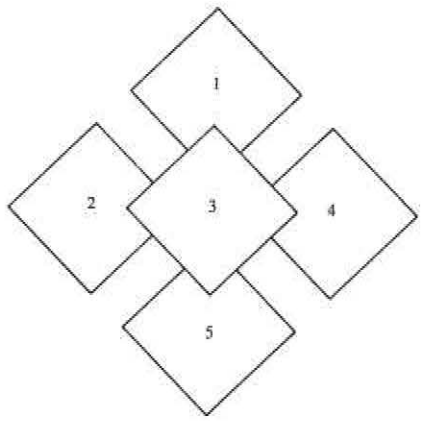
20th Anniversary
1970-1990

SEVENTEENTH ANNUAL REPORT 1989

The International Centre of Insect Physiology and Ecology



Cover

1. Maasai livestock owners making their own ICIPE NGU tsetse trap.
2. Test feed on the ear of a tick-resistant steer, with many sites where ticks have been rejected and others where they are feeding very poorly.
3. New Administrative Building at the ICIPE World Headquarters at Duduville, completed during the year.
4. Polythene sheet and castor oil ICIPE sticky trap for sampling sandflies, set in the open.
5. ICIPE sticky trap for sandflies, set in the entrance to an animal burrow.

MANAGER'S SAMPLE COPY

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1970-1990

SEVENTEENTH ANNUAL REPORT 1989

The International Centre of Insect Physiology and Ecology

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Contents

Foreword

The year 1989 saw the International Centre of Insect Physiology and Ecology (ICIPE) reach three goals that it had set itself in October 1969 at the international planning conference that was convened in Nairobi. This meeting considered the feasibility of establishing *in situ* an advanced centre of research in tropical insect science and pest management, in the very area where these tropical insect problems actually existed.

Firstly, we have clearly demonstrated that mission-oriented research and development (R & D) effort, concentrated on even such previously intractable pest problems as the tsetse, can provide innovative, effective and sustainable technologies to confront these difficulties. Secondly, the ICIPE has demonstrated that, within its own intellectual environment, it can indeed contribute greatly to the development of human capacity in insect R & D. ICIPE postgraduate scholars and postdoctoral fellows have joined the growing national and regional capacity at leadership level in insect science and pest management in Africa, and other developing regions. Thirdly, ICIPE has shown that it could indeed create an insect science dissemination system that is of crucial importance in the growth of the tropical insect science community. These activities are all now taking place, with an assured rhythm which gives us confidence that the 1990s will be the decade when tropical insect science (as an intellectual discipline in research and education) and tropical insect pest management (as a technological discipline in the furtherance of social and economic development in the tropics) reach maturity in both academic and developmental terms.

The ICIPE has achieved all this, and more, through the committed dedication over the years of its staff, its governance, and the larger ICIPE family. At the ICIPE the physical environment has never been of overwhelming importance, since we have always functioned with the philosophy that it is the human brains and human skills that make an institution, rather than merely the bricks and mortar. Nonetheless, the bricks and mortar have arrived in a significant way for the ICIPE and its staff, now ensconced at our world headquarters at Duduville, Nairobi, surrounded by gleaming new walls and roofs in an African idiom. Our campus at Chiromo, Nairobi, is still retained for the ICIPE Science Press and for a future tropical insect activity museum, while Duduville becomes the main arena for R & D effort, graduate training, and management activities. We are pleased with this new development, as it has created an enabling physical environment for our escalating scientific effort.

Nineteen-ninety is the year in which the ICIPE comes of age. We, the ICIPE community, rededicate ourselves to increasing our knowledge of the rich and diverse insect world in the tropics, and to utilise these insights, specifically, to manage insect populations for the betterment of the lives of tropical peoples.

Duduville, Nairobi
June 20, 1990

THOMAS R. ODHIAMBO
Director, ICIPE

Governing Council*

**as at December 31 1989*

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(Completed term of Dr. Saydil Toure, which ended in April 1985)		
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Ex-Officio Member		
Professor Thomas R. Odhiambo[1,2]	ICIPE Director	

Each term lasts three years; I: first term; II: second term.
To maintain a rotation schedule, any term completed by one member for another is excluded from the completing member's tenure.
[1]Member of the Executive Board.
[2]Member of the Nominating Committee (NC).
[3]Member of the Programme Committee (PC).
KG Kenya Government nominee.
SC Nomination from the Scientific Community.
SGI Sponsoring Group for the ICIPE (SGI) nominee.

The following members retired from the Governing Council in 1989: Prof. D. E. U. Ekong, Prof. A. A. P. Leao, Dr. P.T. Obwaka, Ir. L. R. Shultz, Dr. M. Waiyaki and Prof. Dr. H. C. Weltzien.

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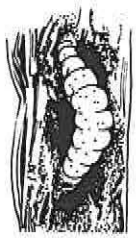
CROP PESTS RESEARCH PROGRAMME



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Crop Pests Research Programme

The aim of CPRP is to develop Integrated Pest Management (IPM) strategies for reducing food crop losses due to insect pests. This will help to increase food production by resource-poor, small-scale farmers in developing countries throughout the tropics, including Africa. The staple food crops and their pests taken up for this work over the past ten years are maize and sorghum with Chilo partellus, Busseola fusca, Eldana saccharina *and* Sesamia calamistis, *and* Maruca testulalis *on cowpea. During the past three years banana and cassava have also been included in view of their importance as food crops, particularly in Africa. The pests that are under study now include the banana weevil* Cosmopolites sordidus, *nematodes like species of* Pratylenchus, *and the cassava green spider mite* Mononychellus *species.*

The programme of IPM research and development is undertaken by four sections or sub-programmes:

- *Bionomics and Applied Ecology (BAE)*
- *Plant Resistance to Insect Pests (PRIP)*
- *Biological Control (BCSP)*
- *Insect Mass-Rearing Technology Unit (IMRT).*

The IPM components under development include the following tactics:

- *Intercropping and other cultural practices*
- *Use of resistant/tolerant crop cultivars*
- *Use of biocontrol agents (parasitoids, predators and pathogens of the pests), supported by (a) assessment of crop losses and economic injury levels, (b) population surveillance and forecasting.*

Development of the above IPM components is undertaken in three stages. The first involves research at the field station and other sites; the next involves testing promising IPM elements under different agro-ecological conditions at national agricultural research systems (NARS) research stations and on farmers' fields under ICIPE's management; the third involves pilot trials with the most effective pest management components on farmers' fields, under their own management, to develop locale-specific IPM packages. Such trials have continued with the following components (intercropping, cultural practices and resistant/tolerant crop cultivars) with a view to finalising the foundation IPM packages for Oyugis and Kendu Bay Divisions in western Kenya.

The work of the Programme has involved collaboration with all the other ICIPE research units. We have exchanged sorghum and maize germplasm with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the International Maize and Wheat Improvement Centre (CIMMYT), respectively, and shared information on the resistance of these crops to stem-borers. As part of our collaboration with the International Rice Research Institute (IRRI) under the ICIPE-IRRI Project we have based scientific teams at each other's institutes. Collaboration with the NARSs of Kenya, Somalia and Zambia has been further strengthened through the African Regional Pest Management R&D Network (PESTNET), with collaborative research, on-farm trials, sharing of information, and training.

BIONOMICS AND APPLIED ECOLOGY (BAE)

This section is developing methodologies and generating information on those aspects of the biology, ecology, and behaviour of the target pests that will provide support for IPM tactics. It also has the responsibility for integrating the IPM components developed by different sections of the Crop Pests Research Programme into effective and sustainable IPM systems.

1.1 POPULATION PATTERNS OF INSECT PESTS ON MAIZE AND COWPEA

A. M. Alghali

Maize (cv. Katumani) and cowpea (ICV 12) were planted at fortnightly intervals between March 30 and August 14 at Mbita Point Field Station in plots of 5 x 10 m. The objective was to identify the key insect pest species and examine their populations on crops planted at regular intervals during the growing season, with a view to finding weaknesses that could be exploited in an IPM programme.

The major pests infesting maize at MPFS were the stem-borers *Chilo partellus* and *Eldana saccharina*. The time of attack varied with the age of the crop. In young plants at four weeks after emergence (WAE) the infestation was exclusively *C. partellus* while at harvest it was a mixture of both species. The level of infestation in the crop also depended on the time of planting. At 4 WAE, *C. partellus* infestation was low on crops planted in April and May, and was higher on those planted between June and August. Infestation was again lower on the crops planted last. At harvest, infestation levels of both species were low on crops planted between April and June, though with slightly higher numbers of *C. partellus*. Peak numbers for both species occurred on maize planted in July, and *E. saccharina* then predominated.

The insect pests of cowpea were the legume pod-borer *Maruca testulalis*, flower thrips *Megalurothrips sjostedti* and a complex of pod-sucking bugs. Relative numbers varied with the planting date. Legume pod-borers were very low in number and occurred only on crops planted in April, May and August. Flower thrips occurred throughout the experimental period with peak numbers on crops planted between May 11–June 8 and a smaller peak for August 17–September 14. Low numbers of pod-sucking bugs occurred on crops planted in July and August. Flower thrips were the most prevalent pest, and legume pod-borers the least.

1.2 ASSESSMENT OF CROP YIELD LOSSES TO INSECTS IN MAIZE

A. M. Alghali

In developing IPM strategies for a crop, it is essential to assess the damage on the farm, and the resultant loss in yield, caused by the insects which attack it. Maize cultivars V 37 and Inbred A were planted on the fields of four farmers each in Oyugis and Mbita Divisions in western Kenya. In each field, plots of the two cultivars were treated with Carbofuran (Furadan) as follows: (a) 2 WAE (weeks after emergence), (b) 4 WAE, (c) 2 and 4 WAE and (d) untreated controls.

The main insect pests were stem-borers of which *Chilo partellus* was the predominant species. In general, stem-borers were low in number, although higher at Mbita than Oyugis (Table 1.1). Applications of Carbofuran at both 2 and 4 WAE substantially reduced the number of stem-borers on the crop. Stem-borer numbers were lower on Inbred A compared with V 37 at Mbita. Damage from leaf feeding was rated on a scale of 1–9 and averaged 1 in all cases. Similarly, the incidence of stem-tunnelling was negligible.

Grain yields did not differ consistently between the various Carbofuran treatments and the controls (Table 1.1). However, yields of V 37 were slightly higher for crops planted at Mbita than for those planted at Oyugis, whilst the reverse was the case for Inbred A. Yields were generally higher for V 37 than Inbred A.

Table 1.1 Numbers of stem-borers at harvest and grain yields obtained for two maize cultivars compared under four regimes of Carbofuran application in western Kenya

Time of application	No. of stem-borers/ 10 plants		Mean grain yield (kg/m²)	
	Oyugis	Mbita	Oyugis	Mbita
Cultivar V 37				
2 WAE†	0.0	5.5	0.23	0.25
4 WAE	0.0	6.5	0.18	0.27
2 and 4 WAE	0.0	0.5	0.13	0.22
None (control)	1.0	8.5	0.18	0.27
Cultivar Inbred A				
2 WAE	0.0	5.0	0.22	0.15
4 WAE	0.0	3.5	0.17	0.13
2 and 4 WAE	0.0	0.0	0.30	0.15
None (control)	0.0	2.4	0.20	0.20

†Weeks after emergence of crop.

1.3 DETERMINATION OF ECONOMIC INJURY LEVELS OF *CHILO PARTELLUS* IN MAIZE

K. V. Seshu Reddy

The economic injury level (EIL) of *C. partellus* was determined in maize (cv. Katumani) at three growth stages, that is 20, 40 and 60 days after emergence (DAE). The plants were grown in protective cages and then artificially infested with 2, 4, 6, 8 or 10 first-instar larvae of *C. partellus*, each representing one treatment at each growth stage. On a control plot, Furadan 5G granules were applied at 0.5 g/plant at 20 DAE and 35 DAE. The experiment was arranged in a complete randomised block design with three replications.

Regression analysis gave a significant linear equation describing the yield at different infestation levels (Table 1.2). The EIL was modelled on this equation, with a gain threshold based on costs of protection and the market price of the crop for 20 DAE, 40 DAE and 60 DAE. The influence of larvae on grain yield was not significant at 60 DAE as shown by the low r^2 value.

Table 1.2 Regression of grain yield (y) in kg/ha on larval density per plant (x) for Katumani maize infested artificially with *C. partellus* at three growth stages: $y = a + bx$

Crop stage (days)	Coeff. of determination (r^2)	Intercept (a)	Slope (b)	EIL†
20	0.96**	3612.5	−265.5	3.2
40	0.94**	3625.0	−212.5	3.9
60	0.15^{ns}	3494.2	−12.9	65.7

†Economic injury level = $\frac{\text{cost of insecticidal treatment/ha}}{\text{market price of crop/kg} \times b}$

**$P < 0.01$.
^{ns}not significant.

1.4 DIEL PERIODICITY OF RESPONSE IN MALE *C. PARTELLUS* TO FEMALE SEX ATTRACTANT

G. C. Unnithan and K. N. Saxena

Earlier studies on the diel periodicity of eclosion and mating in *Chilo partellus* (*ICIPE 1988 Annual Report*) have been extended in order to elucidate the diel rhythm of male receptiveness to female sex pheromone. This was done by means of a laboratory bioassay using male behavioural responses to a hexane extract of female sex pheromone glands.

The experiments were conducted under a cycle of 12 hours light:12 hours dark, with the dark phase (scotophase) adjusted to 0800–2000 hours. The pheromone gland from virgin females less than one day old, along with part of the ovipositor, was excised 6–7 hours into scotophase and extracted in hexane. Extract equivalent to one female was applied on a filter paper strip (0.5 x 5 cm) and arranged in a 7.5 x 19 cm glass jar containing one unmated male, also less than one day old. Solvent alone was used as the control. The assays were made under red light. The male behavioural responses were recorded 5 min after introduction of the filter paper strip. Positive responses were vigorous and continuous flying and attempts to mate with the filter paper strip.

The assays were conducted at intervals throughout scotophase and on into the first hour of photophase (Table 1.3). Very few males responded to pheromone gland extract until after 6 hours of scotophase when 91% flew around the filter paper strip, and 80% attempted to copulate with it. The percentage of males flying then remained high until the end of scotophase, whereas attempts to copulate started declining 2 hours earlier. In the control assay done during hour 7 of scotophase, 20% of males flew, but for only a few seconds, and none arrived at the filter paper strip (Table 1.3). Males that had been kept in the dark for 6 hours during their normal photophase did not show any behavioural response to the pheromone gland extract. On the other hand, 46% of the males transferred to photophase after only 6–7 hours of the 12-hour scotophase, and tested as above, attempted to copulate with the filter paper strip. These observations indicate

Table 1.3 Diel periodicity of mean response of male *C. partellus* to female pheromone gland extract

	Male responses	
Hours of scotophase	Flying (%)	Attempting to copulate (%)
0	3.8^{d}	0.0^{c}
2–3	11.1^{cd}	6.7^{c}
4–5	3.8^{d}	2.5^{c}
6	91.3^{ab}	80.0^{a}
7	98.8^{a}	67.5^{a}
8	99.2^{a}	68.5^{a}
9–10	97.8^{a}	76.7^{a}
10	84.2^{b}	51.7^{b}
11	92.5^{ab}	46.3^{b}
12[1]	20.0^{c}	11.0^{c}
Control[2]	20.0^{c}	0.0^{c}

Within-column means followed by the same letter do not differ significantly ($P > 0.05$).
[1]Within the 1st hour of photophase.
[2]Filter paper dipped in hexane and tested during scotophase.

an endogenous circadian rhythm in the male behavioural response to female sex pheromone.

The time to the onset of the male response to the female pheromone gland extract coincided with the time of peak mating activity and capture of males in field pheromone traps. The results of the present studies will form the basis for a detailed behavioural analysis of pheromone production and perception in *C. partellus*.

1.5 POPULATION MONITORING OF *C. PARTELLUS* ON SORGHUM AND MAIZE

G. C. Unnithan and K. N. Saxena

Both adult and immature populations of *Chilo partellus* were monitored on sorghum planted during the 1988–89 short rainy season (SR), with a view to understanding the relationship between fluctuations in pheromone trap catches of males and the level of infestation and incidence of the immature stages of the stem-borer on the crop. The influence of different crops and crop cultivars on the flight phenology of *C. partellus* was monitored using pheromone traps on sorghum and maize during the 1988 long rainy season (LR) at Mbita Point Field Station (MPFS), and on sorghum cultivars Serena and MB 3 planted in farmers' fields during SR 1988–89.

Chilo partellus infestation on SR sorghum at MPFS in 1988–89 was not as heavy as in the previous LR season, but males were caught in pheromone traps throughout the period of 18 weeks after plant emergence (WAE) (Figure 1.1). Greater numbers of males were caught during the flight period of the second generation which peaked at 12 WAE. The number of males caught in pheromone traps showed a significant positive correlation with larval/pupal population density ($r = 0.553$, $P < 0.05$) and with the percentage of infested plants ($r = 0.698$, $P < 0.01$). A similar relationship was also observed between larval/pupal population density and the percentage of infested plants ($r = 0.809$, $P < 0.01$). Unlike the previous season,

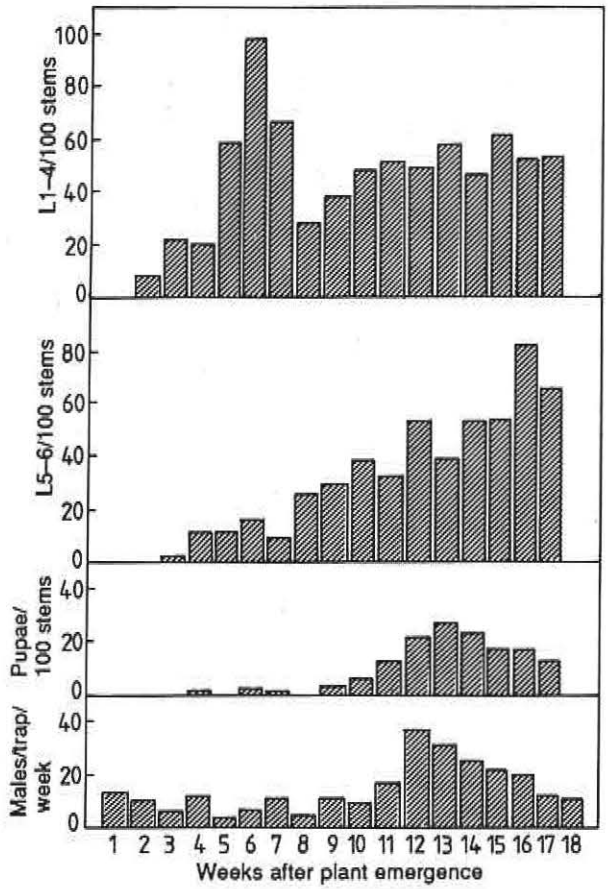


Figure 1.1 *Chilo partellus* larval, pupal and adult population fluctuations on sorghum in relation to plant age during the 1988–89 short rains at Mbita Point Field Station.

the population level present during the flight of the second generation during SR 1988–89 did not affect the pheromone trap effectiveness.

In earlier studies it was observed that pheromone traps set on plots planted with the sorghum cultivar MB 3 caught significantly fewer *C. partellus* males than traps set within plots of several other cultivars, including Serena, during 2–6 WAE *(ICIPE 1988 Annual Report)*. To confirm this finding, populations of *C. partellus* moths were monitored on Serena and MB 3 planted on longer-replicated plots in farmers' fields during SR 1988–89. The results showed no significant difference in weekly catches of males between the two cultivars from 2–19 WAE. The mean numbers of males caught in traps set in Serena and MB 3 were 4.7 and 4.3 per week, respectively. There was also no significant difference in the pupal population density between the two cultivars. However, there were differences in the time of peak emergence of the moths which could indicate differences in the rate of development of the borer on the two cultivars.

