kenya Industrial Research and Development Institute, Kenya

Dr. R. Jones, Director, National Agricultural Research Coordinating Council, Ministry of Agriculture, Sierra Leone

Mr. Lennard Okola, Manager, Administration and Information Division, ICIPE, Kenya

Dr. Z. Nyiira, Principal Research Scientist and Manager, Mbita Point Field Station, ICIPE, Kenya

Dr. A. Hassanali, Head, Chemistry and Biochemistry Research Unit, ICIPE, Kenya

Dr. J. Omuse, Senior Science Secretary, National Council for Science and Technology, Kenya

Dr. W. Opile, Director, Coffee Research Foundation, Kenya

Miss R. Washika, Principal Communications Officer, ICIPE, Kenya

Dr. L. Abe, Coordinator, FAMESA, ICIPE, Kenya

The topics discussed included:

- Determining the needs of research and development institute constituencies
- Consequences of ignoring research and development constituencies
- Disseminating results from research and development institutes
- Research and development institute extension services
- Marketing and commercializing output from research and development institutes
- Protecting innovations from research and development institutes
- Formulating and interpreting contractual agreements
- Social accountability for research

FAMESA has completed a manual—*Management Manual for Productive R & D Institute–Constituency Relationship*—based on these topics for use by research and development institutes in in-country training programmes.

National Training Workshop on Research Management

The first national training workshop on Research and Development Strategic and Project Planning and Budgeting was convened by the National Research Council of Malawi and was jointly organized by the Malawi Bureau of Standards and FAMESA on behalf of ICIPE. Malawi thus became the first recipient of a national course offered under the auspices of FAMESA for the development of management skills in national research and development institutes.

The workshop was held at the Grand Beach Hotel, Salima District, Malawi. The course programme was divided into a training of trainers workshop and a national training workshop. The workshop was officially opened by Dr. F. M. Banda, Director, Malawi Bureau of Standards, and closed by Mrs. Esther Mede, Secretary to the National Research Council of Malawi, Office of the President, Government of Malawi.

Training of trainers workshop

The objectives of the training of trainers workshop were:

- To familiarize the trainers with the curriculum developed by FAMESA
- To demonstrate and teach appropriate pedagogical techniques
- To design a curriculum-based workshop for the national training workshop

Seven trainers selected from universities, national research institutions and statutory bodies were used. Each trainer was allocated a topic from the *Management Manual for Productive R & D: Strategic and Project Planning and Budgeting*. Two FAMESA consultants—Dr. Fletcher M. Banda, Director of Malawi Bureau of Standards, and Dr. Luka Abe, FAMESA Coordinator—conducted the training of trainers workshop.

National training workshop

Twelve senior-level staff members representing universities, national research institutes of agriculture, forestry, surveying, parks and wildlife, and the Council of Science and Technology attended the workshop. The objectives of the national training workshop were:

- To increase responsiveness of research and development institutes to the needs of their countries and eastern and southern Africa
- To improve the allocation of scarce human and material resources
- To improve links between national research and development institutes, policymakers, statutory bodies (parastatals) and industry
- To improve the skills, knowledge and attitude of research and development managers

The expected outcomes were stated as follows:

- A better understanding of the management process in research and development institutes
- An increased awareness of the relationship between research and development institutes and their environment
- A better understanding of the needs, processes and implementation of strategic planning
- Improved project management, with emphasis on planning, budgeting and monitoring
- Information on how to train others in the research and development institutions

Evaluation of the national training workshop

Participants were requested to complete a 12-item questionnaire, which asked for their reactions to aspects of the workshop. The questions were asked to assess:

- The degree to which workshop expectations and objectives were fulfilled

- The scheduling of the workshop
- The effectiveness of the teaching by trainers
- The usefulness of the manual, that is, the importance, adequacy and relevance of its topics

Objectives of the workshop. Up to 64% of the participants said that the general objectives of the workshop were fully achieved, while 34% believed these were only partially met. But 94% said their expectations for the workshop, in terms of acquiring skills and knowledge and of having their attitudes changed, were fulfilled; only 6% said their expectations were not fulfilled.

Duration and volume of work. It is possible that the 35% who stated the workshop objectives were only partially met believed the period was too short and the volume of work too heavy.

Effectiveness of trainers. The trainers were praised for their ability to stimulate, motivate and guide the trainees.

The manual. The manual and training materials were rated excellent and all participants stated they would recommend the manual for use in their institutions.

All participants requested that they be kept active in FAMESA.

Recommendations and plans

The success of this workshop, which represents the first FAMESA national training venture, attests to the demand and need for research and development management training. The National Research Council of Malawi expressed keen interest in promoting further efforts in research and development management training. The publicity given to the course, on the radio and in the daily newspaper in Malawi, is further testimony to how serious the Malawi Government views the need for skills training in research and development management. The National Research Council, in consultation with FAMESA, is drawing up plans for more training in Malawi.

Malawi now has curriculum trainers for research and development strategic and project planning and budgeting; furthermore, FAMESA has been able to expand its pool of consultants and trainers in eastern and southern Africa. Further efforts will be made by FAMESA to consolidate and strengthen the roles of trainers.

Several suggestions and modifications proposed during the workshop will be used to tailor the manual for Malawi. For example, the manual lacks adequate Malawi case studies. FAMESA trainers cited three cases that could be developed: strategic planning for agricultural research in Malawi, budgeting for engineering research at the polytechnic and research proposal formulation at Chancellor College. FAMESA may recommend that each of the trainers develops a case study on these topics.

Conclusion

FAMESA plans to intensify its activities, particularly in delivering training courses to national research systems. Efforts will also be made to prepare relevant case studies to support the manual.