During the period of 15 weeks after crop emergence at MPFS during LR 1989, pheromone trap catches showed four peaks each on sorghum (Serena) and maize (Katumani Composite), as shown in Figure 1.2. The first peak, observed at 2 WAE, represented moths that emerge from the residues of the previous crop and infest the new crop; the other peaks were at 6, 10 and 14 WAE on maize and 7, 11 and 14 WAE on sorghum. The highest numbers of males were trapped in both maize and sorghum 1–2 weeks after peak incidence of pupae, with greater catches during the flight of the second generation. After 14 WAE the

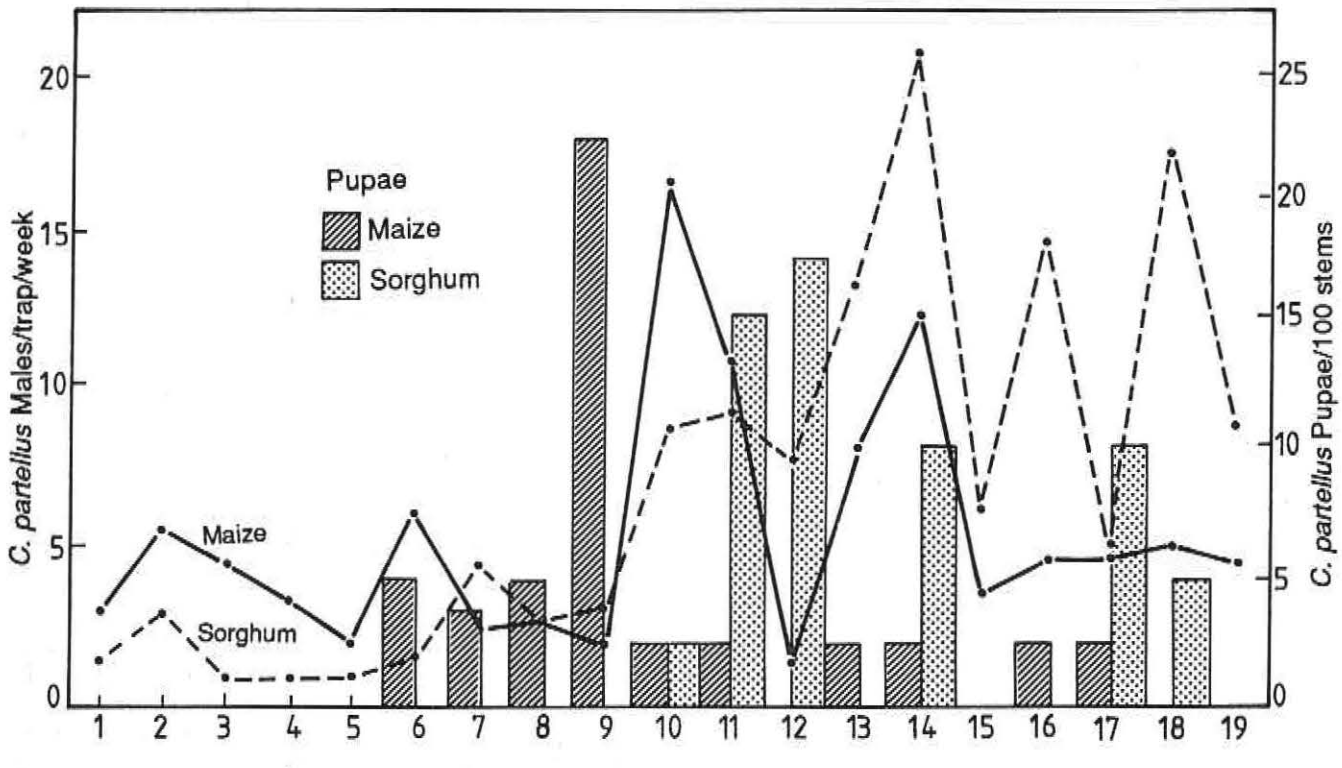


Figure 1.2 *Chilo partellus* flight phenology and fluctuations in pupal populations on sorghum and maize during the 1989 long rains at Mbita Point Field Station.

population continued to be high on sorghum, but declined on maize because the plants dried up after harvest and did not sustain an active population.

1.6 MONITORING INSECT PEST POPULATIONS IN RELATION TO CROP PHENOLOGY IN THE ICIPE-ECA PROJECT AREA

B. T. Nyambo

During the short rains, participating farmers (PF) on the ICIPE-United Nations Economic Commission for Africa (ECA) project in Oyugis Division planted V 37 and H 512 maize varieties intercropped with cowpeas and/or beans, whereas the non-participating farmers (NPF) intercropped maize with beans.

1.6.1 Destructive sampling for crop pests

Insect pests were monitored weekly using a destructive sampling technique on the fields of 25 PF and 5 NPF in the maize/cowpea and maize/bean intercrops, beginning 3 weeks after emergence (WAE) and continuing until 10 WAE. Overall, the incidence of stem-borers was very low up to the end of November, when most of the maize was at the milk stage. On cowpeas, flower thrips and leaf defoliators were the most frequent, whereas beanfly, flower thrips and leaf defoliators were the most damaging on beans.

1.6.2 Monitoring adult stem-borer populations with pheromone traps

The adult populations of *Busseola fusca* and *Chilo partellus* were monitored by trapping, using synthetic pheromone or 1-day-old virgin females, on the maize fields of 5 PF in Oyugis during the 1989 short rains, beginning in the last week of August.

The objective was to study the relationships between male moth trap catches, levels of infestation (egg masses and larval populations), plant damage and phenology, and to investigate the possibility of using traps to reveal initial heavy infestations enabling control strategies to be applied early in the season.

The traps were set soon after the maize had germinated and the catch recorded daily up to the end of November. Monitoring of the immature stages and plant damage at the trap sites began 2 WAE and continued weekly up to 10 WAE.

The weekly moth catches (Table 1.4) varied significantly between sites, with more *B. fusca* moths caught at Site 5 than at the others. *Chilo partellus* catches were rather low, but significantly fewer moths were caught at Site 1 compared to the other sites. Catches at Site 5 were the highest, but overall, were not significantly higher than at Sites 2 and 3.

Table 1.4 Mean weekly catches of male *B. fusca* and *C. partellus* moths in pheromone traps over 13 weeks at five sites in Oyugis Division, South Nyanza, during the 1989 short rains

	Site				
Species	1	2	3	4	5
B. fusca	3.9^{c}	7.4^{b}	4.3^{c}	7.5^{b}	12.9^{a}
C. partellus	2.3^{c}	4.1^{ab}	4.1^{ab}	3.8^{b}	4.5^{a}

For each species, means followed by the same letter do not differ significantly ($P > 0.05$).

The level of stem-borer infestation on the maize crop was very low and neither egg masses nor larvae were recorded between 2–10 WAE, the critical phenological stage. No relationships could be established between trap catches, percentage plant damage and leaf damage ratings.

Studies started in July 1989 on the carry-over populations of stem-borer immature stages on stubble in Oyugis and Kendu Bay Divisions. The objective was to study natural mortality agents under the different stubble management systems practised by the farmers and assess their potential for use in stem-borer management.

1.6.3 Parasitic insects

Up to the end of November 1989, several species of parasitic Hymenoptera and Diptera had been recorded, mostly on *B. fusca* larvae. Some of the parasitoid species appear to be localised, being found only in Oyugis or in Kendu Bay. A few cases of hyperparasitism were also recorded, particularly in Oyugis, and details will be available after proper identification of the specimens. In addition, a few pathogens were recorded on stem-borer larvae.

1.7 THE IDENTIFICATION OF GENE MARKERS IN *CHILO PARTELLUS*

V. A. O. Okoth

In order to identify gene markers, a group of irradiated and a group of non-irradiated *C. partellus* adults were inbred in the laboratory for five generations. A thorough description was then made comparing every generation of these inbreds with the wild type. The characters examined were: scale-type and colour consistency of the hind-wing and dorsal surface of the fore-wing; colour and scales of the body, legs and appendages; circumocular region of the antenna; shape and colour of the eyes; and size of the abdomen.

Examination of a large number of adults revealed that qualitative traits like colour were usually the best for studying markers. It was observed that in wild types the tip of the compound eye was always dark in colour while the rest is light brown or yellowish. Wing deformation caused by irradiation was not inherited in subsequent generations, and was considered to result from physiological disturbances. It was therefore not a useful marker. Wing colouration was directly related to body colouration and the two could be classified together into several types: (1) creamy with small rusty dots, (2) light brown with small rusty dots, (3) dark brown with rusty dots, (4) pure cream and (5) some intermediates. Colours seemed to be controlled by several autosomal polymeric genes. There was a fairly dark wild-type moth whose F_1 cross with the normal one was intermediate; various wing colours segregated in F_2. Some mutants were isolated in F_4 progeny

whose male parents had been irradiated with 35 krad as pupae and crossed with normal females.

1.8 DISTRIBUTION AND INCIDENCE OF BANANA WEEVILS AND NEMATODES IN KENYA

K. V. Seshu Reddy and S .W. Waudo

The most widely distributed banana weevil in the 22 districts surveyed was *Cosmopolites sordidus*. The damage caused by it was expressed as a percent coefficient of infestation (PCI) for each district. Severe damage (over 80%) was recorded in Kisii, South Nyanza, Kisumu, Siaya, Busia, Embu, Kirinyaga, Kilifi, Kwale and Taita-Taveta Districts. The other banana weevils recorded were *Temnoschoita nigroplagiata* and *T. basipennis*. In general, the PCI in cooking bananas was higher, ranging up to 97% (mean 46.3%), than in sweet types, where it ranged up to 67% (mean 33.2%). However, PCI was also directly related to banana plant age and to altitude.

The banana nematodes *Helicotylenchus micronotus, H. multicinctus, Pratylenchus goodeyi* and *Radopholus similis* were common in banana fields in Kenya, with *P. goodeyi* the most prevalent. *Pratylenchus goodeyi* densities reached nearly 230,000/g dry root in cooking banana roots collected in Nairobi district, while up to 96,000 *R. similis*/g dry root were recorded in Nyeri district. Numbers of the burrowing nematode *R. similis* were directly related to banana plant age and to altitude. Numbers of *P. goodeyi* were also related directly to increase in altitude, but inversely to plant age; numbers of *Helicotylenchus* spp., however, decreased with altitude.

1.9 POPULATION PATTERNS OF BANANA WEEVILS

K. V. Seshu Reddy

Disc-on-stump and split pseudostem traps were used to study populations of the weevils *Cosmopolites sordidus* and *Temnoschoita nigroplagiata*. Both species showed a cyclic fluctuation during one year. Disc-on-stump traps were about 41% more efficient in trapping banana weevil adults than the split pseudostem traps. However, the traps were about 30% more attractive to *T. nigroplagiata* than to *C. sordidus*. Continuous trapping over one year reduced the population of weevils by 50%.

PLANT RESISTANCE TO INSECT PESTS (PRIP)

The main objective of PRIP is to develop strategies for the effective utilisation of resistance in sorghum, maize and cowpea as a component of the Programme's IPM strategies. The pests currently under study are:

- *Stem-borers of cereals with particular emphasis on* Chilo partellus
- *Cowpea pod-borer,* Maruca testulalis
- *Cowpea aphid,* Aphis craccivora.

The research during the year continued to focus on three main topics:

1. Evaluation of new lines of target crops with different desirable characters whenever these become available from sources like ICRISAT; the East African Regional Cereal and Legume Network/Semi-Arid Food Grain Research and Development Consultative Advisory Committee (EARCAL/SAFGRAD) of the Organisation of African Unity (OAU); CIMMYT; the International Institute for Tropical Agriculture (IITA) and the national agricultural research systems of Kenya, Somalia, Zambia, etc. The general methodology has been described in previous reports.

2. Elucidation of resistance mechanisms in selected cultivars. The aim is to identify factors that impart resistance or susceptibility. This information can then assist plant breeders in national and international agricultural centres to develop varieties combining pest resistance with other desirable characters.

3. Study of the genetics of pest resistance in selected cultivars with a view to elucidating the mode of inheritance of different resistance components, the type of gene action and heritability. This information will be helpful to plant breeders in planning strategies of breeding for resistance.

1.10 SORGHUM RESISTANCE TO STEM-BORERS

K. N. Saxena

1.10.1 Evaluation of sorghum cultivars for resistance to stem-borers

Two-stage evaluations of additional sorghum cultivars, and some previously tested, were carried out at the ICIPE Mbita Point Field Station (MPFS). Multilocational trials were also held.

1st stage evaluation in single-row plots. These were carried out on 25 lowland-adapted lines from EARCAL/SAFGRAD, which were compared with the cultivar Serena under artificial infestation with 25 pairs of *Chilo partellus*, released in the plot 3 weeks after emergence of the plants. Four major components of resistance (egg infestation, larval/pupal infestation, deadheart and stem-tunnelling damage) were measured and the overall resistance susceptibility index (ORSI) computed for each test line. Grain yields were also recorded.

The relative indices of stem-tunnelling of five cultivars were close to those of the check Serena (0.8–1.2). The remaining cultivars were more susceptible than the check. Thirteen of the tested cultivars were highly resistant to deadheart, with very low relative indices. Resistance to egg infestation was shown by seven cultivars. One cultivar showed resistance (relative indices below 0.8) for both egg and larval/pupal infestation. Two lines showed overall resistance to the borers, relative to Serena; the grain yields of these cultivars and Serena were similar. Four cultivars showed tolerance, as reflected in low deadheart damage and grain yield as high as the check in spite of equal or higher infestation levels.

2nd stage evaluation in multi-row plots. Eleven cultivars including the check Serena, and ICS 3 (=LRB 5), ICS 4 (=LRB 8) and IS 1044 were subjected to multi-row evaluation (Table 1.5). Two cultivars, KAT/83369 and KAT/83487 were included from the first stage evaluation just

Table 1.5 Second stage evaluation of sorghum cultivars in multi-row plots under natural infestation: components of resistance and overall resistance/susceptibility index (ORSI)

Cultivar	Relative infestation index		Relative damage index			ORSI
	Egg	Larvae+ pupae	Dead-heart	Foliar damage	Stem-tunnelling	
Serena	1.0	1.0	1.0	1.0	1.0	1.0
IS 1044	0.5	0.6	0.4	1.0	0.4	0.5
ICS 3 (=LRB 5)	0.9	0.7	1.1	1.0	0.7	1.3
ICS 4 (=LRB 8)	0.9	1.7	1.1	1.0	0.8	1.1
KAT/83369	0.9	1.5	0.9	1.0	1.2	1.1
KAT/83487	1.2	1.4	1.2	1.0	1.3	1.3
ICSV 1	0.6	1.0	0.9	1.0	0.8	0.8
ICSV 197	0.6	1.0	0.6	1.0	0.5	0.7
2KX 17	1.4	1.2	0.6	1.0	1.3	1.1
IS 2269	0.9	1.6	0.4	1.0	0.4	0.8
ESP 26	1.7	1.0	0.5	1.0	1.3	1.1

described. IS 1044 continued to show resistance, and ICS 3 as well as ICS 4 continued to show tolerance to the stem-borers. An additional line, ICSV 197, was found to show overall resistance. IS 2269 showed resistance to deadheart and stem-tunnelling, and ESP 26 to deadheart only.

Multilocation trials. These were conducted with 10 promising sorghum cultivars at Busia, Machakos and Mtwapa. The two ICIPE cultivars (ICS 3 and ICS 4) performed as well at the coast (Mtwapa) as in western Kenya. The grain yield of both was high and insect pest as well as bird damage very low. In fact, ICS 3 even survived midge attack.

1.10.2 Mechanisms of resistance in sorghum

The role of plant chemicals in oviposition (in collaboration with CBRU). Three cultivars have been tested to determine the role of their chemical constituents in resistance to oviposition by *C. partellus*: IS 18520 (= Serena, tolerant), IS 18363 (susceptible) and IS 1044 (resistant). Leaves of 3–4 week-old plants were extracted with petroleum ether, ethyl acetate and methanol. These extracts were tested on filter paper by specially designed techniques. Petroleum ether extracts of the first two stimulated oviposition, whereas the same extract from IS 1044 deterred it. Ethyl acetate extracts of the tolerant and susceptible cultivars were also stimulatory, whereas the same from IS 1044 was inactive. The main constituents of the ethyl acetate extract were *p*-hydroxybenzoic acid and *p*-hydroxybenzaldehyde. The acid was more stimulatory than the aldehyde. Lack of adequate stimulants and presence of deterrent chemicals in IS 1044 would contribute to its resistance to oviposition by *C. partellus*.

The role of physical factors in determining larval settling on sorghum plants. The settling behaviour of the larvae hatching from eggs laid on sorghum plants has been compared among susceptible (IS 18363), tolerant (IS 18520) and resistant (IS 1044) cultivars. The factors investigated include: phototaxis, thigmotaxis, geotaxis, surface moisture and contact chemo-stimulants. The results show that the movement of the newly hatched larvae into the leaf whorl is determined by a combination of geotactic, thigmotactic, hygrotactic and chemotactic stimuli. Phototaxis plays very little part in larval settling.

1.11 MAIZE RESISTANCE TO *CHILO PARTELLUS*

H. Kumar and K. N. Saxena

1.11.1 Evaluation of maize cultivars for components of resistance

Assessment of resistance to stem-borers in maize lines, and investigation of the mechanisms of resistance in selected cultivars, has been proceeding along the same lines as in sorghum.

1st stage evaluation in single-row plots. Forty maize accessions that were received from Zambia, Mozambique, CIMMYT and Kenya, and tested previously at MPFS under natural infestation, were now evaluated under artificial infestation and completely rain-fed conditions at Ungoye field site. During the long rainy season of 1989 (March–July) there were only 2–3 falls of rain in the whole cropping season. The maize accessions were each planted in three single-row plots. The plants were artificially infested at the whorl stage 3 weeks after plant emergence (WAE). The plants were rated for: (a) foliar damage (on a scale of 1–9) at 3 weeks after infestation (3 WAI), (b) stem-tunnelling at harvest, (c) plant height, (d) incidence of maize streak virus (MSV) symptoms and (e) grain yield.

Despite infestation and low rainfall, 11 cultivars showed good growth as indicated by plant height and were well adapted to the semi-drought conditions. Ten cultivars not only showed low foliar damage ratings (< 3) but also a very low stem-tunnelling incidence (3–4%). The incidence of MSV symptoms was high (20–22%) on some six cultivars and low (1–4%) on six others. In four cultivars no MSV symptoms were recorded. Some cultivars combined good adaptability with low borer damage and consequently yielded well under these conditions of low rainfall and low insect infestation.

A few selected maize cultivars were further evaluated at Mbita Point Field Station under artificial infestation and irrigation. The results (Table 1.6) show that cultivars

Table 1.6 Levels of infestation and damage by the stem-borer *C. partellus* on eight maize lines compared with a susceptible line (Inbred A), long rainy season, 1989. Damage assessed at harvest, following artificial infestation with 20 larvae/plant† at 3 WAE

Cultivar	Plants with foliar damage (%)	Foliar damage rating (scale 1–9)	Plants with stem-tunnelling (%)	Stem length tunnelled/ plant (%)	Larvae and pupae/ per plant	Yield/ plant (g)
Inbred A	100^{a}	5^{a}	100^{a}	54^{a}	2.2^{ab}	54^{c}
MMV 400	88^{b}	3^{d}	100^{a}	22^{b}	1.8^{ab}	154^{ab}
V 68	100^{a}	4^{bc}	97^{a}	28^{b}	1.9^{ab}	99^{b}
V 50	100^{a}	4^{bc}	100^{a}	33^{b}	1.3^{bd}	125^{ab}
V 37	100^{a}	4^{c}	97^{a}	22^{b}	2.6^{a}	107^{ab}
Bulk CG 4141	100^{a}	4^{b}	100^{a}	30^{b}	2.0^{ab}	96^{b}
ICZ2-CM	100^{a}	3^{d}	97^{a}	17^{bc}	1.4^{bd}	128^{a}
KRN 1	97^{a}	3^{d}	100^{a}	184^{bc}	1.4^{bd}	111^{ab}
Poza Rica	71^{b}	2^{e}	67^{b}	5^{c}	0.7^{d}	162^{a}

Within-column means followed by the same letter do not differ significantly ($P > 0.05$).
†Freshly-hatched first-instar larvae introduced into the leaf whorl.

like Poza Rica, MMV 400, V 37, V 50 and ICZ2 CM are not only moderately resistant/tolerant to *C. partellus* attack, but also give a good grain yield.

1.11.2 Mechanisms of resistance in maize

This aspect was studied in four cultivars which have shown resistance to the stem-borer. The responses that are involved when an insect colonises a plant *(ICIPE Annual Report: 1984, 1985)* belong to the following categories: (a) behavioural responses determining initial selection or rejection (orientation, feeding and oviposition), (b) physiological responses (utilisation of ingested food and nutrition), (c) larval development and (d) egg production.

Ovipositional responses to plants. The methods employed included tests in the 3-sector chamber or contact chamber described in previous *ICIPE Annual Reports.* When V 37 (resistant) and Inbred A (susceptible) were presented inside the 3-sector chamber in the screenhouse, there was a very high ovipositional preference for the resistant line (Table 1.7).

The role of contact stimuli was tested in the contact chamber. Leaves of Inbred A elicited more oviposition than those of the lines V 37 and MP 704 (Table 1.7). When the leaves of V 37 were compared with wax paper, oviposition on the wax paper was greater than on the leaf. There was, therefore, a strong ovipositional non-preference for the cultivar V 37. It was found that the high density of trichomes on the leaf surface of V 37 (136/cm^2) compared with Inbred A (80/cm^2) inhibited oviposition by *C. partellus.*

Role of plant extracts in oviposition. The role of plant chemicals in stimulating the oviposition response of *C. partellus* was investigated in collaboration with CBRU. Leaves of the susceptible cultivar Inbred A and the resistant cultivar MP 704 were extracted with petroleum ether, ethyl acetate and methanol. These extracts were tested on filter paper for oviposition response, as described above for sorghum. The petroleum ether extract of Inbred A was inactive, whereas that of MP 704 stimulated oviposition. The ethyl acetate extracts of both cultivars were stimulatory at one concentration or another. However

Table 1.7 Ovipositional responses of *C. partellus* to four susceptible and resistant maize cultivars[1] and to wax paper

Test material		Leaf portion[2]	Mean no. eggs laid		Preference for 'A'[3] (%)
A	B		A	B	
Inbred A[4]	V 37	–	716	374	39
Inbred A[4]	MP 704	–	637	180	57
Inbred A[5]	V 37	BU	155	77	48
		TU	187	30	71
		BL	174	85	39
		TL	212	78	45
V 37[5]	Waxed paper	BU	34	142	−64
		TL	97	95	4

[1]Plants used 3 WAE; 10–70 females in 7–10 replicates.
[2]B=basal, T=terminal, U=upper, L=lower.
[3]Calculated as [(A–B)/(A+B)] x 100.
[4]Plants of resistant and susceptible cultivars presented in two separate rows within a 3-sector test chamber.
[5]First fully opened leaves presented inside a circular test chamber.

Table 1.8 Consumption and growth of freshly-emerged fourth-instar larvae of *C. partellus*, and the absorbability, assimilability and nutritive value of the food in each case. Single larvae were offered basal internodes of the stems of plants 4–6 WAE, over a 48-hour period

Cultivar	Mean food consumption		Mean larval wt. gain (mg)	Mean absorbability[1]		Mean assimilability[2]	Mean nutritive value[3]
	Dry wt. (mg)	Fresh wt. (mg)		Dry wt.	Fresh wt.		
Inbred A	0.69	8.0	0.10	0.88	0.89	0.02	0.030
V 37	0.56	6.3	0.05	0.90	0.90	0.01	0.008
Poza Rica	0.58	6.7	0.13	0.82	0.81	0.05	0.022
MP 704	1.68	9.5	0.05	0.96	0.95	0.01	0.005

[1] Calculated as food absorbed/food ingested.
[2] Calculated as larval wt. gain/food absorbed.
[3] Calculated as larval wt. gain/food ingested.

the methanolic extract of MP 704 was inhibitory, acting as a deterrent compared to the stimulatory activity of the extract from Inbred A.

Role of plant extracts in larval feeding. Feeding responses of third instar *C. partellus* larvae to agar-based diets incorporating leaf extracts of Inbred A or MP 704 were compared on the basis of the dry weight of food consumed. The consumption of plain agar plus cellulose gel was very low. It increased after adding sucrose or dry leaf powder of the susceptible cultivar (Inbred A), and was higher than that of gel containing leaf powder of the resistant MP 704. The addition of methanolic extract of Inbred A to agar plus cellulose gel raised consumption to its highest level but the extract from MP 704 was not so stimulatory. Thus, lack of phagostimulants rather than the presence of deterrents is responsible for low feeding of the larvae on MP 704.

Role of food utilisation in antibiosis. The nutritional value of the four cultivars to *C. partellus* larvae was investigated using methods modified from those described by Saxena (1969)†. Absorption of ingested food was almost equally high for all four cultivars (Table 1.8). However, assimilation of the absorbed food (i.e. its conversion into body tissue) and overall nutritive value were highest for the susceptible check Inbred A and the resistant Poza Rica, low for V 37 and very low for the cultivar MP 704. Thus, poor assimilation of V 37 and MP 704 contributes to the resistance of these cultivars to *C. partellus*.

†*Saxena K. N. (1969) Patterns of insect-plant relationships determining susceptibility or resistance of different plants to an insect. Entomologia experimentalis et applicata 2, 751–756.*

1.12 GENETICS OF RESISTANCE TO *CHILO PARTELLUS* IN SORGHUM AND MAIZE

R. S. Pathak

Previous work on the genetics of resistance to the stem-borer, *Chilo partellus*, in sorghum and maize has shown that:

- Resistance in terms of leaf-feeding, percentage deadhearts and percentage stem-tunnelling is polygenic and complex.
- Resistance to leaf-feeding and stem-tunnelling is controlled predominantly by additive genes in both maize and sorghum.
- Resistance to deadhearts is governed by both additive and non-additive (dominance and epistasis) genes, but predominantly by non-additive genes in maize.
- The predominance of additive genetic variance for resistance parameters indicated the use of recurrent selection programmes to develop insect resistant populations/cultivars.
- The high magnitude of non-additive gene effects indicated the possibility of exploiting F_1 heterosis for resistance in maize.

Selection for these traits is made more effective by an understanding of their inheritance. Heritability is of interest to the plant breeder primarily as a measure of the value of selection for resistance. The present study was undertaken to determine and compare the magnitude of heritability estimates for three resistance parameters, leaf-feeding, deadhearts and stem-tunnelling in sorghum and maize.

Broad-sense heritability estimates calculated from variance components (Table 1.9) ranged from 0.33–0.79 in sorghum and 0.64–0.90 in maize. Resistance to leaf-feeding appeared less heritable than resistance to deadhearts or stem-tunnelling in both crops. The estimates of heritability for percent deadhearts appear high in both crops. However, significant non-additive genetic variance for resistance to deadhearts makes the validity of these calculations questionable. In general, heritability estimates based on variance components might be expected to exceed those computed from parent-offspring regressions, since in the latter case genotype-environment interaction might

Table 1.9 Heritability estimates for resistance parameters in sorghum and maize

Cross	Resistance parameter	Heritability
Sorghum		
IS 1044	leaf-feeding	0.33
x	% deadhearts	0.79
IS 18363	% stem-tunnelling	0.56
Maize		
MP 704	leaf-feeding	0.64
x	% deadhearts	0.90
Inbred A	% stem-tunnelling	0.77

interfere. It is necessary to estimate narrow-sense heritability, which is the ratio of additive genetic variance to the total genetic variance estimated from the variances of P_1, P_2, F_1, F_2 and the backcross of the F_1 to each parent. The narrow-sense heritability values are a reliable measure of the comparative efficiency of selection. The heritability estimates given by the different methods are currently being worked out.

1.13 BREEDING FOR STEM-BORER RESISTANT CULTIVARS OF SORGHUM

A. E. M. Nour

Studies were undertaken in four main areas with the following objectives:

- To develop high-yielding sorghum cultivars with a high level of stem-borer resistance.
- To utilise selected cultivars in an IPM programme which would be feasible, economic and of practical use to farmers.

1.13.1 First stage evaluation of sorghum germplasm
Forty-three sorghum cultivars from Sudan and two local checks (Serena and IS 1044) were evaluated for stem-borer resistance at Mbita Point Field Station during the long rains of 1989. The entries were planted in single rows 5 m long and 60 cm apart with an inter-plant spacing of 30 cm, and artificial fertiliser was applied at planting and at the knee-high stage. A randomised complete block design with three replications was used.

Data on flowering dates, plant height, number of tillers/plant, agronomic score, and grain yield were recorded using 10 plants selected at random from each plot. Data were also collected on the total number of *Chilo partellus* egg masses, number of larvae and pupae, foliar damage, percent plants with deadheart, and percent stem-tunnelling. In addition, the ORSI index for each entry was calculated.

Six cultivars gave ORSI values of less than 0.8, and could thus be considered to be resistant. However, the majority of the tested cultivars were in the tolerant range. None of the cultivars out-yielded the two checks. Nevertheless, four of the Sudanese cultivars showed high levels of resistance and good yield potential.

1.13.2 Development of sorghum cultivars for stem-borer resistance and desirable agronomic characters
A crossing programme to combine good agronomic traits with a high level of stem-borer resistance was initiated. In this study the pedigree method of selection was followed. Four varieties, LRB 5, LRB 6, LRB 8, and IS 1044, were planted in the screenhouse. At flowering time the following crosses were made using hand emasculation: (LRB 8 x IS 1044), (LRB 8 x LRB 5), (LRB 6 x LRB 8), (LRB 6 x LRB 5), (IS 1044 x LRB 5), (IS 1044 x LRB 8) and (IS 1044 x LRB 6).

The F_1 seed of these hybrids was immediately planted in the screenhouse to produce the F_2 seed, which was planted in the short rains of 1989 and evaluated as F_2 populations.

1.13.3 Male sterility facilitated by recurrent selection
This new breeding approach (known as MSRS) to upgrade the level of stem-borer resistance in a particular cultivar has previously been used with rice. The method involved crossing several resistance sources using a female parent known to have genetic male sterility. Some of the F_2 seeds and all backcross seeds were mixed to prepare the starting composite population. Following the same procedure during the long rains of 1989, 15 resistant sorghum lines were crossed with Tx.623 A (a widely known male-sterile) as the female parent. Seed from F_2 as well as backcrosses will be obtained next season to prepare the starting composite population.

1.13.4 Evaluation of hybrid sorghum
Since most of the screening work for stem-borer resistance in sorghum has been done on open-pollinated varieties, it is essential to test the possibility of utilising hybrid vigour in developing resistant lines.

Ten well-established male-sterile lines were crossed, each to 15 pollinator parents, during the long rains of 1989 at Mbita Point Field Station. Each male-sterile line (A-line) and the pollinator parent (R-line) were planted side by side. At flowering, hand pollination was used to ensure good seed setting. About 120 successful hybrids were made and grown at the next short rains for further evaluation.

BIOLOGICAL CONTROL (BCSP)

The objective of this sub-programme is to develop strategies for the efficient utilisation of natural enemies in the management of target pests. During 1989, BCSP undertook studies on the natural enemies of target crop pests, livestock ticks, tsetse and medical vectors. The work done in each research programme is included in its respective report. In the Crop Pests Research Programme, BCSP further evaluated the efficacy of Nosema *sp. and* Bacillus thuringiensis *for the control of* Chilo partellus, *determined the host range for* Nosema *sp., identified predators of* C. partellus, *isolated and evaluated entomopathogenic fungi for the control of* C. partellus *and the cassava green spider mite (CGSM),* Mononychellus tanajoa, *and also studied the taxonomy and biology of CGSM. Further studies on the biology of an egg parasitoid of* C. partellus, Trichogramma *sp. nr.* mwanzai, *were also undertaken.*

1.14 FORMULATIONS OF *NOSEMA* SPORES FOR THE CONTROL OF *C. PARTELLUS*

M. O. Odindo, P. A. Amutalla, M. Y. Oriwo, P. B. O. Ogola and T. A. Odero

Following the successful evaluation of *Nosema* sp. on sorghum infested with the stem-borer *Chilo partellus*, it was necessary to test formulations of the pathogen which

Table 1.10 Stem-tunnelling, larval and pupal infestation and emergence holes seen at 7 WAE in sorghum infested at 3 WAE with *C. partellus* larvae and treated with *Nosema* sp.

Treatment	Proportion of plant tunnelled (%)	Mean no. larvae/ plant	Mean no. pupae/ plant	Mean no. holes/ plant	Seed yield (g/plot)
Spray, aqueous	3.4^{b}	0.7^{b}	0.1^{b}	1.2^{bc}	2580.0^{a}
Spray, molasses	7.7^{ab}	1.4^{ab}	0.0^{b}	1.2^{bc}	2418.8^{a}
Sand carrier	15.6^{a}	2.3^{ab}	0.4^{ab}	3.2^{ab}	875.5^{b}
Mill-dust meal	12.5^{ab}	2.7^{a}	0.2^{ab}	3.1^{ab}	475.0^{ab}
Untreated control[1]	19.2^{a}	2.3^{ab}	0.6^{a}	4.2^{a}	432.5^{b}
Untreated control[2]	3.7^{b}	0.5^{b}	0.2^{ab}	1.0^{c}	–

Within-column means followed by the same letter do not differ significantly ($P > 0.05$).
[1]Artifical infestation.
[2]Natural infestation.

might be used in the field for the management of cereal stem-borers. The method of presentation (formulation) of an insect pathogen may affect its efficiency in pest management and thereby its beneficial effect on crop yield. The persistence of the pathogen in the host environment may also be affected, including its availability in the subsequent growing season. In the present study, four formulations of *Nosema* were tested for the control of *C. partellus*. (a) A plain aqueous suspension spray that was prepared from *C. partellus* larval cadavers obtained from the pathogen production unit, purified by filtration and centrifugation and then adjusted to a concentration of 1.5 x 10^6 spores/ml. (b) An aqueous formulation that contained 10% v/v of molasses. (c) A sand carrier formulation that was prepared with fine river sand that had been washed and sterilised and then mixed with an aqueous suspension of *Nosema* spores (3.5 x 10^7 spores/ml). It was kept in a cool place until applied in the field. (d) A mill-dust meal formulation that was based on waste sorghum and maize flour collected from local grain mills, and mixed to a uniform consistency with a pathogen suspension in the ratio of 5:1 w/v. It was air dried and then crumbled to give a granular formulation (granule weight 0.1–0.3 g).

The four formulations were applied on plots of sorghum at 3 weeks after plant emergence (WAE) in a complete randomised block design; all the plots were artificially infested with neonate stem-borer larvae 24 hours before treatment with the pathogen, except one group which was left to acquire natural infestation.

The results of the trial at 7 WAE are shown in Table 1.10. Both the plain spray and the molasses spray significantly reduced levels of infestation and damage by *C. partellus*. Four weeks after treatment these two foliar sprays gave the lowest incidence of tunnelling, infestation and emergence holes. Seed yield was also highest in the plots sprayed with the two aqueous formulations. The mill-dust meal and sand carrier formulations maintained high levels of microsporidian infection in larvae sampled from the treated plots, and it is therefore possible to use these two formulations for introduction of the pathogen in the field.

1.15 THE HOST RANGE OF *NOSEMA* SP. IN SOME LEPIDOPTERAN STEM-BORERS

J. Ogwang

Host range and infectivity are among the most important factors which help to maintain insect diseases in the ecosystem. A wide host range may increase the chances of a pathogen surviving since it may exploit differences in host behaviour and life cycles. Studies were made in both the field and laboratory to determine host responses to *Nosema* sp. in *Chilo partellus*, *Eldana saccharina* and *Busseola fusca*, the three major stem-borers found around Mbita Point Field Station.

Stems of sorghum (cv. Serena) from 12 field plots were dissected. The plants had been treated previously with *Nosema* sp. suspensions at concentrations of 1.4 x 10^4, 1.4 x 10^6 and 1.4 x 10^7 spores/ml. Insects recovered from the stems were brought to the laboratory and examined for *Nosema* spores under a phase contrast microscope. In laboratory experiments, third-instar larvae of *C. partellus*, *E. saccharina* and *B. fusca* were exposed to sorghum stems dipped in a suspension of 4 x 10^8 spores/ml of *Nosema* sp. The larvae were then reared for 10 days before being examined. The presence of *Nosema* spores in the haemolymph was the criterion for determining whether a larva had been infected by the pathogen.

The results obtained from both laboratory-treated and field-treated insects showed that *C. partellus* was more susceptible to *Nosema* infection than *E. saccharina* whilst *B. fusca* appeared to be refractory (Tables 1.11 and 1.12).

Table 1.11 Infection of three stem-borer species with *Nosema* sp. (four replicates)

Species	No. exposed	Infected (%)	Mean no. infected
C. partellus	40	23.8	9.5^{a}
E. saccharina	40	11.8	4.7^{b}
B. fusca	40	0.0	0.0^{c}

Means followed by a different letter are significantly different ($P < 0.05$).

Table 1.12 Incidence of *Nosema* sp. after application to natural populations of three species of stem-borers on 20 plots

Species	Mean no./ plot	Infected (%)	Mean no. infected/plot
C. partellus	23.3	6.7	1.6[a]
E. saccharina	18.6	1.7	0.4[b]
B. fusca	5.3	0.0	0.0[c]

Means followed by a different letter are significantly different ($P < 0.05$).

The limited susceptibility of *E. saccharina* may nevertheless be important to survival of the pathogen. Since this species is a late-stage crop pest that is known to aestivate in dry sorghum stems, infected individuals could maintain the inoculum during the off-season.

1.16 FURTHER EVALUATION OF *B. THURINGIENSIS* FOR THE CONTROL OF LEPIDOPTERAN PESTS

M. Brownbridge

1.16.1 Chilo partellus

The research emphasis has continued to be on the evaluation of Kenyan strains of *Bacillus thuringiensis (B. t.)* and has involved both laboratory and screenhouse experiments.

(a) With a view to the future large-scale fermentation of the pathogen, experiments are in progress to optimise the growth conditions for selected *B. t.* strains. Three strains (M-44-2, A 3 and A-C-2) have been chosen on the basis of their superior toxicity for *C. partellus* larvae. Parameters under investigation include optimisation of temperature (and, later, media based on locally available materials) for growth, sporulation and toxin formation. At 29°C, the three strains begin to sporulate after 8 hours, with full sporulation of the culture after 24 hours. Toxicity is expressed initially at 8–12 hours after inoculation, with full expression occurring after 24–32 hours of fermentation. The growth achieved and the toxicity levels expressed compare very favourably and positively with the reference strain *B. t. kurstaki* HD-1. Experiments are continuing using higher fermentation temperatures.