Collaborative Research Project
Social science interface research **129**

Collaborative Research Project

In 1985 ICIPE, in collaboration with the Rockefeller Foundation, initiated a research project to study factors in the interface between the biological and social sciences that cause constraints to crop and animal production among resource-poor farmers in Kenya. Results from this collaborative Social Science Interface Research Project (SSIR) will provide ICIPE researchers with information on some of the traditional agricultural practices of small Kenyan farmers so that ICIPE scientists may help those farmers improve their productivity. The specific question SSIR is addressing is how ICIPE may bring its skills and expertise in basic biological research and pest management technology to bear on food security and income generation, the two priorities of resource-poor farm households. Late in 1985, the International Food Policy Research Institute sponsored a postdoctoral fellow to work with ICIPE on a study on intercropping sugar cane and food crops.

SOCIAL SCIENCE INTERFACE RESEARCH

A. Pala Okeyo

The SSIR office coordinates a project titled "Food Security and Production Constraints at the Household Level". Our first efforts have been to develop an interdisciplinary research strategy that integrates social science perspectives, particularly those of anthropology, with the research programmes of ICIPE. Social scientists in the project have been involved in both testing field work and designing research with ICIPE's biological scientists.

ICIPE, the Rockefeller Foundation and the International Food Policy Research Institute finance both substantive research and the personnel costs of the project. The Rockefeller Foundation has so far provided the major support for the programme. As host, ICIPE provides the research facilities needed for the study.

ICIPE also provides a unique demonstration of a technology-generating scientific institute located in Africa that conducts research aimed at increasing food production by reducing food losses due to pests. Despite its significant advances in pest and vector management, ICIPE has realized that successful adoption of its recommendations depends not only on high-quality science, but also on making the technology it develops and advocates economically and technically practical and feasible for the smallholder farmers in Africa.

SSIR works in collaboration with ICIPE's Crop Pests and Livestock Ticks research programmes at three study sites in Kenya. The project explores national agricultural policy and the options available for scientific and policy interventions in small-farm production; it aims to determine the efficacy of the agricultural technology developed by ICIPE and the chances of that technology being accepted by Kenya's small-scale farmers.

Given the policy of the Kenya Government to ensure an appropriate balance between food and non-food crops in the economy, a major focus of this research project is to identify cropping combinations that can be tested in the field and that take into account smallholders' cash and food objectives and farm conditions. SSIR thus combines results from field studies on intercropping with its own investigations into the social practices of agriculture.

At the Seme (Kisumu) study site the project team, comprising an agronomist and an anthropologist, is investigating the effect of intercropping cotton with the major food crops of the area—sorghum, maize, cowpea and beans—on pest populations and yields. Three experimental plots have been established to test three intercropping combinations: cotton/sorghum, cotton/beans and cotton/maize. In two other experiments we

are examining the performance of the sorghum/cowpea crop combination, which at ICIPE has shown positive field results in suppressing pest populations. Our research has identified several production constraints that are partly determined by social constraints, such as equipment available for preparing land for cultivation, quality of seed or planting materials, the cropping calendar, plant populations and soil fertility. For example, plant populations recommended by ICIPE's field stations tend to be too high for successful duplication on farmers' fields, given the farmers' labour constraints and poor soil fertility. Further research will determine the optimum stand in an intercropping system.

Additional detailed surveys will be carried out on the farmers' access to and control of agricultural resources and on their investment priorities and risk management strategies. Responses to these surveys will help us to assess the farmers' awareness and experience of constraints to improving their agricultural production. These data will form the basis for modifying and adjusting ICIPE's pest management strategies.

At the Awendo (South Nyanza) study site, where ICIPE is collaborating with the Rockefeller Foundation and the International Food Policy Research Institute, two experimental plots have been established near the South Nyanza Sugar Factory to test different patterns of intercropping sugarcane with such food crops as Katumani maize, Mwezi Moja beans and local varieties of cowpeas and groundnuts. Both trial plots and farmer-managed intercropped plots are monitored to identify and quantify pest populations, to measure plant sizes and to assess weed growth and plant diseases. Preliminary investigations show the cane/bean combination to be the most compatible of the intercropping pairs.

In addition, detailed agricultural/social science surveys have been carried out on a sample of eighty farm households in the area. Interviews have been conducted on many aspects of agricultural production, including patterns of time allocation and labour input, grain storage habits and estimates of storage losses, knowledge of insect pests, and local intercropping practices. Data from these surveys have helped to modify the structure of the field experiments, making them more sensitive to farm conditions. For example, changes were made in the crop mix and the time of planting in the field trials.*

SSIR and ICIPE's Livestock Ticks Research Programme began in October 1986 to explore the socio-economic bases of livestock production on Rusinga Island, in Lake Victoria. The aim of this project is to assess the island's livestock production in the context of the island's economy so as to develop appropriate technology for improving the livestock (especially cattle) management on the island through more efficient tick control methods.

Together with ICIPE's Crop Pests Research Programme and the United Nations Economic Commission for Africa, SSIR is working on the "Joint ICIPE/ECA Project on Reduction of Food Losses through Insect Pest Management and Use of Small-Scale and Low-Cost Farm Equipment in Africa". This project is based in Oyugis and Kendu Bay (South Nyanza).

**Results of the work of the agronomist and anthropologist working at the Seme study site and of the anthropologist working at the Awendo study site will be reported in the* ICIPE 1987 Annual Report.

Administration and Information

Administration and Information Division

Since January 1986 the two divisions of (1) Administration and (2) Communication and Information have been merged to form the present Administration and Information Division. The new division is divided into four departments: (1) Human Resources, (2) Administrative Services, (3) Publishing and Documentation and (4) Communication Services. In addition the Division is responsible for Capital Development and the International Guest Centre System, while on policy issues the Principal of Mbita Point International School also reports to the Manager for Administration and Information.

Among the highlights of 1986 were the 17th Annual Research Conference, from 26 to 30 April; the official opening of Mbita Point Field Station by His Excellency President Daniel T. arap Moi on 7 August; the Foundation-Stone-Laying for the new ICIPE Headquarters Complex at Kasarani, Duduville Capital Development Programme Phase II, by the Director-General of the OPEC Fund for International Development, Dr. Y. Seyyid Abdulai, on 12 September; the Second Triennial Review of ICIPE from 4 to 18 October; and the signing of the ICIPE Charter on 27 November. The Administration and Information Division played a critical and often leading role in all these important events.