(b) Screenhouse trials were carried out on eight *B. t.* strains. All provided good levels of plant protection when applied as an aqueous suspension to sorghum plants artificially infested with 20 neonate *C. partellus* larvae. Of the eight strains tested, M-44-2, A 3 and A-C-2 provided the best protection according to all parameters measured. Plant growth was better, fewer deadhearts developed, the rate and number of grain-bearing heads formed and emerging for harvest was higher, and internal plant damage, measured at harvest, was significantly lower. Yields were 5–7 times greater than those obtained from the unprotected control plants. These strains have therefore been selected for full field evaluation, and pilot trials are currently underway at Mtwapa (on the coast) and Embu (in central Kenya). These are areas of reported high natural *C. partellus* infestation, and the data collected from these trials should enable larger scale trials to be undertaken during the 1990 long rains.

(c) Further trials were carried out in the screenhouse on the effectiveness of different *B. t.* application techniques. Three methods were considered which could be used by the small-scale farmer with minimal outlay on equipment. These were: (i) application of an aqueous *B. t.* suspension with a hand-held sprayer, (ii) application of an aqueous *B. t.* suspension by squeeze bottle and (iii) application of a powder formulation prepared by mixing a *B. t.* suspension with posho mill dust (a waste product from the milling of maize, sorghum and cassava) and then allowing the mixture to dry. All treatments were applied directly into the leaf funnel of artificially infested sorghum plants. All three methods provided similar levels of plant protection. Grain yields were not significantly different from the non-infested controls and were again about seven times greater than those of the infested control plants. The powder appeared to persist in the leaf funnel of the plants right up to head formation, and may act as a type of slow release formulation. This will be tested in future trials, as will the persistence of the aqueous *B. t.* preparations.

(d) The susceptibility of newly hatched larvae to the *B. t.* strains chosen for field trials was tested in laboratory experiments. Here, three *B. t.* treatment regimes were adopted, along with suitable controls: (i) treatment of *C. partellus* egg masses only, (ii) treatment of maize leaves placed in tubes containing *C. partellus* egg masses and (iii) treatment of egg masses and leaves. The eggs were treated in the blackhead stage, and the surviving larvae were counted 48 hours after hatching.

Larval mortality of 100% was obtained for all three treatments, compared to 0–5% mortality in the controls. The results indicate that the neonate larvae are highly susceptible to *B. t.* and ingestion of a small portion of the treated egg shell at hatching is sufficient to kill them. The data also show that if larvae ingest *B. t.* on plant material shortly after emergence, then death is very rapid and plant damage will thus be minimal. This is of obvious importance for the control of *C. partellus* in the field.

1.16.2 Busseola fusca

The susceptibility of other borer species to the three *B. t.* strains considered for *C. partellus* control was also investigated. Fifth-instar *B. fusca* larvae were collected from the field and placed on fresh sorghum stems dipped in *B. t.* suspensions. Mortality levels of 50–75% were obtained after 72 hours, but it must be stressed that not all of the larvae offered the sorghum stems actually fed on them, as they were in the diapausing stage. If mortality levels were adjusted only to the number of larvae which fed on the stems, then 80–100% mortality was obtained. *Busseola fusca* must, therefore, be considered as very susceptible to the selected *B. t.* strains, even when in the relatively resistant fifth-instar stage.

1.16.3 Spodoptera exempta

Commercial preparations based on the strain *B. t. kurstaki* are known to be ineffective against this pest. Research in

previous years has thus been directed towards the elucidation of toxic *B. t.* strains. Following the identification of three highly virulent strains in laboratory experiments, powders of each strain were produced to evaluate their efficacy in the field. Field trials were conducted against secondary outbreaks of this pest in the Lambwe Valley area of South Nyanza, near Mbita Point Field Station. The arrival of adult moths was monitored using a network of pheromone traps in a known outbreak area. This enabled the exact time and location of potential high population areas to be identified. Egg masses were then located by search.

The control strategy was initially directed towards neonate larvae by spraying egg masses and the surrounding vegetation with a *B. t.* preparation based on a new isolate, MF 4B-2, recovered from a Kenyan soil sample. This treatment reduced the larval population by 95%. Good control of second and third-instar larvae was obtained using spray applications of powder preparations of different *B. t.* strains: K 26-21, a new strain isolated in Kenya, on maize, and the AO-7 isolate of *B. t. aizawai* (from Japan), on millet. K 26-21 reduced the pest population by about 93% after 48 hours on maize seedlings at all concentrations tested. The AO-7 isolate, applied at a 2% w/v concentration, reduced pest populations by over 90% within 48 hours. Prophylactic spraying of infested grass areas surrounding a maize crop prevented the migration of older larvae into the crop.

The use of *B. t.* was minimised through these control strategies, and all crops were successfully protected from armyworm damage. Such an approach to the management of armyworm populations may be considered for use on small farms in Kenya.

1.17 EVALUATION OF FUNGAL PATHOGENS FOR THE CONTROL OF STEM-BORERS

N. K. Maniania

This study is the first stage of research on the pathogenicity of different strains of entomopathogenic fungi affecting the stem-borer complex in Kenya.

1.17.1 Isolation of entomopathogenic fungi

These are generally isolated from insect cadavers collected from the field or from field-collected insects that later die of mycosis during laboratory quarantine. The greater wax moth, *Galleria mellonella*, originally used to bait entomoparasitic nematodes, can also be used to pick up soil-borne fungi.

This method was tested at MPFS. Samples of soil were collected from eight localities in South Nyanza District and 20 larvae of *G. mellonella* were buried in portions of the soil in plastic lunch boxes (21 x 15 x 8 cm) which were then kept for 3 weeks at room temperature. Every week, diseased larvae were removed from the soil and insects with external fungal symptoms transferred to a moist chamber. Those without fungal symptoms were surface-sterilised with alcohol (70%) or sodium hypochlorite (1%) for 3 minutes and rinsed three times in sterile distilled water to allow further development of possible pathogens. Two fungal species have been isolated so far, *Beauveria bassiana* and *Metarhizium anisopliae* (Table 1.13). Two strains of *M. anisopliae* and one of *B. bassiana*, tested for pathogenicity against larvae of *Chilo partellus* and *Busseola fusca*, were virulent to both pests.

In conclusion, the "*Galleria* bait method" can be successfully used to isolate effective entomophagous fungi from the soil.

Table 1.13 Entomopathogenic fungi isolated from soil samples from S. Nyanza District using the "*Galleria* bait" method

Locality	Fungus	Number of larvae infected[†]
MPFS	*B. bassiana*	2
MPFS	*B. bassiana*	9
MPFS	*B. bassiana*	11
Migori	*M. anisopliae*	2
Oyugis	*B. bassiana*	1
	unidentified	1
Ungoye	*B. bassiana*	2
Isebania	–	0
Karachuonyo Kanam	–	0
Karachuonyo Kanam	–	0
Gwasi God Oloo	–	0

[†]Number of dead *G. mellonella* larvae with fungal infection, out of 20 larvae buried in the soil.

1.17.2 Susceptibility of C. partellus *to entomopathogenic Hyphomycetes*

The most important step in developing a fungus as a mycoinsecticide is the selection of the correct strain. For example, both *M. anisopliae* and *B. bassiana* have a wide range of hosts, but there are intraspecific differences in pathogenicity between isolates of the same species of fungus. The pathogenicity of fungi for hosts which are rarely or never attacked in nature can be tested experimentally with infections under controlled conditions.

Susceptibility of C. partellus *eggs, and larvae hatching from contaminated eggs.* Egg masses were infected in the laboratory with conidial suspensions of four isolates of *B. bassiana*, one isolate of *M. anisopliae*, and two isolates of *Paecilomyces fumosoroseus*. At a concentration of 10^8 conidia/ml, all the fungal strains tested, except ICIPE 1, caused more than 82% mortality of the egg masses; larvae of *C. partellus* hatching from treated eggs were also susceptible to all strains, except ICIPE 10 (Table 1.14). Dose-mortality relationships were demonstrated for the most active strains although the deferred larval mortality from egg masses treated with ICIPE 4 was 100%, whatever the dose. The influence of egg age on susceptibility to fungi was tested on egg masses aged 12, 24, 48 and 72 hours. The ability of fungi to infect eggs decreased with the age of the eggs. In contrast, larval mortality was not influenced by the age at which the egg was contaminated with *B. bassiana* (ICIPE 4) and *M. anisopliae* (ICIPE 18). Both isolates are therefore promising candidates to control the early stages of *C. partellus*.

Susceptibility of C. partellus *larvae.* Several strains of hyphomycete fungi were tested against *C. partellus* in the laboratory. Second-instar larvae were dipped in conidial suspensions containing 10^8 conidia/ml and mortality was

Table 1.14 Susceptibility of *C. partellus* egg masses to Hyphomycetes at a concentration of 10^8 conidia/ml

Fungal species	ICIPE strains	Egg masses[1] Hatched (%)	Killed by fungus (%)	Deferred larval mortality[2] (%)
B. bassiana	1	30.0	43.8	51.3
	2	0.0	88.8	66.3
	4	17.5	82.5	100
	12	15.0	82.5	91.3
M. anisopliae	18	0.0	100	
P. fumoso-roseus	10	8.8	90.0	18.8
	11	0.0	100	
Controls	untreated	93.5	0.0	16.6

[1]Mean of four replicates/treatment of 20 egg masses, 12 hours old.
[2]Mean of four replicates/treatment of 20 newly-emerged larvae hatched from treated egg masses; accumulated mortality due to fungus for 10 days after emerging.

then recorded daily for 10 days. The susceptibility of *C. partellus* larvae to fungal infection varied with the species and the strain. All isolates of *M. anisopliae* were pathogenic, killing over 78% of larvae (Table 1.15). In contrast, two isolates of *P. fumosoroseus* were not pathogenic. However, *B. bassiana* showed wide differences in pathogenicity between isolates. Two isolates out of seven induced high larval mortalities (90% and 100%), while two were moderate in their activity and three were considered non-pathogenic.

The time to 50% larval mortality varied from 2–5 days for all isolates of *M. anisopliae* and for four isolates of

Table 1.15 Susceptibility of *C. partellus* larvae to entomopathogenic fungi: mortality rates and time-mortality response of second-instar larvae exposed to 10^8 conidia/ml

Fungus	ICIPE strain	Mean larval mortality (%)[†]	Lethal time (days) 50%	90%
B. bassiana	1	16.3	–	–
	2	41.3	–	
	3	66.3	5	–
	4	90.0	<5	10
	12	71.3	<5	–
	35	100	<2	<5
	46	5.0	–	–
M. anisopliae	18	100	<2	<3
	19	80.0	<4	–
	20	78.8	<5	–
	30	96.3	3	8
P. fumoso-roseus	10	1.3	–	–
	11	28.8	–	–

[†]Four replicates of 20 second-instar larvae/replicate/treatment; natural mortality in untreated controls < 10%.

B. bassiana. The most virulent isolates induced at least 90% mortality within 3–10 days (Table 1.15). ICIPE 18 was the most pathogenic strain.

The most active strains of *B. bassiana* (ICIPE 4 and ICIPE 35) were isolated from the banana weevil *Temnoschoita nigroplagiata* and from soil, respectively. Although ICIPE 2 was isolated from *C. partellus*, its performance was poor. The original host of strain 18 is unknown, but strains 19 and 20 were isolated from soil, and strain 30 from *B. fusca*. This underlines the importance of careful selection of fungal isolates for biological test purposes. The bioassay results indicate that ICIPE isolates 4, 18, 30 and 35 hold much promise for the control of *C. partellus*.

Similar studies are in progress for *B. fusca* larvae. We are particularly interested in fungal strains which could have a broad spectrum of activity.

1.18 PREDATORS OF *C. PARTELLUS* EGGS

K. Ogedah

Preliminary studies have been carried out at Mbita Point Field Station to identify and evaluate major predators of *Chilo partellus* eggs on sorghum (cv. Serena), planted on a 20 x 20 m plot. Visual observations to check for predators started 3 days after plant emergence, and continued for about 2 weeks.

The predators collected were provisionally identified as *Diaperasticus erythrocephala*, *Chrysopa* sp. and several species of ants, beetles, and spiders. Ants (37.1%) and *D. erythrocephala* (31.4%) dominated the predator population, followed by *Chrysopa* sp. (22.8%), beetles (5.9%) and spiders (2.8%).

Attempts were made to rear *Chrysopa* sp. in the laboratory and study their life history. Laboratory diets consisted mostly of 30% sucrose solution for adults, and *C. partellus* eggs, supplemented with 30% sucrose, for larvae. It was found that the larvae take about 3 days before they hatch, and then need a further 9 days, on average, before pupating, followed by a period of about 9 days before the adults emerge.

More detailed studies are under way, but already it appears likely that this complex of predators plays a vital role in reducing *C. partellus* populations in the field.

1.19 TESTS OF A FUNGAL PATHOGEN FOR THE CONTROL OF THE CASSAVA GREEN SPIDER MITE

M. O. Odindo, L. O. Were, J. O. Obilo and J. A. Ongoma

It has been shown that the fungal pathogen *Hirsutella thompsonii* does not occur widely in natural field populations of the cassava green spider mite (CGSM), *Mononychellus tanajoa, (ICIPE 1988 Annual Report)*. A limited field trial of *H. thompsonii* was carried out in 1989 on cassava at Ogongo, about 25 km from Mbita Point Field Station. Six varieties of cassava were planted: Serere, Tamici, Kibandameno, Black, 46106/27 and Dodo. Starting about 1 month after planting, samples of leaves were taken every 2 weeks. The level of mite infestation

was determined by examining the leaves under a dissecting microscope.

At 5 months after planting, foliar sprays of *H. thompsonii* were applied on the varieties Kibandameno and 46106/27, followed by a second spray application 2 weeks later. Control plots were sprayed with distilled water. The pathogen suspension was prepared by scraping the top off the fungal growth on Sabouraud dextrose agar. This material was then macerated in a kitchen blender, filtered and made up to 10 litres in a Solo 455 sprayer.

The levels of infection and mortality in CGSM were monitored by sampling from the plots. The infestation of CGSM increased tremendously in March and April 1989 on all varieties, with 46106/27 and Kibandameno supporting the highest numbers. After these two varieties were sprayed with *H. thompsonii* in April, the populations of CGSM were reduced from 756 and 724 mites/plant on 46106/27 and Kibandameno, respectively, and to 141 and 188 mites/plant in May.

Similarly, there were records of higher numbers of mite cadavers on sprayed plots. In August, for example, the mean mortality of CGSM on sprayed plots of 46106/27 was 31.8% whereas on the control plots it was 0.8%. Examination of mite cadavers showed the presence of *H. thompsonii*. There were also indications that one or two applications of the pathogen in the field may be sufficient for prolonged subsequent mite control. Some 5 months after application of *H. thompsonii*, mortality of 81.6% was recorded on variety 46106/27, as compared to 20.4% in control plots. This factor is being investigated.

1.20 CLASSIFICATION OF THE CASSAVA GREEN SPIDER MITE, *MONONYCHELLUS* SP.

T. N. Murega

The cassava green spider mite (CGSM) is now an extremely important pest throughout the cassava belt of Sub-Saharan Africa. However, the identity of the mite is still controversial. Two species, *Mononychellus tanajoa* (Bondar) and *M. progresivus* Doreste, have been reported from Africa, identified by relating setal lengths to inter-setal distances for certain dorsal setae.

Recent indications are that perhaps only one somewhat variable, non-homodynamic, species occurs. Evidence for this comes from hybridisation studies *(ICIPE 1988 Annual Report)*, discriminant function analysis of female dorsal body setae *(ICIPE 1986 Annual Report)*, isoenzyme typing, and morphometric analysis of the ontogeny of setae from juvenile stages of the mite. It is also noteworthy that the aedeagii of all the CGSM males examined from Africa show the species to be *M. progresivus*. The aim of the present study was to elucidate the genotype involved in expression of the setae, as well as the genetic basis for the phenotypic expression of the male genital armature.

Samples were collected from six sites in Kenya where cassava growing is important in Coast, Eastern, Central, Nyanza and Western Provinces. The lengths of dorsal setae D1–D3 for the six founder lines (n = 6) as well as their diploid F_1 daughters (n = 180) were measured (Table 1.16). The inter-setal distances were also measured, analysed and classified. The males used in establishing the six strains (n = 6) as well as the parthogenetically-produced F_1 sons (n = 180) were monitored and the profile of the genital armature studied. The founder females and their daughters showed considerable variation in setal measurements and short, intermediate and long-setaed phenotypes were recorded (Table 1.16). The profiles of all the aedeagii examined were of the same shape suggesting the existence of only one species.

It is also clear, because none of the three phenotypes bred true, that setal inheritance is not under the control of a single dominant gene acting in a simple Mendelian fashion. The presence of three segregating phenotypes suggests a polygenic mode of inheritance involving three pairs of non-allelic genes. This implies that they are inherently unstable morphological characters. The present results are consistent with earlier observations on spider mites of the *Tetranychus urticae* group that the setae are never consistent in length, while the distances between them vary widely from one population to another. They may also shift, drop or add extra pairs during the course of development. The results therefore suggest that *M. progresivus* is the only species of CGSM in Africa.

1.21 EFFECT OF *CHILO PARTELLUS* DIET ON DEVELOPMENT OF *APANTELES SESAMIAE*

J. M. Chacko

This trial was conducted to compare the nature of development of the parasitoid *A. sesamiae* on *C. partellus* when the latter was feeding on a natural diet (sorghum) or on an artificial diet. Twenty fifth-instar caterpillars

Table 1.16 Mean dorso-central setal (D1–D3) measurements (μm) for females of six founder lines and inbred F_1 female progeny obtained from them

	Founder line				Inbred F_1			
	D1	D2	D3	S[1]	D1	D2	D3	S
Msambweni	31.5	40.0	45.8	+++	22.3	27.5	33.2	+++
Kitui	22.9	28.6	42.9	++	21.6	25.6	30.2	++
Embu	22.9	25.7	28.6	+	19.9	24.6	30.6	++
Rusinga	20.0	22.9	25.7	+	18.5	21.0	25.7	+
Busia	25.7	28.6	31.5	++	20.3	25.5	31.3	+++
Siaya	25.7	28.6	37.2	+	17.6	21.4	26.2	+

[1]Setal form: + short, ++ intermediate, +++ long.

feeding on sorghum stems in the laboratory were each placed in a glass vial (7.5 x 2.5 cm), along with a portion of tunnelled stem. Twenty fifth-instar caterpillars feeding on an artificial diet were offered pieces of sorghum stem for 14 hours in individual vials. (Earlier observations showed that the parasitoid was not easily attracted to the host in the absence of host plant material.) One mated, 1-day-old *A. sesamiae*, obtained from field-collected *Busseola fusca*, was introduced to each of the vials for 10 minutes, after which the parasitoids were removed and the caterpillars allowed to develop on their original diet.

Soon after introduction into the vial, the parasitoid located the host frass on the stem. After vigorously antennating on the frass, it entered the stem and remained within for periods varying from a few seconds to 1–2 minutes and in one case up to 5 minutes. Sometimes the caterpillar came out of the tunnel; at other times it pushed the parasitoid out of the tunnel. In three cases, the caterpillar killed the parasitoid by chewing it, though in two of them the caterpillars were successfully parasitised.

The duration of development of the immature stages was the same in caterpillars feeding on a natural diet (mean ± s.d., 18.4 ± 1.0 days) as on an artificial diet (18.0 ± 1.5 days). Out of 20 caterpillars in each case, ten raised on natural food were parasitised and yielded adults (mean 20.6 ± 4.1) compared with six raised on artificial food (mean 17.7 ± 5.2). The ratios of males to females were 1:2.1 and 1:1.8 respectively.