THE ICIPE CHARTER

On Thursday 27 November 1986, at a Meeting of Plenipotentiaries held at the Kenyatta International Conference Centre and chaired by the United Nations Development Programme Resident Representative in Kenya, Mr. Gian L. Pennacchio, a new ICIPE was born. Kenya, the host government, and Zambia signed a Charter converting ICIPE into an intergovernmental organization with full international status. Côte d'Ivoire initialled the Charter, pending actual signature at a later date. Other countries that attended the Meeting of Plenipotentiaries were Korea, the Netherlands, Norway, the Philippines, the Sudan and Sweden.

The old legal framework, under which ICIPE was registered as a private company under the Laws of Kenya, had built-in constraints that made the Centre's operation as an international research and training institution cumbersome. This became increasingly obvious as ICIPE entered into collaborative arrangements with national programmes outside the host country. For example, ICIPE is already working in the Philippines, but owing to its lack of an internationally recognized legal status, it has had to operate under the umbrella of the International Rice Research Institute (IRRI). Agreements at the governmental level have been signed with Côte d'Ivoire, Somalia and Uganda. Further collaborative research and training agreements have been signed with institutions in Kenya, Brazil, China, Cameroon, Tanzania, Uganda, Burundi, Ethiopia, Sierra Leone, Malawi, Nigeria, the United Kingdom, West Germany, Sweden, the USA and Switzerland. The full implementation of these agreements raises the question of ICIPE's legal status, and as a result it became imperative for the old ICIPE to give way to a new juridical entity that would be recognized internationally. This was achieved with the signing of the ICIPE Charter on 27 November 1986, and the Centre is now international both functionally and legally.

The Charter provides for a Governing Council, established by the Founding Subscribers, as the main policy organ of ICIPE. The functions and responsibilities of the Governing Council include:

- Selecting, appointing and terminating the appointment of the Director of ICIPE
- Securing funding for ICIPE through the Sponsoring

Group for the ICIPE (SGI) and other supplementary sources, but with the Director retaining responsibility for coordinating all fund-raising activities
- Formulating policies for the scientific programmes and the management of the Centre
- Reviewing and approving the Centre's budget and auditing the accounts
- Approving capital development programmes of the Centre
- Approving financial regulations and staff regulations of the Centre
- Electing new members of the Council
- Appointing the Executive Board

As was the case with the old Governing Board, Council members are selected for their experience and expertise in relevant disciplines and professions, with due regard to geographical distribution.

Among the functions and responsibilities of the Executive Board is the establishment of a Programme Committee, which shall be responsible for the formulation of policies regarding the scientific, educational and training programmes of ICIPE.

The Charter safeguards ICIPE's independence and autonomy.

CAPITAL DEVELOPMENT

Mbita Point Field Station

During the year Phase II of Mbita Point Field Station was completed. This comprises an international guest centre complex, a one-bedroomed apartment block and extensions to both St. Jude's Clinic and Mbita Point International School. Apart from minor work and expansion that may be necessary in the future, the Field Station is now almost at its optimum physical size.

Duduville Phase II

The tender for contract 1 of Duduville Capital Development Programme Phase II was awarded to Mowlem Construction Company Limited in June 1986, and the ground was broken on 1 July. The contract covers all the laboratories, insectaries and animal breeding units, the maintenance workshops, estate services, medical clinic and central stores. By the end of the year construction work was going according to schedule and the contractor's estimate of 63 weeks for completion looked reasonable.

Contract 1, valued at approximately KSh. 78 million, does not include complexes for the administration, the Outreach and Training Unit, the library, the editorial and publishing unit and the conference centre. Funding for these remaining complexes, as well as for extension of the existing Duduville International Guest Centre, is still being sought, and it is hoped that the entire Duduville Capital Development Programme will be completed prior to ICIPE's 20th anniversary in 1990.

SENIOR MANAGEMENT

With the appointment of Professor Dean L. Haynes, from Michigan State University, as Deputy Director with effect from July 1986, the Centre's senior management team is now again at full strength. There were no other changes during the year, and all the research programmes and research support units remained under the leadership of substantive appointees.

SECOND TRIENNIAL REVIEW

The Second Triennial Review of ICIPE took place from 4 to 18 October 1986 under the chairmanship of Professor Dr. Werner J. Kloft, of the University of Bonn. The Review team was greatly impressed with the progress that has been made at ICIPE since the First Triennial Review in 1983, and has already submitted its report to both the Sponsoring Group for the ICIPE (SGI) and ICIPE management.

COMMUNICATION SERVICES DEPARTMENT

R. Washika

16th Annual Research Conference

The 16th Annual Research Conference, held from 20 to 23 April 1986 at ICIPE's Duduville International Guest Centre, attracted a record crowd of over 200 participants drawn from the scientific and donor communities associated with ICIPE's research and training activities. Participants also included policy makers and administrators from the region interested in scientific research and development programmes.

The Conference focused on the Tsetse Research Programme and the Bionomics and Applied Ecology activities of the Crop Pests Research Programme. The rest of the Centre's research and training activities were presented in poster sessions.

For the traditional Annual Research Conference guest lecture, ICIPE was honoured by the presence of Dr. Montague Yudelman, a staunch supporter of ICIPE since its founding and one of the chief architects and the first chairman of the Sponsoring Group for the ICIPE. Dr. Yudelman, backed by a wealth of experience in agricultural development from his long tenure as Director for the Agriculture and Rural Development Department of the World Bank, presented a well-researched lecture entitled "Forty Years of Agricultural Development, 1945–1985".

Dr. Yudelman, who was accompanied by his wife, also presented the 1986 Medal for Innovative Research to Mrs. Mary L. A. Owaga for innovative research on animal scent as an attractant to trap tsetse. Dr. Yudelman was one of the founders of this award scheme.

At a separate function during the Conference, a cross-section of Conference participants, members of the ICIPE Governing Board and senior ICIPE staff met and interacted over dinner with a distinguished delegation of members of the Scientific Council for Africa, a high-level scientific policy advisory organ of the Organization of African Unity, which was meeting in Nairobi during this period.

International Study Workshops and Conferences

Neem Conference

ICIPE hosted and joined the University of Giessen, West Germany, in the organization of the Third Neem Conference held at Duduville International Guest Centre in July 1986. The Conference was funded by the German Agency for Technical Cooperation. 75 participants from 21 nations attended the Conference.

For the last five years field trials have proved the potentiality of neem. Such trials include the well-known large-scale field trials by ICIPE's Professor R. C. Saxena at the International Rice Research Institute, the Philippines, using neem extracts to spray on rice pests and neem cake blended urea as a slow-release nitrogen fertilizer. One of the major recommendations of this conference was that aid agencies should support all activities, from research to applications, in the production of neem products, particularly in developing countries where neem trees are abundant.

International Conference on Tropical Entomology

ICIPE played a leading role in the organization and staging of the First International Conference on Tropical Entomology, held in Nairobi from 31 August to 5 September 1986. Under the chairmanship of Professor Thomas R. Odhiambo, a National Organizing Board, consisting of representatives of all institutes and organizations in Kenya interested in tropical entomology, worked tirelessly for almost 12 months to complete arrangements for a conference whose success was later hailed as a milestone in the history of entomology in the tropics.

About 350 entomologists attended, representing more than 60 countries. The Council of the International Congresses of Entomology, the body that proposed the idea of holding a conference in the tropics focusing on tropical entomology, was represented by four of its members.

Thirteen symposia comprising invited papers, an impressive poster session, numerous contributed papers and four plenary sessions were part of the week's scientific activities. This was complemented by a well-planned social programme that included visits to game parks, cultural centres in Kenya and a reception and banquet presided over by senior Kenya Government cabinet ministers.

A major recommendation supported by all present was that the Council consider holding conferences on tropical entomology on a regular basis in suitable venues in the tropics.

National Seminar on Germplasm Conservation and Seed Technology

On 13 August 1986 ICIPE, in collaboration with Kenya's Ministry of Agriculture and Livestock Development and Ministry of Foreign Affairs, organized a one-day seminar devoted to reviewing the status of germplasm conservation in Kenya with a view to developing a national policy on the use of this national genetic resource for development.

The Seminar was attended by over 50 key scientists, administrators and policy makers representing government ministries, the African Academy of Sciences, universities in Kenya, the National Museums of Kenya, the Agricultural Development Corporation, the Kenya Seed Company, and the Kenya Rural Enterprise Programme, the aid agency that generously provided funds for the staging of this Seminar. Kenya's Director of Agriculture, Mr. S. N. Muturi, presented the main paper while Kenya's Permanent Secretary of Foreign Affairs, Mr. B. Kiplagat, and the Chairman of the African Academy of Sciences, Professor Thomas R. Odhiambo, gave introductory speeches.

Among the main recommendations were: to organize training at all levels in germplasm conservation, to organize seminars/workshops to consider specific aspects of germplasm conservation, to establish a major national centre for germplasm conservation, to mobilize public awareness in conservation issues and to formulate clear policies and laws to safeguard local initiatives in this area.

Visitors

The Centre received a wide variety of visitors, ranging from His Excellency the President of Kenya, Daniel arap Moi, accompanied by most of his cabinet ministers, to representatives of ICIPE donors and diplomatic missions in Kenya, university students and staff and individual guests. Some of the visits took in the field station at Mbita Point while others included ICIPE's research sites at Nguruman, Marigat and West Pokot.

Among the distinguished visitors received in 1986 were the following.

- His Excellency the President of Kenya, Daniel arap Moi, officially opened the Mbita Point Field Station on 8 August 1986.
- Dr. Y. Seyyid Abdulai, Director-General of the OPEC Fund for International Development, Vienna, officiated at the Foundation-Stone-Laying Ceremony for Duduville Capital Development Programme (Phase II) on 13 September 1986.
- Professor Adebayo Adedeji, Executive Secretary of United Nations Economic Commission for Africa, accompanied by senior ECA staff, visited the Centre on 23 October 1986 to familiarize himself with ICIPE's programmes of research and training.
- His Excellency Dr. J. Diesel, Ambassador of the Federal Republic of Germany to Kenya, spent an afternoon at ICIPE on a familiarization tour.
- A two-man mission from the African Development Bank in Abidjan, Ivory Coast, spent three days at ICIPE in November to explore areas of possible collaboration between the Bank and ICIPE.
- Over ten Kenyan ambassadors/high commissioners accredited to various missions abroad visited Mbita Point Field Station in August to acquaint themselves with ICIPE's contribution to development activities. His Excellency Mr. C. S. Mageto, Kenya's Ambassador to the USA, later visited the ICIPE headquarters in

Nairobi for wide-ranging discussions with ICIPE's senior management staff.

- Professor Nils Chr Stenseth, Chairman of the Zoology Department at the University of Oslo, Norway, visited ICIPE and most of its research sites in May 1986.
- Professor T. Hidaka, of Kyoto University, Japan, a long-standing supporter of ICIPE and a former chairman of the ICIPE/Japan Association, spent about four days at ICIPE.
- Dr. Robert Armstrong, Chief of the Agricultural Division of the United States Agency for International Development in the Regional Economic and Development Services Office for Eastern and Southern Africa, and Mr. Leo Arao, the Division's new Pest Management Adviser, visited ICIPE in September 1986.
- Dr. Hiromitsu Takizawa, Executive Director of the Japan Society for Promotion of Science, visited ICIPE in May 1986.
- Delegates to the International Conference on Tropical Entomology in September 1986; to the International Conference on Drought, Desertification and Food Deficit in Africa in June 1986; and to the Third Neem Conference in July 1986, visited ICIPE.
- Dr. John Monyo, Executive Secretary of the Technical Advisory Committee of the Consultative Group on International Agricultural Research, visited ICIPE in May 1986 to acquaint himself with the scope and mode of collaboration/cooperation that exists between ICIPE and other international agricultural research centres.