1.21.1 Response of Apanteles sesamiae *to frass of the host borer insect*

One-day-old mated females of *A. sesamiae* were released individually in petri dishes containing fresh frass of *C. partellus* or *B. fusca* feeding on sorghum or maize, in order to study the response of the parasitoid to the frass. Twenty parasitoids were maintained for each of the following treatments: (a) frass of *C. partellus* feeding on sorghum, (b) frass of *C. partellus* feeding on maize, (c) frass of *B. fusca* feeding on maize and (d) frass of *B. fusca* feeding on sorghum.

After releasing the parasitoid into the petri dish, its activities were observed for 5 minutes and points awarded as follows:

Approaching the frass..... 1 point
Antennation of frass..... 1 point
Attempt to oviposit..... 5 points.

Statistical analysis showed no difference in the response of the parasitoid to the different treatments.

1.22 COMPETITION BETWEEN PUPAL PARASITOIDS OF *C. PARTELLLUS*

M. J. Chacko and K. Ogedah

Since *Tetrastichus sesamiae* attacks pupae of *Chilo partellus* in the laboratory, the purpose of this study was to find out the nature of the competition, if any, between *T. sesamiae* and other pupal parasitoids of *C. partellus*.

Forty healthy pupae of *C. partellus* were individually exposed to 1-day-old *T. sesamiae* for 3 hours. Immediately thereafter 20 were re-exposed to 1-day-old *Pediobius furvus* for 3 hours and then allowed to develop. From the 20 pupae exposed to *T. sesamiae* only, moths emerged from 11 and parasitoids from eight, there being neither from one. From the other batch of 20 pupae, moths emerged from six, *T. sesamiae* from eight and *P. furvus* from six.

The study is being continued with host pupae of different ages and with different intervals of parasitism by the two species.

1.23 FACTORS CONTROLLING EGGS AND LARVAE OF *C. PARTELLUS*

M. J. Chacko and K. Ogedah

A field trial has been initiated to assess the role of: (a) *Trichogramma* sp. alone, (b) *Trichogramma* sp. plus predators and other factors and (c) predators and other factors, in the control of eggs and young caterpillars of *Chilo partellus*.

1.24 BIOLOGY OF *TRICHOGRAMMA* SP. NR. *MWANZAI*

Lu Quing Guang† *and K. Ogedah*

This study continues the evaluation of *T.* sp. nr. *mwanzai (see ICIPE 1988 Annual Report)* and covers bioecological aspects of a native strain. Field surveys have shown that this species is more abundant than the other species of *Trichogramma* in western Kenya.

The development and fecundity of the parasitoid on *Chilo partellus* eggs aged 0 and 2 days were not different. However, on 3-day-old eggs the number of parasitoid progeny declined, and no progeny were produced from 4-day-old eggs.

Peak emergence of adult parasitoids occurred during the morning between 0700 and 1100 hours. Host selection by *T.* sp. nr. *mwanzai* was compared using eggs of *C. partellus*, *Busseola fusca* and *Eldana saccharina* (the three important cereal stem-borers in this region). The studies were also extended to the silkworm *Bombyx mori* and the grain moth *Ephestia kuhniella*. The eggs of *C. partellus* were most preferred, while *B. mori* was not accepted. Under natural conditions, *T. mwanzai* also failed to parasitise *B. fusca* eggs, although there was no significant difference in parasitisation compared to *C. partellus* when the eggs were artificially exposed.

A life and fertility table was constructed for *T.* sp. nr. *mwanzai* in the laboratory. It indicated that the maximum longevity for the wasp was 6 days and the maximum reproductive period was 4 days. This native parasitoid had a net reproductive rate (r_o) of 49.66 and an intrinsic rate of increase (r_m) of 0.43.

†*Postgraduate Research Fellow, until October 31 1989.*

INSECT MASS REARING TECHNOLOGY UNIT (IMRT)

1.25 REARING THE MAIZE STEM-BORER, *BUSSEOLA FUSCA*, ON AN ARTIFICIAL DIET

F. O. Onyango

The incidence of larval diapause and the lack of an artificial diet have been major constraints in the rearing of *B. fusca* continuously in the laboratory. A successful insect pest control programme relies on the availability of high quality experimental insects in sufficient numbers, at specified times and stages of development. Hence, during 1988 and 1989, the major emphasis of IMRT at Mbita Point Field Station has been directed towards developing an artificial medium to rear *B. fusca* for continuous and sustained production in order to supply the insects to other parts of the Crop Pests Research Programme.

Five successive insectary generations of *B. fusca* have been reared on the artificial diet with minimum intervening larval diapause. The insect's biological performance is summarised in Table 1.17.

Busseola fusca larvae appear to have become increasingly adapted to the artificial diet over time, probably through selection pressure. The later generations are now being perpetuated only by non-diapausing larvae.

Studies on oviposition were postponed because of protracted problems in synchronising pupation and eclosion. These issues will be the subject of a separate study.

ICIPE-IRRI RESEARCH PROJECT

In accordance with the recommendations of the ICIPE Governing Board, a work plan of activities was signed by ICIPE and IRRI on August 8 1987. ICIPE collaborates with IRRI in various aspects of basic work leading to the control of some important pests of rice, especially chewing types of insect such as leaffolders (in all rice growing environments), and stem-borers (with special emphasis on deep water rice). The studies will provide an understanding of tropical pest biology, causes of abundance, crop losses and the design of pest management techniques.

In 1989, our studies included biochemical bases of insect resistance, behaviour and biology of the rice leaffolder on selected rices, stem-borer behaviour on callus initiated from susceptible and resistant rice varieties, effect of incidence of rice leaffolders on yields of selected susceptible, moderately resistant and resistant rice varieties, mating behaviour of rice leaffolders and use of virgin females for monitoring field populations, insect pheromones, and attraction of rice insect pests to different colours.

1.26 STUDIES ON THE BEHAVIOUR OF RICE LEAFFOLDERS *CNAPHALOCROCIS MEDINALIS* AND *MARASMIA PATNALIS*

Z. R. Khan and R. Ramachandran

1.26.1 Behaviour of C. medinalis *on susceptible and resistant rice varieties*

Adult rice leaffolders, *Cnaphalocrocis medinalis*, did not exhibit any ovipositional preference between resistant TKM 6 and *Oryza perennis* and susceptible IR 36 and Rexoro plants, in choice and no-choice tests. Eggs were laid mostly 10–15 cm away from the tip of outer leaves. However, a large proportion of first instars were observed feeding on the slightly folded whorl leaf in all varieties (Figure 1.3A). When first-instar larvae were given a choice of whorl leaf and outer leaf of the same variety, significantly more larvae settled on the whorl leaf of TKM 6 and IR 36 whereas no preference for the whorl leaf was observed in Rexoro and *O. perennis* (Figure 1.3B). Larval survival

Table 1.17 Performance of *B. fusca* reared on artificial diet for five successive generations

	Generations				
	1	2	3	4	5
Percent survival to pupal stage	38.2 (110)[1]	41.0 (117)	33.6 (226)	42.4 (430)	69.6 (46)
Mean larval period (days)	70.0 (43)	64.8 (48)	48.0 (82)	49.1 (136)	44.8 (31)
Growth index[2]	0.5	0.6	0.7	0.9	1.6
Mean pupal period (days)	14.5 (13)	14.9 (35)	13.9 (70)	15.1 (95)	14.8 (23)
Mean pupal weight (mg)					
Male	141.0 (7)	152.1 (22)	160.4 (33)	150.3 (47)	172.6 (16)
Female	145.4 (8)	184.9 (17)	189.7 (39)	163.2 (60)	193.6 (10)
Mean adult longevity (days)					
Male	4.8 (5)	5.0 (17)	4.6 (930)	5.0 (3)	4.8 (5)
Female	3.0 (17)	4.6 (17)	4.4 (34)	4.7 (3)	4.2 (7)
Sex ratio (M:F)	1:1.0 (14)	1:1.2 (37)	1:1.2 (68)	1:0.7 (97)	1:0.6 (17)

[1]Figures in parentheses are the numbers of insects evaluated.
[2]Growth index = (% survival to pupal stage)/(mean larval period).

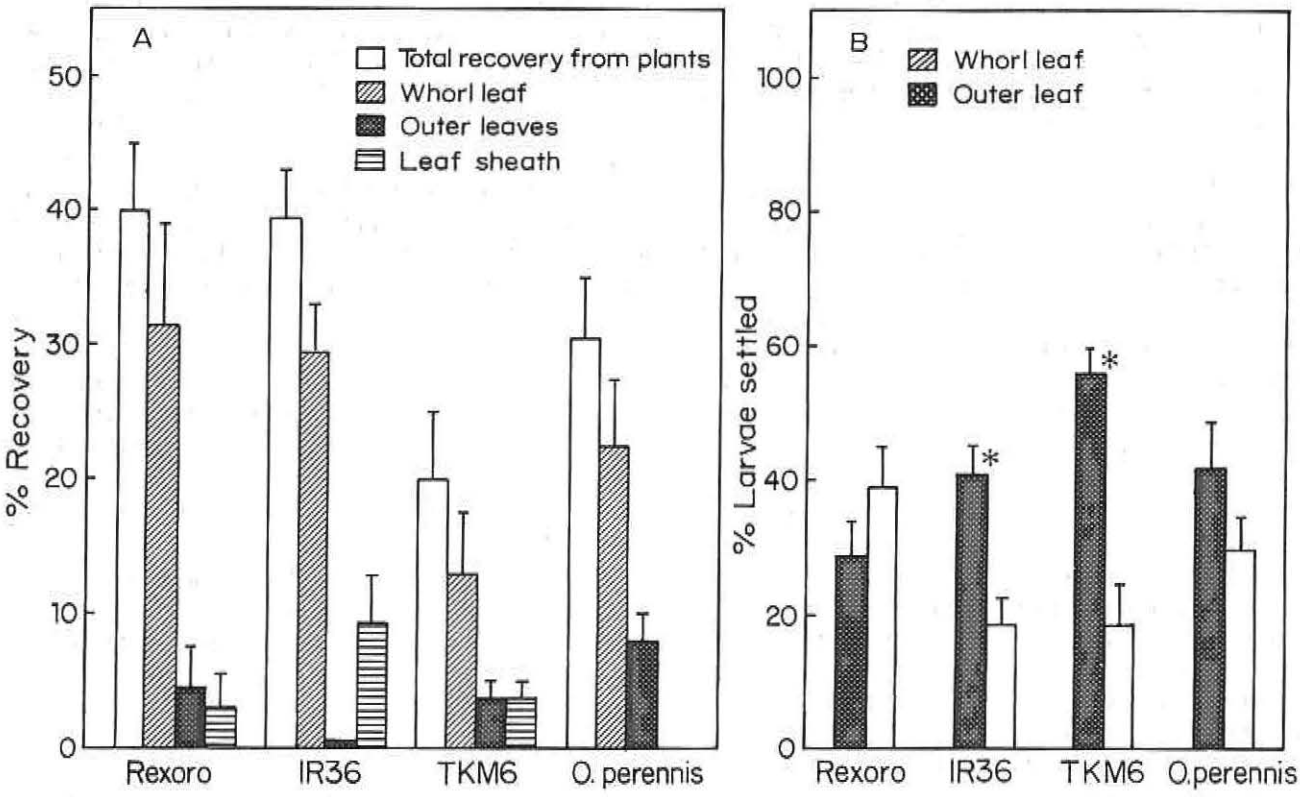


Figure 1.3 (A) Recovery and within-plant distribution of first-instar *C. medinalis* larvae on susceptible (IR 36 and Rexoro) and resistant (TKM 6 and *O. perennis*) rice plants and (B) settling behaviour of first-instar *C. medinalis* larvae in a choice test between whorl leaf and outer leaf in a laboratory bioassay. Bars show standard errors. (*Significant preference for whorl leaf, $P < 0.05$.)

and weight gain was higher on the whorl leaf compared with outer leaves. In the insectary, recovery of first-instar larvae 24 hours after artificial infestation was higher on susceptible varieties than on resistant varieties (Figure 1.3A). Observations on the movement of first-instar larvae from outer leaves to the whorl leaf indicated that on TKM 6 they took longer to reach the new leaf than on susceptible IR 36. Leaf characteristics such as trichomes (more abundant on TKM 6) hinder within-plant movement of first instars to the preferred feeding site (the whorl leaf). This may be considered as one possible mechanism conferring resistance against leaffolders on some rice varieties.

1.26.2 Modulation of phototactic behaviour of C. medinalis *larvae by plant factors*

First-instar larvae of *C. medinalis* oriented upwards on a vertical filter paper and downwards on a rice leaf when the light was coming from above, and the direction of orientation on these two substrates was reversed when the light came from below (Table 1.18). Reversed orientation persisted when the substrates were held horizontally with the light coming from one side. No difference was observed in the magnitude of this reaction on susceptible and resistant rice varieties, but on non-host grasses the directional orientation was lost. Application of rice plant steam distillates caused a dose-dependent decrease in the phototactic reaction of larvae on filter paper, while application of 500 ppm of the extract on dried rice leaf caused loss of orientation. Application to

Table 1.18 Modulation of the phototactic behaviour of first-instar *C. medinalis* larvae by plant factors

	Reaction index†	
Experimental conditions	Rice leaf	Filter paper
Substrate vertical, light from above	–60	92
Substrate vertical, light from below	–61	46
Substrate vertical, no light	8	36
Substrate horizontal, light from one side	–50	40
Substrate horizontal, no light	–4	–11

†$\frac{\text{(No. of larvae on light side – no. on dark side)}}{\text{(Total no. released)}} \times 100$

the filter paper of a mixture of seven volatile chemicals identified from rice also caused a decrease in phototaxis. It is concluded that rice plant volatiles, along with some other hitherto unidentified rice plant factor, cause a reversal of the normal reaction to light which leads to downward orientation on rice leaves. Attempts are under way to utilise this phenomenon in simple bioassays to identify possible varieties showing resistance to leaffolders.

1.26.3 Orientation of C. medinalis *larvae to plant volatiles*

The orientation was studied of first-instar larvae to selected volatile chemicals, identified in the head-space collection over susceptible rice plants. First instars were tested in a Y-tube bioassay with 10 µl of 10^{-3} mg/ml and 10^{-4} mg/ml

solutions of 1-hexanol, *cis*-(3)-hexen-1-ol, hexanal, myrcene, d-limonene, pinene, *trans*-caryophyllene, cineole, and a mixture of all these compounds. Only d-limonene at 10^{-3} mg/ml attracted significantly more larvae than the control, but the increase was only 18%.

1.26.4 EAG responses of adult leaffolders to rice plant volatiles

Rice plant volatiles extracted by molecular distillation elicit significantly high electroantennogram (EAG) responses in rice leaffolders (*ICIPE 1988 Annual Report*). A total of 97 volatile chemicals have now been evaluated for the EAG responses of males and females of the sympatric leaffolder species *C. medinalis* and *M. patnalis*. The chemicals comprised aliphatic saturated and unsaturated aldehydes and alcohols, and aliphatic hydrocarbons, ketones, monoterpene alcohols, epoxides, sesquiterpenes, and aromatic compounds. The responses of both species were similar to all compounds except three monoterpenes and two sesquiterpenes. Responses of *M. patnalis*, an oligophagous leaffolder, were higher than those of the polyphagous *C. medinalis*. In both species, EAG responses of males to saturated and unsaturated aliphatic aldehydes were significantly higher than those of conspecific females, whereas the latter responded more to monoterpenes.

In both species and both sexes, high EAG responses were recorded for compounds of the green leaf odour complex. Nonanal and hexanal were the most active aliphatic aldehydes, while 1-hexanol elicited the highest response among the alcohols tested. The EAG responses to terpenes were equal to the response to 1-hexanol. All compounds tested elicited a negative EAG potential except thymol and carvacrol which were positive (Figure 1.4).

It was concluded that both sexes respond to plant volatiles and that the monoterpenes terpineol, myrtenal and citronellal may be kairomones for the leaffolders. Compounds eliciting high EAG responses are being tested in field cages for trapping efficiency. Since males alone also responded to several compounds, the possibility is being explored of integrating plant volatiles with pheromones to increase the efficiency of pheromone traps.

1.26.5 EAG responses of leaffolders to pheromones

In an effort to identify the pheromones of rice leaffolders, male moths of *M. patnalis* and *C. medinalis* were tested for their EAG responses to 21 pheromone standards. Z13-18Ac and Z11-16Ac were identified as possible pheromone components of both species. *Marasmia patnalis* responded twice as strongly to Z13-18Ac as *C. medinalis* did, but the situation was reversed for Z11-16Ac. Thus, both leaffolders appear to use the same two chemicals as pheromone components, probably in different proportions to maintain species isolation. Field experiments are under way to determine the pheromone blend that gives maximum trap catches and to compare its efficiency with that of virgin females.

1.26.6 Bioassay of caryophyllenes against C. medinalis

Trans-caryophyllene, a sesquiterpene that occurs in rice plants, has been shown to vary in concentration between susceptible and resistant varieties. The pure chemical was bioassayed to elucidate its behavioural and physiological effects on *C. medinalis*. Caryophyllene oxide, derived from, *trans*-caryophyllene, adversely affected the spinning behaviour and settling behaviour of first- and third-instar larvae, and the oviposition behaviour of adults. Caryophyllene oxide also had antifeedant and growth-reducing effects on third-instar larvae.

1.26.7 Responses of C. medinalis *to rice plant resistance*

Oryza brachyantha, a wild rice of West African origin, was found to be highly resistant to rice leaffolders. To understand the causes of this resistance, studies were undertaken on the physiological and behavioural responses of *C. medinalis* leading to its establishment on IR 31917-45-3-2 (rice parent), *O. brachyantha* and their F_1 progeny (Table 1.19). *Cnaphalocrocis medinalis* adults exhibited a strong ovipositional preference for the rice parent when presented with both parents and their offspring. In a no-choice ovipositional assay, fewest eggs were laid on the wild rice. Wild rice and F_1 both suffered significantly less damage than the rice parent. No pupation occurred on wild rice, and all insect growth parameters were adversely affected on F_1. In laboratory choice experiments, first-instars and third-instars settled preferentially on the rice parent and the standard resistant check (TKM 6) when presented with these plus wild rice and F_1. Similarly, in time-course experiments on larval settling and dispersal, within 10 minutes of release significantly fewer larvae were recovered on the wild rice and the F_1, as compared

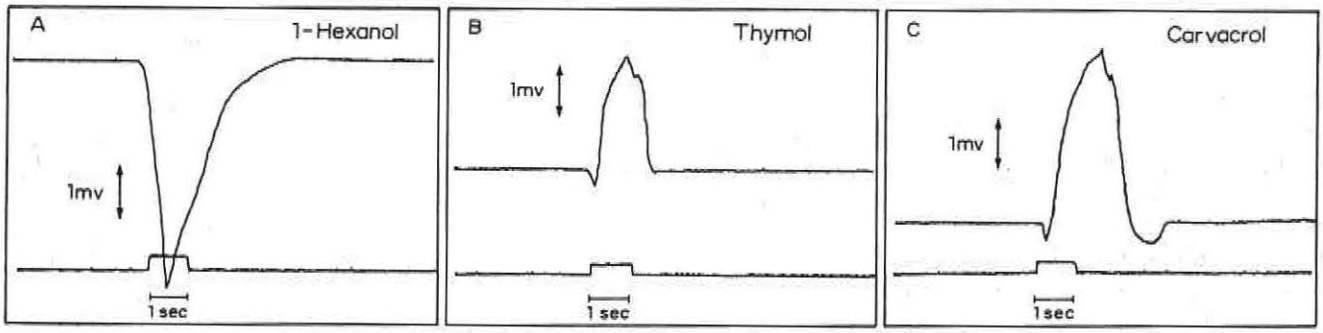


Figure 1.4 (A) Fast-negative potential elicited by 1-hexanol, and positive potentials elicited by (B) thymol and (C) carvacrol plant volatiles in *C. medinalis*.