PUBLISHING AND DOCUMENTATION DEPARTMENT

In an effort to modernize its typesetting facilities, the Centre has acquired a CRTronic 150 phototypesetter, which has been interfaced with a Wang Word Processor. These facilities will be improved even further in the near future, and the Publishing and Documentation Department hopes to take full advantage of the powerful new computer system being planned for the Centre, which will make desk-top publishing possible and cost-effective. In the meantime, the Department's aim is to be self-sufficient in both typesetting and graphics, as these have been identified as major bottle-necks in non-commercial science publishing, especially in Africa.

During the year the Department produced the *1985 Annual Report* and the *ICIPE Profile*, and also launched the ICIPE Science Press Guest Lecture Series with the publication of Victor Rabinowitch's reminiscences of ICIPE, *Lessons from History*, which became an instant success. Production of *Dudu*, the quarterly newsletter, also continued, though with less regularity than usual owing to a number of intractable problems. It is hoped that from next year, with better facilities and more staff, the publishing programme will be strengthened and the Centre's periodical publications will be published on schedule.

A novel initiative in dissemination of research results came from Mr. Charles Creekmore, a UN volunteer science writer, who introduced a feature service targeted at the international news media. Although it is too early to judge the outcome, Mr. Creekmore's long experience in science journalism has already added a new dimension to the Centre's dissemination efforts.

Arrangements were concluded during the year for the ICIPE Science Press to take over the publication and distribution of *Insect Science and Its Application* from Pergamon Press with effect from January 1987.

Scientific Editorial Unit

T. R. Odhiambo, S. W. Mwanyoky, E. A. Opere

Insect Science and Its Application is the backbone of the Scientific Editorial Unit. This bimonthly journal is in its seventh volume this year, reaching a pagination of 808. The pagination planned for the year was 840.

This year the unit published a special issue of the journal—Volume 7, Number 3—on the Proceedings of the VII International Congress of Protozoology. The guest editors for this issue were Dr. P. R. Gardiner, of the International Laboratory for Research on Animal Diseases, and Dr. L. H. Otieno, of ICIPE.

The *Insect Science and Its Application* journal and the *Current Themes in Tropical Science* book series have been published by Pergamon Press Limited since their initiation in 1980. Since then, the requests for volumes in the book series have by far surpassed their print-runs. The number of subscribers to the journal is still low, and every effort will be made in the future to increase the subscriptions.

Negotiations and plans are under way to have the journal and the book series published, marketed and distributed by the ICIPE Science Press, which is a new entity recently established by ICIPE, from early 1987. Arrangements are being made for the uninterrupted publication of the journal and the high editorial and production standards already set will be maintained.

Two promotion leaflets, one for the journal and another for the book series, have been prepared for the promotion and marketing of these two publications. Similar promotion will be given to all publications that the ICIPE Science Press produces in the future.

This is an exciting new endeavour, with new challenges, and we look forward to suggestions and proposals from the ICIPE community and the wider reading public beyond.

Library and Documentation Services

N. Nsubuga, R. P. Ortega, M. Mathai

The goal of the Library and Documentation Services continued to be that of providing a strong information and documentary base for ICIPE's research activities. During 1986, however, the major thrust in activity was computer application and the strengthening of the reference and periodicals collections.

Computer application
Work was started to put the library catalogue data, the ICIPE publications list and the user profiles on to computer. We used a Wang PC acquired for the then Communication and Information Division at the end of 1985. Although we had less time than we needed on the machine, we input about 65% of the above-mentioned files' records and started running them alongside their manual counterparts.

Acquisition
The library acquired 235 books, about 20% of which went to strengthen the reference collections at the main library in Nairobi and at the Mbita Point Field Station branch. Journal subscriptions, which were reviewed and vetted for pertinence, increased in number. There were ten new subscriptions, which brought the total to 100 titles. Another 40 titles were received through donations and exchange subscriptions to make the total number of current titles 140. In addition, 47 offprints of articles by ICIPE scientists were collected.

Archives
Processing and indexing the archival collection, set up at the end of 1985, continued and followed a department-by-department approach. Although some departments were yet to be covered, the archives opened for service in September 1986.

Publications
The library continued to issue its quarterly *Library and Documentation Bulletin*. All four issues for the year were published on schedule and helped increase staff awareness of publications available in the library. A *Library and Documentation Guide* to introduce the various aspects of ICIPE's library service was also published.

Services
Keeping ICIPE staff aware of the library's offerings continued to be a main objective of the library and documentation services. Besides the quarterly bulletins mentioned, selective dissemination of information profiles were maintained and subscription to regular DIALOG searchers on the Commonwealth Agricultural Bureau International (CABI) Abstracts Database continued. In addition, four retrospective computer bibliographic searches were done using the CABI database. Using the ICIPE collections, partner libraries in and around Nairobi and the British Library Document Supply Centre, the library fulfilled 1109 document supply requests.

Interlibrary cooperation
The service continued to collaborate with other libraries and information-based institutions. About 25% of the documents delivered to our readers was accounted for by interlibrary loans and other kinds of cooperation. Useful ideas on subjects, ranging from borrowing procedures to computerization, were exchanged at meetings and consultations with other local and international information professionals. Besides maintaining its involvement in this traditional interlibrary lending, the ICIPE library also participated in a new interlibrary arrangement to share experience in library computer applications.