Table 1.19 Behavioural and physiological responses of *C. medinalis* larvae to rice cultivar IR 31917-45-3-2, *O. brachyantha* and their F_1 progeny

	Ovipositional responses		Larvae	Damage	Pupation	Pupal wt.
	No choice[1]	Choice test[2]	settled[3]	rating[4]	(%)	(mg)
IR 31917-45-3-2	170[a]	73[a]	74[a]	8.7[ab]	71[a]	20.8[a]
Oryza brachyantha	40[c]	5[c]	5[c]	0.3[d]	0[c]	–
F_1	83[b]	22[b]	21[b]	2.3[c]	36[b]	14.8[c]
IR 36 (susceptible)	–	–	–	9.0[a]	70[a]	21.2[a]
TKM 6 (resistant)	–	–	–	7.3[b]	62[a]	17.6[b]

Within-column means followed by the same letter do not differ significantly ($P > 0.05$).
[1]Number of eggs/5 females/2 days.
[2]Percentage of eggs laid/5 females/2 days.
[3]Percentage of first instars settled in a multiple choice test.
[4]On a scale of 0–9.

to the rice parent and the standard resistant check (Figure 1.5). These results indicate that resistance in *O. brachyantha* is due to strong antixenosis and antibiosis mechanisms, part of which have been successfully transferred to the F_1. Efforts are under way to identify the biochemical basis of resistance in the wild rice.

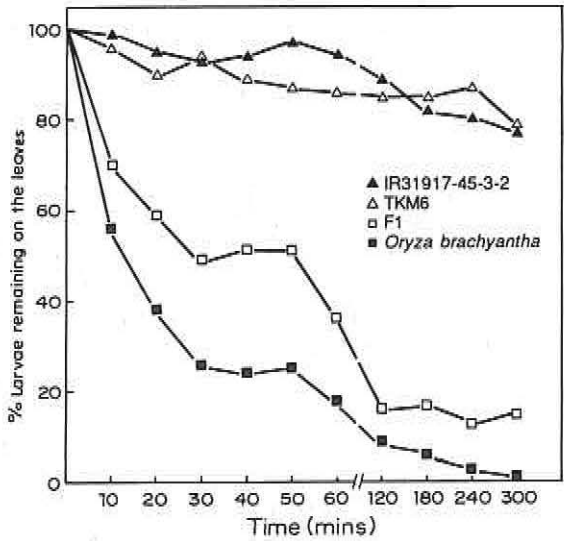


Figure 1.5 Settling and dispersal of first-instar *C. medinalis* on rice parent (IR 31917-45-3-2), wild rice (*O. brachyantha*), their F_1 hybrid and the standard resistant check, TKM 6.

1.26.8 Effects of silica on larval feeding and settling responses

The presence of silica in plant tissues, by wearing out the mandibles, makes it harder for stem-borers and leaffolders to feed.

Seedlings of the susceptible rice variety LMN III were grown in nutrient solutions containing different levels of silica. After 45 days the leaves were cut into 2-cm lengths. The leaf pieces were infested singly with neonate larvae of *C. medinalis* pre-weighed to 0.001 mg. After 48 hours the larvae were weighed again.

At higher concentrations of silica there was a significant decrease in larval weight gain compared to the controls (Table 1.20), due to reduced feeding. This was also reflected in the leaf area consumed from treated plants. The presence of silicated cells on the leaves inhibited scraping of the green tissue by feeding larvae. No significant differences were found, however, in the settling response of third-instar larvae on treated and untreated leaves.

Table 1.20 Percent weight gains after 48 hours of neonate *C. medinalis* larvae fed on silica-treated leaf portions (average of 10 larvae per treatment)

Amount of silica (ppm)	Weight gain (%)	Difference from control[†]
0	140.9	–
5	112.0	28.9[ns]
10	112.1	28.7[ns]
25	72.0	68.9**
50	94.4	46.5*
100	98.7	42.2*

[†]*t*-test: [ns]no significant difference; $*P < 0.05$; $**P < 0.01$.

1.26.9 Comparison of leaffolder damage to rice varieties of different levels of resistance

Percent leaf damage and yield loss caused by *C. medinalis* and *M. patnalis* were compared on a susceptible variety IR 36, moderately resistant variety IR 4707-106-3-2, and a resistant variety TKM 6 at infestation levels of 0, 10, 20 and 30 larvae per hill. Field plots of 10.5 m^2 were encaged from transplanting until harvest to prevent damage by other insects, as well as escape of the artificially introduced leaffolder larvae. Differences in percent leaf

Table 1.21 Mean leaf damage and mean yield, at different infestation levels

Infestation (larvae/hill)	Mean leaf damage (%)	Mean yield (g/plot)
0	0.0[c]	1668.7[a]
10	4.5[b]	1848.2[a]
20	7.8[a]	2000.3[a]
30	9.7[a]	1932.5[a]

Within-column means with the same letter do not differ significantly ($P > 0.05$).

Table 1.22 Biology of *C. medinalis* on susceptible IR 36 and resistant TKM 6 rice varieties

Variety	Larvae pupating (%)	Growth period (days)	Pupal growth index	Adult weight (mg)	Longevity female (days)	Longevity male (days)	Fecundity (eggs/female)
IR 36	93	18.2	5.1	21.4	7.5	8.2	86.6
TKM 6	81	19.1	4.2	17.9	9.0	8.6	99.6
Difference†	12**	0.9**	0.9**	3.5**	1.5^{ns}	0.4^{ns}	12.8^{ns}

†*t*-test: ^{ns}no significant difference; ** $P < 0.01$.

damage by the two species were not significant, but there were significant differences among the four levels of infestation (Table 1.21). In the yield trial, however, no significant differences were found either between species or among levels of infestation. The high dosage of nitrogen applied (120 kg/ha) may have enabled the rice crop to compensate for whatever damage was caused by the leaffolders.

1.26.10 Biology of C. medinalis *and* M. patnalis *on a susceptible and a resistant rice variety*

Variety IR 36 was used as a susceptible check and TKM 36 as a resistant check. For each variety, one hundred *C. medinalis* were reared to pupation in individual cages on the rice plants. Larval survival, growth index and pupal weight were all significantly higher on the susceptible than on the resistant variety (Table 1.22), and the growth period was shorter. Adult emergence was 55% and 31% respectively. Longevity of each sex and fecundity did not differ significantly on the two varieties.

Larval settling response and subsequent adult emergence was also investigated on these two rice varieties, with and without choice, and singly and in competition, for *C. medinalis* and *M. patnalis*.

1.23.11 Weeds as alternative hosts for rice leaffolders

Several species of weeds present in rice fields are reported to be alternative hosts for rice leaffolders. Pairwise comparisons were made of settling preference, feeding rate and food assimilation of 24 individual third-instar larvae of *C. medinalis* and *M. patnalis* on plants of 12 major graminaceous weed species versus rice varieties IR 36 (susceptible) and TKM 6 (resistant) (Figure 1.6).

For six weed species, the proportion of *C. medinalis* settling did not differ significantly from the proportion settling on either the susceptible or resistant rice varieties. For the remaining weeds settlement was significantly greater on one or both varieties of rice. *Marasmia patnalis* settled on fewer weeds than *C. medinalis*, and there were only two against which there was no significant bias compared to one or both varieties of rice (Figure 1.7).

1.26.12 Artificial diet for Marasmia patnalis

A total of 23 chemically-defined diets were formulated and tested for rearing *M. patnalis* larvae, including Pritam Singh's general purpose diet. One diet found to be promising contains agar-agar, white beans, wheatgerm, soy flour, infant-milk (Enfalac™), brewer's yeast, methyl-*p*-hydroxybenzoate, sorbic acid, tetracycline and

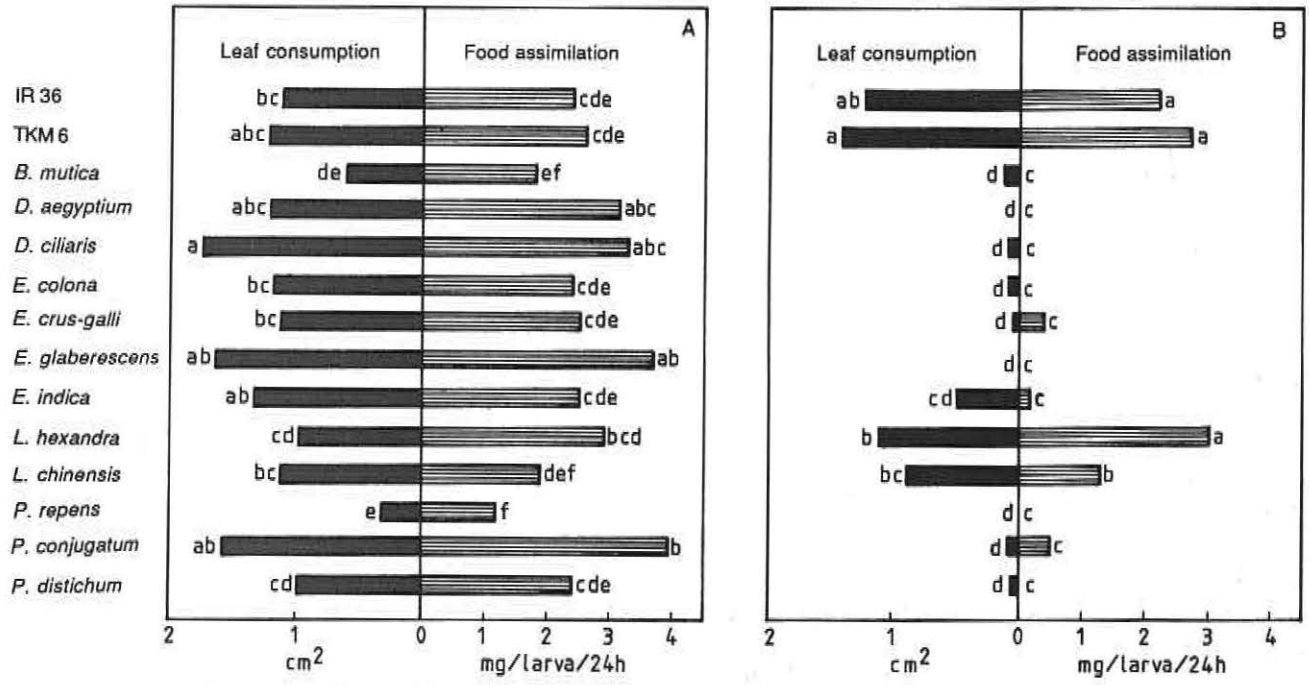


Figure 1.6 (A) Leaf consumption and food assimilation of third-instar larvae of *C. medinalis* and (B) *M. patnalis* on twelve graminaceous weed species. In each column, bars with the same letter do not differ significantly in value ($P > 0.05$).

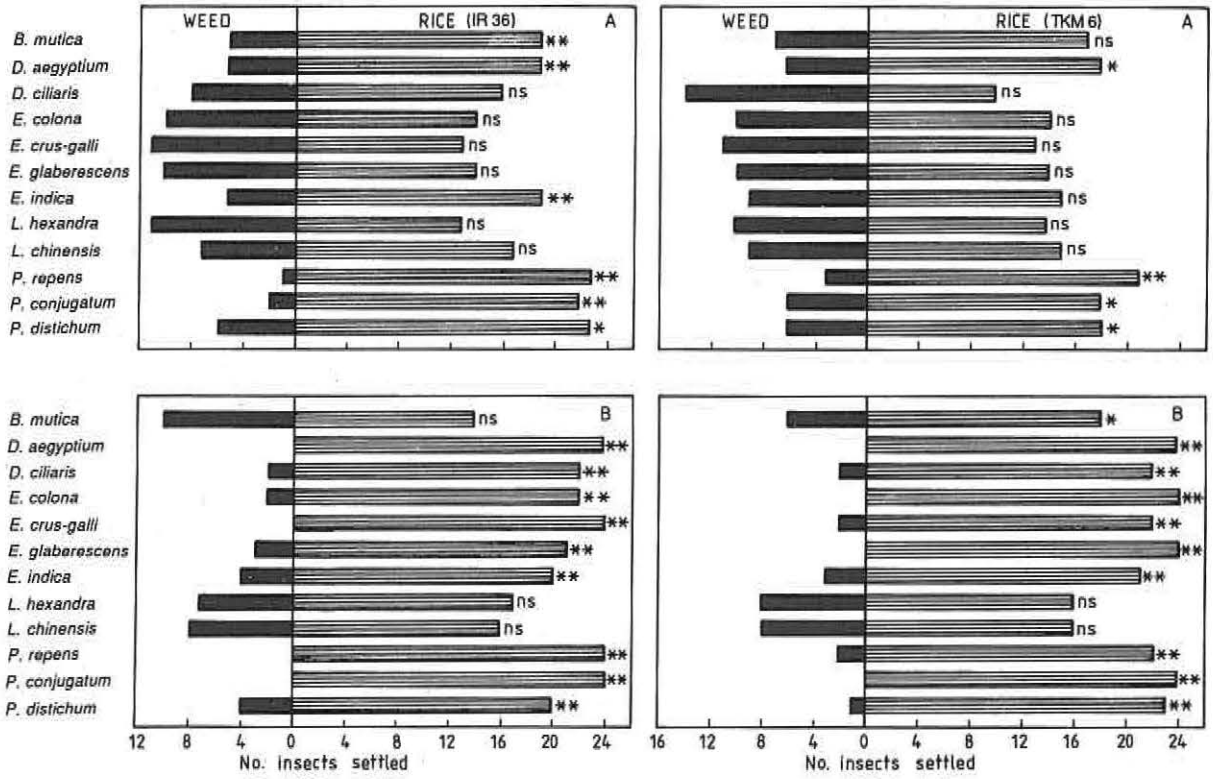


Figure 1.7 (A) Settling preference of third-instar larvae of *C. medinalis* and (B) *M. patnalis* between the susceptible IR 36 and the resistant TKM 6 rice varieties and twelve graminaceous weed plants.

formaldehyde. Neonate larval *M. patnalis* were placed singly in test tubes containing the diet and their feeding and growth observed. After 14 days on the diet 72% of the larvae survived; of these, half were able to moult to later instars and pupate. Further testing and modification of this diet is under way with regard to diet efficacy, microbial contamination and rate of larval development.

1.26.13 Mating behaviour of Marasmia patnalis

The mating frequency of same-aged pairs of *M. patnalis* moths 0–7 days old was observed in the laboratory under a 12 hour light:12 hour dark cycle. Mating occurred in all pairs, except those less than 1 day old.

In a 75 x 25 m² field, water traps were baited with virgin females to determine their attractiveness to conspecific males. Two virgin females of randomly chosen age (1, 2, 3 or 5 days) were released in each water trap, and catches were counted the following day. Results show that at a low natural population there is no significant difference in the number of male *M. patnalis* collected in relation to the age of the bait female.

1.27 STUDIES ON THE BIOLOGY OF THE YELLOW STEM-BORER, *SCIRPOPHAGA INCERTULAS*

Z. R. Khan and R. Ramachandran

1.27.1 Yellow stem-borer pheromone

Re-analysis of the pheromones of *S. incertulas* females revealed the presence of two more compounds — *cis*-13-octadecanal and *cis*-11-hexadecanyl-1-acetate — in addition to the already identified *cis*-9-hexadecanal and *cis*-11-hexadecenal. These four compounds are present in the ratio of 1.15:0.1:1.0:3.4 respectively. Electro-antennogram analysis showed that they elicit very high responses in *S. incertulas* males.

1.27.2 Effect of silica on the penetration behaviour of first-instar larvae on rice

Silica is known to impart resistance to feeding and penetration of stem-borer larvae in several crop plants, including rice.

We determined the role of silica in rice varieties with varying degrees of resistance to *S. incertulas* penetration. In one trial, LMN 111, a borer-susceptible deepwater variety, was used as the test plant. Seedlings were grown on nutrient solutions with varying levels of silica and penetration of larvae was observed. Average penetration time increased with the level of silica supplied in the nutrient solution (Table 1.23), being shortest in control plants and longest in plants grown in solutions with 100 ppm silica. These differences could be attributed to the increasing amount of silica present in the plant tissues, as shown by analysis (Table 1.23).

In a second trial, larval penetration time was relatively longer on moderately resistant IR 36 than on susceptible Rexoro at all levels of silica enrichment (Figure 1.8). On resistant TKM 6, penetration time was much longer than for IR 36 and Rexoro plants. However, 10–20% of larvae failed to penetrate the stems of control as well as treated TKM 6 plants.

It can be concluded from larval penetration times that the addition of silica enhances the resistance of susceptible and moderately resistant rice varieties to yellow stem-

borer infestation. The resultant delay in penetration exposes the larvae to adverse environmental conditions, including attack by natural enemies.

Table 1.23 Penetration of yellow stem-borer larvae in LMN 111 rice variety grown in nutrient solution with different levels of silica (average of 30 larvae per treatment)

Treatment (silica levels, ppm)	Silica content in plant (%)	Penetration time (minutes)
0	0.46[e]	2.80[c]
5	0.67[e]	5.47[bc]
10	1.25[d]	6.10[bc]
25	2.31[c]	8.67[bc]
50	4.43[b]	10.80[b]
100	6.30[a]	21.23[a]

Within-column means followed by the same letter do not differ significantly ($P > 0.05$).

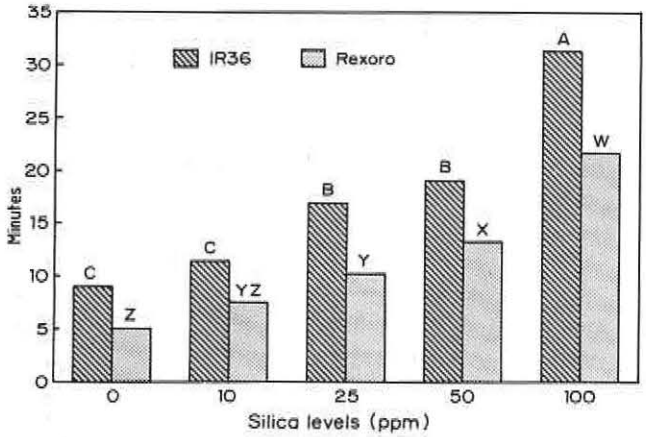


Figure 1.8 Penetration time of yellow stem-borer larvae in moderately resistant IR 36 and susceptible Rexoro plants grown in nutrient solution with different levels of silica (average of 20 larvae per treatment). Values with the same letter do not differ significantly ($P > 0.05$).

1.27.3 A parafilm sachet method for infesting rice plants with stem-borer larvae for varietal screening

A simple technique was developed to study the penetration behaviour of stem-borers. A parafilm sachet (5 x 5 cm) was attached to the stem of the test rice plant. A small cut was made at the corner of the sachet where the larvae were introduced; the cut portion was then sealed. This method assured uniformity in infestation level and also prevented larval escape from the test plant. Using this method, penetration time of yellow stem-borer larvae was studied in LMN 111, Rexoro, IR 36 and TKM 6. In the resistant variety TKM 6 a considerable number of larvae were not able to penetrate the plant, while in susceptible LMN 111 and Rexoro all the larvae penetrated. All the larvae also penetrated in IR 36, but the penetration time was longer than in Rexoro and LMN 111.