1986 Seminars Hosted by ICIPE

SPEAKER	TITLE
Dr. Bhupinder P. S. Khambay, Rothamsted Experimental Station, UK	Trends in the Design of Newer Synthetic Pyrethroids
Dr. Brian Johnston, Pharmacia Biotechnology, Uppsala, Sweden	Modern Approaches to Protein Purification
Dr. Alf Bakke, Norwegian Forest Research Institute, Norway	Pheromone Ecology of Bark Beetles
Dr. M. F. B. Chaudhury, ICIPE, Nairobi, Kenya	Insect Neuropeptides
Dr. Oliver Dominik, Cornell University, Ithaca, New York, USA	Hormonal Control of Wandering Behaviour in *Manduca sexta*
Professor L. M. Riddiford, University of Washington, Seattle, Washington, USA	Hormonal Control of Sequential Gene Expression in Insect Epidermis
Mr. Peter Njagi, University of Queensland, Australia	Some Studies on Behaviour and Sensory Physiology: Prelude to Investigations on Role of Labellar Taste Sensilla in Feeding Activity of Male *Dacus tryoni* (Frogg) on Cue-Lure
Dr. Joel Margalit, Ben-Gurion University of the Negeu, Beer-Sheva, Israel	Biological Control of Mosquitoes
Professor Nils Christian Stenseth, Department of Biology, University of Oslo, Norway	Use and Abuse of Mathematical Modelling in Ecological Research
Dr. Edward A. Lisowski, State Natural History Survey Division Champaign, USA	Systematics and Ecology of the Sunflower Maggot, *Strauzia* (Diptera: Tephritidae)
Dr. Bernard Rutti, University of Neuchatel, Switzerland	Induction of Immune Resistance in Rabbits Against *Ixodes ricinus*
Dr. Nicholas Georgiadis, Biological Research Laboratories, Syracuse, New York, USA	Grazer-Induced Cyanogenesis in the Grazer-Adapted Grass *Cynodon plectostachyus*
Dr. Takeshi Agatsuma, Kochi Medical School, Japan	Electrophoretic Studies on the Lung Fluke, *Paragonimus westermani*, in the Southeast Asia
Dr. T. Okuda, Nagoya Women's University, Nagoya, Japan	Anatomical and Biochemical Studies on Diapause of a Lady-Beetle, *Coccinella septempuncta brucki* Mulsant
Dr. Peter G. Waterman, University of Strathclyde, UK	Phytochemical Studies on African Plants
Dr. Paul B. Capstick, ICIPE, Nairobi, Kenya	Livestock Ticks Research Programme: Rusinga Island
Professor Rollin C. Richmond, Department of Biology, Indiana University, Bloomington, Indiana, USA	Molecular Cloning and Initial Characterization of the *Esterase-6* Locus of *Drosophila melanogaster*

1986 Conferences Attended by ICIPE Staff

Abe, L. O.
- 6th International Conference of African Association of Insect Scientists (AAIS), Monrovia, Liberia 24–26 March.
- Malawi National Training Workshop on Strategic and Project Planning and Budgeting, Salima District, Malawi, 28 March–4 April.
- FAMESA (Financial and Administrative Management of Research Projects in Eastern and Southern Africa)/Ford Foundation Workshop on Research and Development (R&D) Institute-Client Relationship, Nairobi, Kenya, 30 June–10 July.
- FAMESA (Financial and Administrative Management of Research Projects in Eastern and Southern Africa)/IDRC (International Development Research Centre) Validation Workshop on Facilities and Materials Management, Nairobi, Kenya, 20 July–1 August.
- 10th IFAD (International Fund for Agricultural Development) Governing Council Meeting, Rome, Italy, 9–12 December.

Amimo, F.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Ampofo, J. K. O.
- 7th Biennial Host Plant Resistance to Insects Workshop, Kansas, USA, 18–20 March.
- 6th International Conference of African Association of Insect Scientists (AAIS), Monrovia, Liberia, 24–26 March.
- International Working Group on the Implementation of the African Regional Pest Management Research and Development Network (PESTNET) for Integrated Control of Crop and Livestock Pests, Nairobi, Kenya, 22–26 June.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Amutalla, P. A.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Banda, H. K.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Bartkowski, J.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Capstick, P. B.
- Ecology and Epidemiology of Ticks and Tick-Borne Diseases Workshop, Nyanga, Zimbabwe, 17–21 February.
- International Working Group on the Implementation of the African Regional Pest Management and Research and Development Network (PESTNET) for Integrated Control of Crop and Livestock Pests, Nairobi, Kenya, 22–26 June.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.
- Nairobi Cluster and Kenya Veterinary Association Scientific Meeting, Nairobi, Kenya, 21–22 October.

Chapya, A.
- 3rd International Neem Conference, Nairobi, Kenya, 10–15 July.

Chaudhury, M. F. B.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.
- Nairobi Cluster and Kenya Veterinary Association Scientific Meeting, Nairobi, Kenya, 21–22 October.
- Entomological Society of America National Meeting, Reno, Nevada, USA, 7–11 December.

Chiera, J. W.
- Ecology and Epidemiology of Ticks and Tick-Borne Diseases Workshop, Nyanga, Zimbabwe, 17–21 February.
- 6th International Conference of African Association of Insect Scientists (AAIS), Monrovia, Liberia, 24–26 March.
- International Working Group on the Implementation of the African Regional Pest Management Research and Development Network (PESTNET) for Integrated Control of Crop and Livestock Pests, Nairobi, Kenya, 22–26 June.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Darji, N.
- KEMRI (Kenya Medical Research Institute)/KETRI (Kenya Trypanosomiasis Research Institute) VII Annual Medical Scientific Conference, Nairobi, Kenya, 3–7 February.

de Castro, J. J.
- Ecology and Epidemiology of Ticks and Tick-Borne Diseases Workshop, Nyanga, Zimbabwe, 17–21 February.
- International Working Group on the Implementation of the African Regional Pest Management and Research and Development Network (PESTNET) for Integrated Control of Crop and Livestock Pests, Nairobi, Kenya, 22–26 June.
- VI International Congress of Parasitology, Brisbane, Australia, 24–30 August.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.
- Nairobi Cluster and Kenya Veterinary Association Scientific Meeting, Nairobi, Kenya, 21–22 October.
- 4th Tanzania Veterinary Association Scientific Conference, Arusha, Tanzania, 2–4 December.

De Lima, C. P. F.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Dhadialla, T. S.
- UCLA (University of California at Los Angeles) Symposium on Molecular Entomology, Steamboat Springs, Columbia, USA, 30 March–6 April.
- Joint ICIPE/Pharmacia Course on Biochemical Separation Methods and Molecular Biology Techniques, Nairobi, Kenya, 8–13 September.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Dransfield, R. D.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.
- Nairobi Cluster and Kenya Veterinary Association Scientific Meeting, Nairobi, Kenya, 21–22 October.

Essuman, S.
- Joint ICIPE/Pharmacia Course on Biochemical Separation Methods and Molecular Biology Techniques, Nairobi, Kenya, 8–13 September.

Forawi, W.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Hassanali, A.
- 3rd International Neem Conference, Nairobi, Kenya, 10–15 July.

Haynes, D. L.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.
- Nairobi Cluster and Kenya Veterinary Association Scientific Meeting, Nairobi, Kenya 21–22 October.
- Entomological Society of America National Meeting, Reno, Nevada, USA, 7–11 December.

Irungu, L. W.
- KEMRI (Kenya Medical Research Institute)/KETRI (Kenya Trypanosomiasis Research Institute) VII Annual Medical Scientific Conference, Nairobi, Kenya, 3–7 February.

Jondiko, I. J.
- The International Workshop on University/Industry Cooperation, Nairobi, Kenya, 9–20 January.
- 3rd International Neem Conference, Nairobi, Kenya, 10–15 July.
- 2nd International Symposium: Progress in Natural Product Chemistry, Nottingham, UK, 14–17 July.
- 15th IUPAC International Symposium on the Chemistry of Natural Products, The Hague, Netherlands, 17–22 August.

Jura, W. G. Z. O.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.
- Joint ICIPE/Pharmacia Regional Course on Biochemical Separation Methods and Molecular Biology Techniques, Nairobi, Kenya, 8–13 September.

Kaaya, G. P.
- IV International Colloquium of Invertebrate Pathology, Veldhoven, Netherlands, 18–22 August.
- International Society for Development and Comparative Immunology Conference on Molecular Immunology in Invertebrates, West Berlin, Germany, 28–30 August.
- Nairobi Cluster and Kenya Veterinary Association Scientific Meeting, Nairobi, Kenya, 21–22 October.

Kaddu, J. B.
- KEMRI (Kenya Medical Research Institute)/KETRI (Kenya Trypanosomiasis Research Institute) VII Annual Medical Scientific Conference, Nairobi, Kenya, 3–7 February.
- The Use of Computerized Satellite Images in Pest Control Seminar, Nairobi, Kenya, 12 June.
- 6th International Congress of Parasitology, Brisbane, Australia, 24–29 August.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Kamau, C.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Kariuki, C.W.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5September.

Kokwaro, E. D.
- 5th International Symposium on Spermatology (ISS), Fujiyoshida, Japan, 22–29 August.
- XI International Congress on Electron Microscopy, Kyoto, Japan, 31 August–7 September.

Kongoro, J. A.
- 3rd Biennial Conference of Cambridge E.M. Users Group on Surface Topography and Immunocytochemistry, Cambridge, UK, 26 June.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Latif A. A.
- Ecology and Epidemiology of Ticks and Tick-Borne Diseases Workshop, Nyanga, Zimbabwe, 17–21 February.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Lwande, W.
- 3rd International Neem Conference, Nairobi, Kenya, 10–15 July.

Massamba, N. N.
- Inaugural Symposium of Norwegian Desert Reclamation Foundation and Conference on Control of Desertification, Kristiansand, Norway, 15–19 June.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

McDowell, P. G.
- American Chemical Society, 30th Annual Summer Symposium on Analytical Chemistry, Utah, USA, 18–20 June.
- International Society of Chemical Ecology Inc. Third Annual Meeting, California, USA, 21–24 June.

Mongi, O. A.
- VI International Congress of Parasitology, Brisbane, Australia, 24–30 August.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Mutero, C. M.
- 4th Congress on the Protection of Human Health and Crops in the Tropics, Marseilles, France, 1–4 July.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Mutinga, M. J.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.
- World Congress of Parasitology, Melbourne, Australia.

Nesbitt, S. A. T.
- 6th International Conference of African Association of Insect Scientists (AAIS), Monrovia, Liberia, 22–26 June.

Newson, R. M.
- Ecology and Epidemiology of Ticks and Tick-Borne Diseases Workshop, Nyanga, Zimbabwe, 17–21 February.

- International Working Group on the Implementation of the African Regional Pest Management and Research Development Network (PESTNET) for Integrated Control of Crop and Livestock Pests, Nairobi, Kenya, 22–26 June.
- VII International Congress of Acarology, Bangalore, India, 3–6 August.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.
- Scientific Meeting of Nairobi Cluster and Kenya Veterinary Scientific Meeting, Nairobi, Kenya, 21–22 October.

Nyamori, M.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Nyindo, M. A.
- International Working Group on the Implementation of the African Regional Pest Management and Research Development Network (PESTNET) for Integrated Control of Crop and Livestock Pests, Nairobi, Kenya, 22–26 June.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Nyiira, Z. M.
- FAMESA (Financial and Administrative Management of Research Projects in Eastern and Southern Africa)/Ford Foundation Workshop on Research and Development (R&D) Institute-Client Relationship, Nairobi, Kenya, 30 June–10 July.
- International Symposium on African Wildlife Research and Management, Nairobi, Kenya, 8–11 December.