1.27.4 Settling behaviour on susceptible and resistant rice calluses

The settling behaviour of *S. incertulas* was studied on calluses of the susceptible strain Rexoro and resistant *Oryza ridleyi*. Free and no-choice bioassays were performed, introducing five and two newly-hatched larvae, respectively, in about 100 mg of callus of each variety placed in a Gelman petri plate. Twenty plates were used for each test and observations were taken 24, 48 and 72 hours after infestation.

In both tests the larvae indicated a marked preference, selecting and settling on susceptible rather than resistant calluses (Table 1.24). Plant morphological characters make no contribution to resistance when larvae are exposed to calluses alone. Biochemical properties may therefore be responsible for larval settling preferences. Resistance of rice genotypes could thus be reflected in larval settling behaviour on the callus.

Table 1.24 Percentages of yellow stem-borer larvae settled on susceptible Rexoro and resistant *O. ridleyi* calluses over time

Hours after infestation	Choice test		No-choice test	
	Rexoro	*O. ridleyi*	Rexoro	*O. ridleyi*
24	83.4	16.6	85.0	40.0
48	89.1	10.9	77.5	20.0
72	86.4	13.6	80.0	30.0

1.28 ATTRACTION OF RICE PESTS AND THEIR PREDATORS TO LIGHT OF DIFFERENT COLOURS

Z. R. Khan

In a preliminary experiment in 1988, the attractancy of light of eight different colours (ultraviolet, violet, blue, green, yellow, orange, red and white) was tested in light traps on twelve selected insect species (*ICIPE 1988 Annual Report*). Follow-up experiments were conducted for two seasons in 1989.

White light proved to be the most efficient colour tested (Figure 1.9). Compared to the others, white light traps attracted significantly higher numbers of plant-hoppers, leafhoppers and rice bugs, as well as predators—*Cyrtorhinus* sp., *Microvelia* sp., *Opius* sp. and members of the family Formicidae. White light and ultraviolet light were the most attractive to both leaffolders, *Cnaphalocrocis medinalis* and *Marasmia patnalis*, although very low catches of these two species were recorded. The same colours were also most attractive to the yellow stem-borer, *Scirpophaga incertulas* and the striped stem-borer, *Chilo suppressalis*.

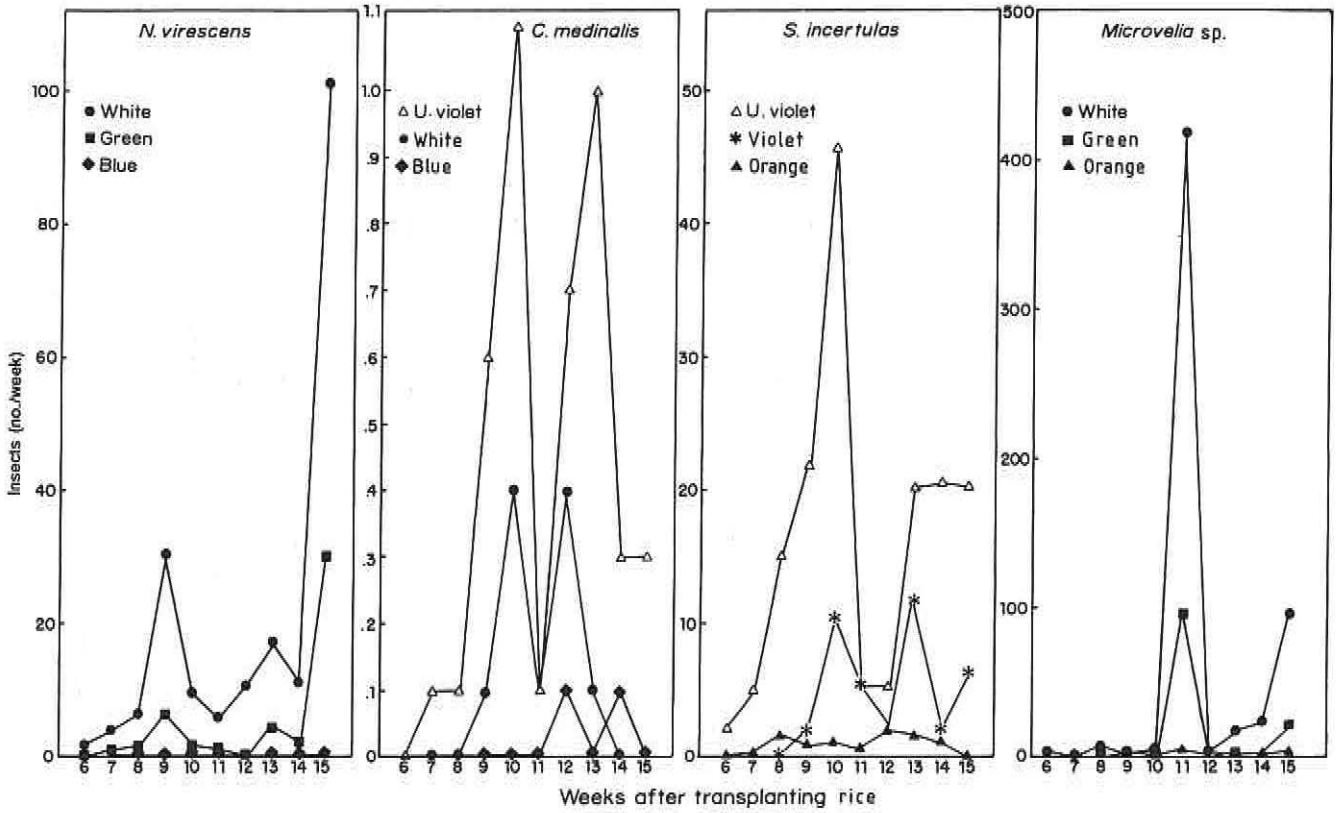
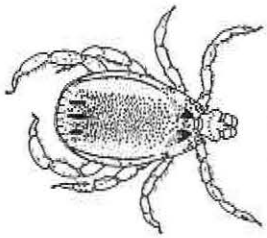


Figure 1.9 Average weekly catches of three selected rice pests and one predator (*Microvelia* sp.) in light traps of different colours.

The following insects were consistently attracted to particular light colours in both the wet season and the dry season: the green leafhopper *(Nephotettix virescens)*, the white-backed planthopper (*Sogatella furcifera*), *Cnaphalocrosis medinalis*, *S. incertulas*, *Cyrtorhinus* sp., *Opius* sp. and Formicidae. On the other hand, the rice bug *(Leptocorisa oratorius)*, the brown planthopper *(Nilaparvata lugens)*, *Chilo suppressalis*, *M. patnalis* and *Microvelia* sp. showed heterogeneous choices between seasons. Nevertheless, white light remained the most generally attractive for the insect species observed.

LIVESTOCK TICKS RESEARCH PROGRAMME



2 Livestock Ticks Research Programme

The Livestock Ticks Research Programme (LTRP) made progress in the quest for the control of ticks in Africa through integrated pest management. An Integrated Tick Management (ITM) programme with five components was established consisting of immunology, natural resistance, ecology, farm management and biological control; each component also contains subcomponents. One of the immunology subcomponents, an anti-tick vaccine, received about 60% of LTRP resources. The first phase of the screening of polypeptide antigens extracted from Rhipicephalus appendiculatus *was accomplished on cattle during the year. Eight of these antigens have been identified as vaccine candidates. All of them disrupted the feeding and oviposition capability of adult ticks which fed on vaccinated cattle, while six of them, in addition, disrupted the tick life cycle by preventing moulting of a large proportion of fed larvae. The vaccine candidates were found to prevent attachment of ticks, and vaccinated cattle did not develop a hypersensitive reaction. A considerable number of ticks also died through squashing or other causes. Salivary gland antigens did not confer direct protection on cattle but enhanced their state of natural resistance against tick infestation. It was also established that tick polypeptide antigens can be manipulated to serve such other purposes as distinguishing between cattle with high and low natural tick resistance and for immunological potentiation of natural resistance.*

Research on other components of ITM was intensified in 1989. At Mutara Ranch work continued on the selection of Boran cattle for tick resistance; a new herd of 100 yearling heifers has been selected for ranking for resistance. Long-term studies on naturally acquired resistance to tick infestation indicated that after prolonged exposure to the same tick species, the manifestation of decreased engorgement weight may be lost, probably due to the acquisition of immunological tolerance by the host. The concept of anti-tick pasture was developed for the ecological component; a cheap natural product was identified which showed promise as an efficient acaricide, as a sub-component of farm management; while indigenous breeds of chickens were found to be efficient predators of ticks with potential for use in biological control.

Research on the biology of R. appendiculatus *and* Amblyomma variegatum *was intensified with the aim of identifying other weaknesses and vulnerabilities which could be exploited in further ITM subcomponents. Studies on epidemiological-biological modelling of ticks were started with* R. appendiculatus *as the model. The development and survival studies in the Trans-Mara were completed, but those in Nairobi and Mbita Point will continue in 1990. Development and survival studies on* A. variegatum *in these contrasting biotopes also continued in 1989.*

Research activity continued at the field sites. Interesting results are emerging from the studies at Mariakani, especially on the question of the correct choice of dipping intervals for animals protected against East Coast fever through vaccination. A noteworthy achievement for the Programme is the acquisition by ICIPE of a site at Kuja River in South Nyanza as a field site.

2.1 PROGRESS IN THE ESTABLISHMENT OF INTEGRATED TICK MANAGEMENT (ITM) FOR TICK CONTROL IN AFRICA

O. O. Dipeolu, A. O. Mongi, D. K. Punyua, A. Latif, A. O. J. Amoo and S. M. Hassan

The focus is on *Rhipicephalus appendiculatus* and *Amblyomma variegatum*. The development of any technology based on integrated pest management must have a strong research base which serves as a fountain of knowledge to stimulate evolution of the components. Figure 2.1 shows the areas of tick research which serve as the source of information for the development of ITM. The Programme's research in each area is systematic and comprehensive, and leads to the identification of weaknesses and vulnerabilities in the biology of ticks. These are constituted into "tick population decreasing factors" from which the components of ITM evolve.

We have incorporated five components within the ITM (Figure 2.1). These are immunology, natural resistance, ecology, farm management and biological control. Each of these components consists of subcomponents and innovations. For example, the goal of studies on tick immunology is not confined to the production of anti-tick vaccine alone, but to other possibilities which can utilise tick polypeptide antigens as natural resistance potentiators and natural resistance selection mediators. The ecological component creates an "anti-tick pasture" based on vegetative management and tick trapping. The basis of the farm management component is improvement of those management practices which can decrease the tick population on the pasture and also on the animal. An innovation is that all the subcomponents are derived from indigenous-based husbandry practices which have been developed and long used by African farmers for tick control.

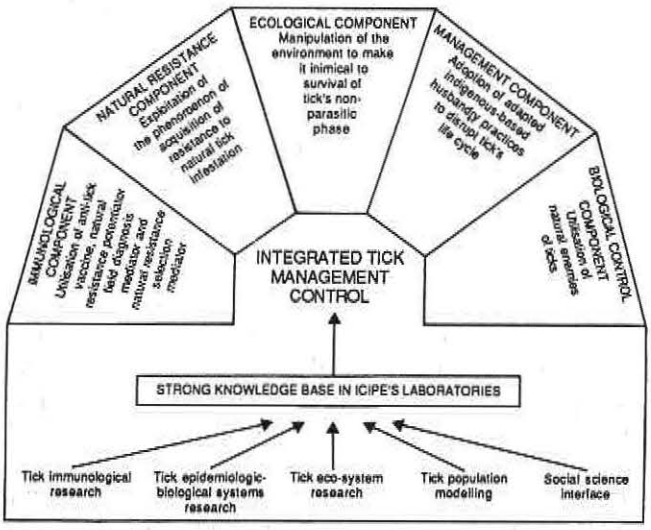


Figure 2.1 Components and inputs of the Livestock Ticks Research Programme (ITM) plan for integrated tick management and control.

It should be emphasised that the focus of the Programme's ITM is the natural resource rich farmers of Africa, otherwise referred to as "resource-poor farmers". This is a response to the reality of livestock production in Africa, where the various types of low-resource farming produce 94% of the livestock. The establishment of the Programme's ITM arose from a thorough understanding of the dynamics of livestock production in Africa. Among the basic factors in natural resource rich farming are that labour, land, water and capital are serious constraints, hence the term "resource-poor" which had been applied to such farmers. These farmers have to resort to the use of natural and local resources, in which the family or the household provide the critical source of labour, hence the term "natural resource rich farmers". The Programme has therefore made most of the subcomponents of the ITM cheap and simple enough to be implemented by the farmer and his household. Other characteristics of the ITM are:

(a) The subcomponents are adaptable to local, social and environmental conditions.
(b) It uses zero or very much reduced acaricides.
(c) It makes use of stored knowledge by taking existing agricultural practices as the starting point, i.e. the best of traditional technology for tick control is incorporated.

Arrangements have been concluded to validate the components in the field in various parts of Kenya in 1990.

2.2 PROGRESS IN THE PRODUCTION OF AN ANTI-TICK VACCINE

O. O. Dipeolu, A. O. Mongi, M. A. Nyindo, S. Essuman, E. I. P. Kamanga-Sollo and T. R. Odhiambo

The production of a vaccine against *Rhipicephalus appendiculatus* had top priority in 1989 and efforts towards this goal consumed about 60% of programme resources. Polypeptide antigens extracted from ticks by the Programme were screened in cattle. These antigens had been earlier shown to prevent successful feeding of *R. appendiculatus* on rabbits to varying degrees. About 14 polypeptide antigens from solubilised *R. appendiculatus* whole-tick extracts were screened, after purification with monoclonal antibody affinity and selection of gel permeation peak fractions. Two crude antigens, salivary gland extract and solubilised membrane-bound protein from the midgut of *R. appendiculatus*, were also screened. Freund's incomplete adjuvant was used with most of the antigens, the route of application was intramuscular, and the cattle used were Friesian and Boran x Friesian.

The conventional protocol was adopted with two boosters following the immunisation dose at intervals of 14 days. Adults, nymphs and larvae were used for tick challenge on each animal in order to simulate natural conditions as far as possible. Four cattle were used for each antigen with a corresponding number as controls. The biological parameters measured for determination of efficacy of each polypeptide antigen are comprehensive and are summarised in Table 2.1.

Table 2.1 Biological parameters of *R. appendiculatus* measured during immunisation experiments on cattle

Adult feeding strategy	Oviposition strategy	Larvae and nymphs
(a) Total no. fed	(a) Mean wt. of eggs	(a) Total no. fed
(b) Total no. rejected	(b) Mean no. eggs laid	(b) Total no. rejected
(c) Mean engorgement wt.	(c) Mean wt. per egg	(c) Mean engorgement wt.
(d) No. above critical engorgement wt.	(d) Convertible blood mass	(d) Mean engorgement period
(e) Mean mature wt.	(e) Oviposition efficiency	(e) Moultability (%)
(f) No. with pre-mature wt.	(f) Eclosion period	(f) Mean moulting period
(g) Mean pre-mating wt.	(g) Fed ticks which oviposit (%)	
(h) No. with pre-mating wt.	(h) Egg hatchability (%)	
(i) Mean engorgement period	(i) Mean unfed female wt.	
(j) Mean unfed male wt.		

Eight antigens, all from the solubilised whole tick extract, were firmly established as vaccine candidates. The protection of these vaccine candidates was effected through:

(a) Significant reduction in engorgement weight.
(b) Significant reduction in the number of adult female ticks reaching mature weight.
(c) Significant increase in the number of ticks which did not feed enough to attract males for mating.
(d) Significant reduction in the quantity of eggs laid by fed ticks.
(e) Significant reduction in the number of engorged females which oviposited.
(f) Significant reduction in egg hatchability.
(g) Suppression of tick population at least up to the second generation.
(h) Disruption of the tick life cycle through prevention of moulting in a very significant proportion of fed larvae.

The crude solubilised membrane-bound midgut antigen also showed early promise of being a vaccine candidate through significant reduction of engorgement weight and oviposition capability of ticks which fed on cattle vaccinated with it.

The vaccine candidates did not cause any sensitisation reaction in cattle. Long-term studies showed that the vaccine candidates stabilise themselves with time and consolidate their effect on the feeding strategy while they enhance their effect on the oviposition strategy of the tick. A summary of the characteristics of the eight vaccine candidates is shown in Table 2.2. A study of the mechanisms of protection of the vaccine candidates indicated that these consist of rejection of ticks through inability to attach, and death through squashing or other causes. Analysis showed that rejection of ticks constitutes the biggest component of protection, while deaths due to squashing and other causes are almost equal. Male ticks are also killed, especially on days 3 and 7 after exposure to vaccinated cattle.

An important finding of this investigation was the recognition of the role which tick salivary gland antigens may play in the overall strategy of protection of livestock against tick infestation with anti-tick vaccine. In our investigation, we found that salivary gland antigens derived

Table 2.2 Characteristics of the tick-derived polypeptide antigens established as vaccine candidates against infestation with *R. appendiculatus*

Parameter	Characteristic
Stages of tick affected	Adult, nymph, larva
Number of ticks engorging	Usually small
Engorgement wt.	Moderate: big reduction in no. of ticks with mature wt.; big increase in no. of ticks with pre-mating wt.
Oviposition	Large effect
Egg viability	Moderate effect: significantly reduced hatchability
Likely effect on tick population in the field	Strong prospect because: 1. Significant reduction in oviposition capacity up to the 2nd generation 2. Significant reduction in engorgement wt. up to the 2nd generation
Mechanism of protection	1. Rejection of ticks through inability to attach 2. Death due to squashing or other causes

from *R. appendiculatus* conferred no direct protection on cattle against successful feeding by this tick. However, the manifestations of natural resistance, especially reduced engorgement weight and number of eggs oviposited, were significantly enhanced in cattle immunised with salivary glands compared with non-immunised control cattle. This phenomenon was repeated during long-term studies with up to ten successive infestations. In addition, there was increased disruption of the life cycle during successive infestations through significant reductions in the proportion of immature stages which fed, and in the quantity of blood that they consumed. This is an indication that salivary gland antigens have the potential for being manipulated as "natural resistance potentiators", i.e. they increase the degree of natural resistance of the host to tick infestation. The right choice of adjuvant may be needed to eliminate the typical hypersensitive reactions in hosts caused by salivary gland antigens, before they

can be successfully used as natural resistance potentiators.

Studies on several other aspects of the biological activity of the vaccine candidates are in progress, while pilot field tests on their efficacy under natural conditions will take place in 1990.

2.3 *RHIPICEPHALUS APPENDICULATUS* POLYPEPTIDE ANTIGENS PURIFIED BY MONOCLONAL ANTIBODIES

A. O. Mongi, O. O. Dipeolu and T. R. Odhiambo

As the adverse effects of chemical pesticides in the environment become better known, the development of alternative methods of effective tick control has become an important area of research. One alternative, embracing biological control based on immunological principles and approaches, employs tick-derived immunogens. We obtained these by a series of chromatographic procedures, which were tedious and the results difficult to repeat. We therefore employed monoclonal antibodies (MAbs), directed specifically to solubilised *R. appendiculatus* antigens, for the purification of polypeptides desired for use as candidate vaccines. Several stable, positive hybridomas were obtained by fusion of mouse myeloma NS-1 with spleen cells from mice immunised with specific, but polyclonally affinity-purified, antigens from whole tick extract. Selected MAbs were further characterised down to their specificity for the polypeptide antigens that they recognised in dot-blot, enzyme-linked immunosorbent assays (ELISA) and immunoblot tests. In addition, the subclass of each MAb was ascertained; most of the MAbs studied produce IgG isotypes. The isotype of the selected MAb was further purified on a protein A-Sepharose 4B column, where pure antibodies were obtained—the subject of research in recent years.