Ochieng, R. S.
- International Working Group on the Implementation of the African Regional Pest Management Research and Development Network (PESTNET) for Integrated Control of Crop and Livestock Pests, Nairobi, Kenya, 22–26 June.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Odero, B. N.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Odhiambo, T. R.
- Scientific Meeting on the African Chairs of Technology Programme in Food Processing, Biotechnologies and Nutrition and Health, Dakar, Senegal, 15–22 March.
- UCLA (University of California at Los Angeles) Symposium on Molecular Entomology, Steamboat Springs, Columbia, USA, 30 March–6 April.
- Seminar on Strategies to Resolve Africa's Ecological Deterioration and Economic Decline, Abidjan, Ivory Coast, 13–18 April.
- World Health Assembly on the Role of Intersectoral Cooperation in National Strategies for Health for All, Geneva, Switzerland, 5–10 May.
- EEC (European Economic Community)/USAID (United States Agency for International Development) Sponsored Technical Group Meeting on Agricultural Research Networks, Brussels, Belgium, 5–9 July.
- International Meeting Towards a Second Green Revolution: From Chemical to New Biological Technologies in Agriculture in the Tropics, Rome, Italy, 8–10 September.
- SAREC (Swedish Agency for Research Cooperation with Developing Countries) Seminar–The Role of Research in Development, 27 September–2 October.
- Third World Academy of Sciences Council Meeting, Trieste, Italy, 28 October.
- International Pan-African Nutrition Conference, Philadelphia, Pennsylvania, USA, 5–6 November.

Odindo, M. O.
- 6th International Conference of African Association of Insect Scientists (AAIS), Monrovia, Liberia, 24–26 March.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Okech, M. A.
- 6th International Conference of African Association of Insect Scientists (AAIS), Monrovia, Liberia, 24–26 March.

Okeyo, A. Pala
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.
- Joint World Food Program and African Development Bank High-Level Policy Seminar, "Food Aid in Sub-Saharan Africa", Abidjan, Ivory Coast, 8–11 September.
- UNICEF (United Nations Children's Fund) and the National Institute of Research, "Seminar on Gender Dimensions in Development Research", Gaborone, Botswana, 1–4 December.
- World Bank Regional Workshop on Agricultural Research in Eastern and Southern African, Nairobi, Kenya, 11–16 December.

Oloo, G. W.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Omolo, E. O.
- Economic Commission on Africa/Multinational Programming and Operational Center, The Maize Research Network in Eastern and Southern Africa Planning Workshop on Collaborative Research, Lusaka, Zambia, 11–14 February.
- 2nd International Conference on Plant Protection in the Tropics, Kuala Lumpur, Malaysia, 17–20 March.
- International Working Group on the Implementation of the African Regional Pest Management Research and Development Network (PESTNET) for Integrated Control of Crop and Livestock Pests, Nairobi, Kenya, 22–26 June.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Otieno, L. H.
- KEMRI (Kenya Medical Research Institute)/KETRI (Kenya Trypanosomiasis Research Institute) VII Annual Medical Scientific Conference, Nairobi, Kenya, 3–7 February.
- VI International Congress of Parasitology, Brisbane, Australia, 24–29 August.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.
- Research-Coordination Meeting on the Development of Methodologies for the Application of the Sterile Insect Technique for Tsetse Eradication or Control, Vienna, Austria, 22–26 September.
- Nairobi Cluster and Kenya Veterinary Association Scientific Meeting, Nairobi, Kenya, 21–22 October.

Otieno, W. A.
- 6th International Conference of African Association of Insect Scientists (AAIS), Monrovia, Liberia, 24–26 March.
- International Working Group on the Implementation of the African Regional Pest Management Research and Development Network (PESTNET) for Integrated Control of Crop and Livestock Pests, Nairobi, Kenya, 22–26 June.
- IV International Colloquium of Invertebrate Pathology and Microbial Control, Veldhoven, Netherlands, 17–22 August.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Owaga, M. L. A.
- 6th International Conference of African Association of Insect Scientists (AAIS), Monrovia, Liberia, 22–26 March.

Pathak, R. S.
- Workshop on Improvement of Grain Legume Production Using Induced Mutations, Washington, D.C., USA, 1–5 July.
- National Seminar on Germplasm Conservation and Seed Testing, Nairobi, Kenya, 13 August.

- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Punyua, D. K.
- 2nd International Conference on Haemoparasitic Diseases and Their Vectors, Zaria, Nigeria, 24–26 February.
- VII International Congress of Acarology, Bangalore, India, 3–6 August.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Rubin, D. S.
- The International Irrigation Management Institute and the Rockefeller Foundation, Workshop on "The Role of Social Science in Managing Agricultural Technology", Lahore, Pakistan, 24–27 September.

Saxena, K. N.
- International working group on the Implementation of the African Regional Pest Management Research and Developmment Network (PESTNET) for Integrated Control of Crop and Livestock Pests, Nairobi, Kenya, 22–26 June.
- 6th International Symposium on Insect-Plant Relationships, Pau, France, 1–5 July.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Seshu Reddy, K. V.
- International Working Group on the Implementation of the African Regional Pest Management Research and Development Network (PESTNET) for Integrated Control of Crop and Livestock Pests, Nairobi, Kenya, 22–26 June.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Smalley, M. E.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Turner, D. A.
- European Economic Commission Symposium on Tsetse Control, Ispra, Italy, 4–6 March.

Unnithan G. C.
- International Congress of Dipterology, Budapest, Hungary, 24–27 August.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

Vundla, M.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.
- Joint ICIPE/Pharmacia Course on Biochemical Separation Methods and Molecular Biology Techniques, Nairobi, Kenya, 8–13 September.

Waladde, S. M.
- International Symposium on Plant-Insect Relations, Pau, France, 1–5 July.
- International Conference on Tropical Entomology, Nairobi, Kenya, 31 August–5 September.

1986 Publications by ICIPE Staff

Abdullahi, H.; Nyandat, E.; Galeffi, C.; Messana, I.; Nicoletti, M.; Marini Bettolo, G. B. Cyclohexanols of *Halleria lucida*. Phytochem. 25 (12): 2821–2823.

Ampofo, J. K. O. Effect of resistant maize cultivars on larval dispersal and establishment of *Chilo partellus* (Lepidoptera: Pyralidae). Insect Sci. Applic. 7 (1): 103–106.

———. Maize stalk borer (Lepidoptera: Pyralidae) damage and plant resistance. Environ. Entomol. 15 (6): 1124–1129.

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