We have attempted the production and isolation of MAbs directed against *R. appendiculatus*. Selected purified MAbs were used in immunoaffinity chromatography for the purification of the tick antigens that they recognised. The purity of these antigens was determined by sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE) analysis, visualised by silver staining. They were also matched with the immunoblot patterns to confirm that they corresponded. Immunisation studies were then used to test the usefulness of some of the MAb-purified antigens by screening in cattle. This procedure is intended to indicate candidate polypeptide antigens that can be grouped together in various ways in the design of an anti-tick vaccine. The results are described elsewhere in this report. We are planning to extend these studies by using different doses, routes, adjuvant systems and intervals between boosters on livestock of varying breed and age.

2.4 EFFECTS OF NATURALLY-ACQUIRED IMMUNITY PLUS IMMUNISATION WITH MEMBRANE-BOUND PROTEINS

S. Essuman, A. Hassanali and E. N. ole Sitayo

If an integrated tick management plan is developed in which an anti-tick vaccine is a component, the vaccine should be able to augment any existing, naturally-acquired immunity to tick infestation. We immunised rabbits which already had naturally-acquired immunity to *Rhipicephalus appendiculatus* with SMP-gut (solubilised membrane-bound proteins of tick midgut: preparation described in *ICIPE Annual Report* for 1986 and 1988). We then assessed the effects on ticks of the double immune response.

Sixteen rabbits were divided into four groups. Groups 1, 2 and 3 were exposed once, twice and three times, respectively, to *R. appendiculatus* infestation; Group 4 remained tick-naive. Infestations were carried out on alternate ears at 2-week intervals using 30 male and 30 female ticks. Engorged weight, egg batch weight and egg hatchability were determined for the females used in each infestation. Twenty-one days after the last infestation, each rabbit in Groups 1, 2 and 4 was immunised with 0.3 mg SMP-gut in Freund's complete adjuvant. The rabbits were then challenged with adult ticks (in the same way as for the previous infestations) and the same parameters were again evaluated (Table 2.3).

The effects were severe on those ticks which fed on rabbits that had previously been fed on by ticks, with or without immunisation. There were reductions in engorged weight of 43–90% and corresponding falls in egg batch

Table 2.3 Some effects on female *R. appendiculatus* engorged on rabbits immunised with SMP-gut

	Engorged weight		Egg batch		
Treatment	Mean (mg)	Reduction (%)	Mean wt. (mg)	Conversion factor†	Hatch (%)
1 infestation (control)	424.5	–	180.2	0.424	56.6
1 infestation + immunisation	174.7	58.8	71.0	0.406	37.5
2 infestations	219.1	48.4	89.4	0.408	50.5
2 infestations + immunisation	42.2	90.1	14.6	0.345	37.3
3 infestations	97.8	77.0	21.7	0.221	29.9
Immunisation only	241.6	43.1	110.0	0.456	55.6

†Egg batch weight/engorged weight.

weight. In addition, a smaller proportion of the weight gained by feeding was converted into eggs (0.424 falling to 0.221) and the percentage hatching was also lower. It is evident from these results that the combination of tick infestation with SMP-gut immunisation produced a better immune response than tick infestation alone.

2.5 HOST PROTECTION BY INTERFERENCE WITH THE TICK FEEDING PROCESS

E. I. P. Kamanga-Sollo, S. M. Waladde, D. Ben-Yakir,† R. Galun,† P. B. Capstick and O. O. Dipeolu

Tick gustatory receptor proteins are located in the cheliceral digits. They are chemoreceptors stimulated by phagostimulant components in the host blood, namely glutathione (GSH) and adenosine triphosphate (ATP) in combination with glucose. The objective is to isolate components of the receptor proteins which bind with GSH and ATP. If these were used as antigens to immunise the host, the resultant antibodies in the blood could block the gustatory receptors and inhibit tick feeding.

Cheliceral digits from both male and female *Rhipicephalus appendiculatus* were harvested in cold phosphate buffered saline. The proteins were extracted using Triton X-100, 1% deoxycholic acid and sonication. They were analysed using 10% SDS-PAGE, followed by Coomassie blue staining which identified 10 polypeptides with relative molecular mass of 94–14 kDa. Male and female ticks both gave similar protein profiles. Efforts are being made to identify polypeptide bands which bind to radioisotope-labelled GSH or ATP.

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2.6 IMMUNISATION USING MIDGUT PROTEINS FROM THREE SPECIES OF TICKS

H. L. Kutima† and E. I. P. Kamanga-Sollo

Three groups of rabbits were immunised with midgut membrane-bound proteins (GMBP) derived from partially engorged female *Rhipicephalus appendiculatus*, *R. e. evertsi* and *Amblyomma variegatum* ticks, in order to see whether cross-resistance occurred between these species. The use of SDS-PAGE on GMBP demonstrated protein bands with molecular weights of 160 kDa–140 kDa. Many of the isolated proteins were common to all three species.

Immunised rabbits showed resistance to female tick challenge by prolonging feeding time and by reducing engorgement weight, egg mass weight and hatchability. For nymphs and larvae, the moulting period was reduced and mortality increased.

Immunisation of rabbits with GMBP antigens generated cross-protection against challenge infestation with both the same instar and different instars of the ticks. Cross-protection was more pronounced in the homologous than in the heterologous systems. The ELISA technique detected circulating antibodies in the antisera to GMBP from both systems four weeks after the primary dose. Ouchterlony double immuno-diffusion reactions with anti-tick GMBP sera precipitated 2–3 precipitin lines with homologous GMBP antigens. Lines of complete identity also formed when antisera to GMBP antigen reacted with GMPB antigen from both homologous and heterologous tick species.

Western blot analysis of *R. appendiculatus* GMBP with serum from rabbits immune to *R. e. evertsi* and *A. variegatum* revealed considerable cross-reactions. Similarly, GMBP of *R. e. evertsi* and/or *A. variegatum* with each homologous and heterologous anti-serum showed a high proportion of cross-reactions. The effect of cross-reacting antigens was therefore to confer cross-protection.

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2.7 IMMUNE RESPONSES OF RABBITS TO SALIVARY GLAND ANTIGENS FROM *R. APPENDICULATUS*

M. K. Salah, M. A. Nyindo, O. O. Dipeolu and S. Essuman

Recent studies have shown that when tick-naive rabbits are immunised with crude salivary gland antigens (SGA) from *Rhipicephalus appendiculatus*, a degree of protection is conferred on the host against subsequent challenge with the same tick species. The serum of the immunised host can recognise SGA polypeptides with molecular weights of 15–110 kDa.

The main objective is to determine the immunogenicity and protective value of selected salivary gland polypeptide antigens from *R. appendiculatus* in rabbits, concentrating on those with a molecular weight of 65–110 kDa.

For the preparation of SGA, both sexes of *R. appendiculatus* were fed on rabbits' ears for 3–4 days. The salivary glands were dissected out in phosphate buffered saline on ice and were then sonicated and centrifuged. The supernatant was stored at –20°C as crude SGA. The protein concentration of the crude SGA was determined and the proteins were resolved on 10% SDS-PAGE. Immunoblotting was carried out to determine the proteins of interest, and these were then separated and used to prepare antisera in rabbits. The immunised rabbits will receive a homologous challenge with *R. appendiculatus*, and the reproductive performance and feeding performance of the ticks will be studied.

2.8 IMMUNISATION AGAINST TICKS USING SOLUBILISED GUT MEMBRANE AND HAEMOLYMPH PROTEINS

S. K. Mbogo, E. O. Osir and A. O. Mongi

Haemolymph bathes all tick tissues and contains many physiologically vital proteins which include enzymes and hormones. As reported earlier (*ICIPE 1988 Annual Report*), haemolymph was characterised using SDS-PAGE,

and the presence of sex-specific and age-specific proteins was established.

Rabbits were immunised with *Rhipicephalus appendiculatus* haemolymph proteins in an attempt to block vital tick proteins, and then assessed for any anti-tick effects. Groups of five rabbits were immunised with (1) haemolymph proteins alone, (2) haemolymph proteins in combination with solubilised tick gut membrane proteins (STGMP), (3) STGMP alone and (4) not immunised. The serological response of the rabbits was then determined using the double immunodiffusion test.

The effects of these immunogens were assessed by challenging both immunised and non-immunised rabbits with all instars of *R. appendiculatus* and checking for any deviation from the normal life cycle of the tick. Parameters considered included: duration of feeding to engorgement, mortality, engorgement weight (for adults) and moulting (for larvae and nymphs). The fecundity of engorged females was also assessed.

For any immunogen to be of value in ultimately protecting hosts against tick infestation, it must offer better protection than that conferred by natural infestation alone.

All the immunogens used had deleterious effects on larvae, nymphs and adults. Haemolymph proteins alone or STGMP alone offered similar protection, but a combination of both was better. Each has the potential to be used to immunise hosts against ticks because similar results to those reported for the primary infestation were recorded. Later, specific antibodies that will produce deleterious changes in ticks can be identified and used to immunise hosts against ticks.

2.9 ASSAY SYSTEM FOR DETECTING THE PRESENCE OF ANTIBODIES IN ANIMALS EXPOSED TO TICK INFESTATION

E. I. P. Kamanga-Sollo, M. A. Nyindo, S. Essuman and O. O. Dipeolu

The presence of antibodies against ticks in tick-naive animals has been documented (*ICIPE 1987 Annual Report*). The aim of this study is to develop an ELISA to detect antibodies in rabbits and cattle that have been exposed to tick infestation. It is hoped that this will be a more sensitive and specific method than the immunodiffusion earlier described (*ICIPE 1987 Annual Report*). Antigens from the salivary glands of *Rhipicephalus appendiculatus* were adsorbed on Immulon plates (Dynatech) and antibody titres in both cattle and rabbits could be demonstrated one week after infestation with ticks. All animals that had been exposed to tick infestation could be identified using this method. Efforts are currently directed to the development of the method for field screening of animals exposed to ticks, in order to identify any cross-reactivity with specific tick antigens being purified in the laboratory. These specific antigens are to be incorporated in the tick vaccination trials.

2.10 LONG-TERM STUDIES ON NATURALLY ACQUIRED RESISTANCE TO TICK INFESTATION

O. O. Dipeolu, A. O. Mongi and E. I .P. Kamanga-Sollo

There is a belief that natural resistance to ticks has been an important regulator and stabiliser of tick populations on livestock in Africa. One of the questions which has arisen on the manipulation of the phenomenon of natural resistance for tick control is its long-term efficacy. The reasoning is that if the phenomenon of natural resistance were absolutely and indefinitely effective, tick infestation on livestock should have been eradicated in Africa. The aim of these long-term studies is to investigate those factors which could affect the efficacy of natural resistance of animals to tick infestation.

Rhipicephalus appendiculatus adults, nymphs and larvae were fed on rabbit ears, using six rabbits for each life stage. Feeding was repeated every three weeks on the same rabbits. The experiment was terminated after the tenth infestation.

Results have been processed up to the eighth infestation. For the larval and adult stages, there was a sharp drop in engorgement weight from the second infestation until the fourth adult infestation and fifth larval infestation. Thereafter the engorgement weight started to rise and in the case of the larval stage (Figure 2.2), the engorgement weight at the eighth infestation was higher than that of the primary infestation. However, the percentage of larvae which moulted to nymphs, and the moulting period, were both lower than those of the primary infestation, while the percentage of larvae which succeeded in feeding on the rabbits was also lower (Figure 2.2).

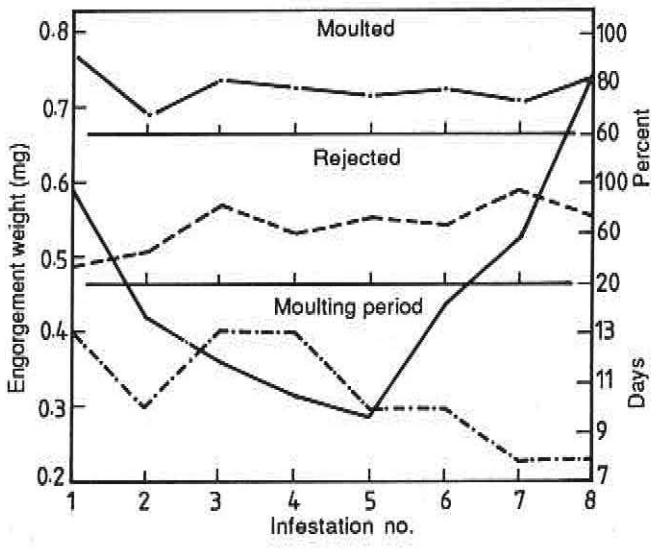

Figure 2.2 Effects on four parameters for *R. appendiculatus* larvae, over eight successive feeds on rabbits; engorgement weight: solid line, others as shown.

The increase in weight of adult ticks was not as significant as in the case of larvae. It was also not sustained and fell to the level of the second infestation during the seventh and eighth infestations. The number of eggs laid by fed adult ticks was also affected by the number of infestations; it fell sharply from a range of 2720–5997 in the primary infestation to 427–717 in the succeeding infestations. Although this was reflected in the weight of the egg mass, it was also observed that the average weight of one egg (0.070 mg) from the primary infestation was significantly higher than those from the succeeding infestations which ranged from 0.031–0.046mg. Whereas all the adults which fed during the primary infestation laid eggs, only 68–92% oviposited during the succeeding infestations. Egg hatchability varied widely; it was observed, however, that from the second infestation onwards, some ticks laid eggs which did not hatch. The result for the nymphs was totally different in that no substantial increase in engorgement weight was observed again after the sharp drop at the second infestation.

These results indicate that after long exposure to the same tick species, one of the important manifestations of natural resistance (i.e. decreased engorgement weight) may be lost. This could be due to the acquisition of immunological tolerance by the host. Similar investigations are being undertaken on cattle, and the effects of other factors such as concurrent infections are being investigated.

2.11 STUDIES ON THE EMBRYONIC DEVELOPMENT AND BIOLOGY OF *R. APPENDICULATUS* EGGS

O. O. Dipeolu

Even though the percent hatch of eggs is an important factor in the regulation of population in ixodid ticks on pasture, little is known of the biological parameters which influence the embryonic development and the process of hatching. On-going studies in the immunology unit of the Programme indicate that some polypeptide antigens prevent the hatching of a high proportion of eggs laid by *Rhipicephalus appendiculatus* females which have fed on vaccinated cattle. Since this is an important effect which can be utilised to assess the role of anti-tick vaccines in the reduction of the tick population on pasture, a proper understanding of the process of embryonic development of tick eggs and the influence of size on their hatching is desirable. This investigation was therefore undertaken to provide basic information on important biological characterisations of the egg stage of *R. appendiculatus*.

Laboratory and field strains (Kikuyu, Intona, Rusinga, Ukunda) were used. The structure of the egg and eggshell was studied under light microscopy, and they were measured with an eyepiece micrometer in a dissecting microscope. The embryonic development of the eggs was studied at various temperatures from the day of oviposition until hatching started, while the relationship between the biological viability of eggs and their sequence of oviposition was also investigated.

The lowest and highest lengths of eggs encountered were 0.652 mm and 1.185 mm, respectively, and the highest and lowest breadths were 0.869 mm and 0.474 mm, respectively. Eggs of early oviposition were slightly larger in size than those of later oviposition. The lowest surface area encountered was 0.337 mm^2 in one of the egg batches laid by laboratory strain ticks kept at 28°C, and the highest was 0.939 mm^2 in one of the egg batches laid by a Kikuyu strain tick kept at 22°C. However, the size of the egg does not affect its viability in terms of hatchability, as well as the engorgement and moulting of the ensuing larvae and nymphs. The eggs of the laboratory strain had a wider range of lengths and breadths than those of the field strains.

There are differences in the structure of the shell of eggs laid by the laboratory and field strains. While both possess a yellowish-white outermost membrane which is thicker on one lateral side than the other, this is followed in the case of eggs of the laboratory strain by a blue membrane which is thicker on the lateral side of the egg, which possesses the thinner external yellowish-white membrane, while the innermost membrane is a black one which is uniformly thick around the egg. For eggs of the field strain, however, the membrane next to the outermost yellowish-white one is a black membrane which is uniformly thick around the egg, which possesses a thin outermost blue membrane. Eight phases were recognised during the embryonic development. These, as well as the periods of their accomplishment at various temperatures, are given in Table 2.4.

The biology of larvae and nymphs which were produced from batches of eggs laid during the initial, middle and end of oviposition by laboratory and field strains was similar in terms of hatching, engorgement and moulting. Also, the feeding and oviposition performances of adult ticks produced from batches of eggs laid sequentially by laboratory and field strains were similar.

2.12 PREDATION OF LIVESTOCK TICKS BY CHICKENS

S. M. Hassan, O. O. Dipeolu, A. O. J. Amoo and T. R. Odhiambo

On Rusinga Island, where the local chickens are kept in close association with the cattle, we found that chickens are natural predators of ticks. *Rhipicephalus appendiculatus*, *Amblyomma variegatum* and *Boophilus decoloratus* were recovered in large numbers from the crops and gizzards of chickens which were slaughtered after scavenging among tick-infested cattle (Table 2.5). The numbers of ticks recovered ranged from 2–545 with an average of 129 per chicken. When exposed to ticks seeded among the vegetation (experiment performed at the Coast) chickens picked up both engorged and unengorged ticks, and these were subsequently recovered in the same way. There was a preference for unengorged ticks, and chickens had difficulty ingesting engorged *A. variegatum*.

It was observed that the behaviour of the cattle helped the birds to feed on ticks. For example, an animal would

Table 2.4 Embryonic development in *R. appendiculatus* in relation to temperature

Phase number	Description	Cumulative number of days since oviposition†			
		18°C	22°C	28°C	32°C
0	Egg with vitellin and compact globules	4	3	1	1
1	Disintegration of globules	8	5	2	1
2	Accessability of globules into vitellin	10	6	3	1
3	Invagination forms the anterior and posterior poles and lateral side	9–25	6–17	3–12	2–9
4	Single deep invagination forms across middle of egg from anterior to posterior pole	24–27	17–21	13–15	9–12
5	Development of larval organs	25–38	17–29	13–17	10–14
6	Rudimentary dorsal scutum recognisable; larva without palps and hypostome	35–44	27–30	16–19	13–15
7	Larva fully grown with legs, palps, hypostome and scutum recognisable	42–51	29–34	18–23	15–17
8	Rolling movement of larva inside shell; intermittent contractions of egg; hatching	50–55	34–38	23–25	17–20

†The day of oviposition is taken as 0.

Table 2.5 Ticks recovered from crops and gizzards of local chickens 3–5 hours after release among local cattle (number of engorged ticks in parenthesis)

Chicken no.	*R. appendiculatus*		*A. variegatum*		*B. decoloratus*		Total	
1	9	(1)	0	–	4	(4)	13	(5)
2	39	(15)	2	(1)	2	(2)	43	(18)
3	323	(49)	3	(1)	5	(2)	331	(52)
4	90	(21)	13	(1)	16	(5)	119	(27)
5	93	(24)	7	(4)	8	(3)	108	(31)
6	23	(1)	7	(4)	7	(7)	37	(12)
7	67	(14)	3	(0)	2	(2)	72	(16)
8	4	(1)	15	(2)	2	(0)	21	(3)
9	1	(0)	1	(0)	0	–	2	(0)
10	486	(119)	53	(26)	6	(3)	545	(148)
11	120	(6)	11	(3)	0	–	131	(9)
	1255	(251)	115	(42)	52	(28)	1422	(321)

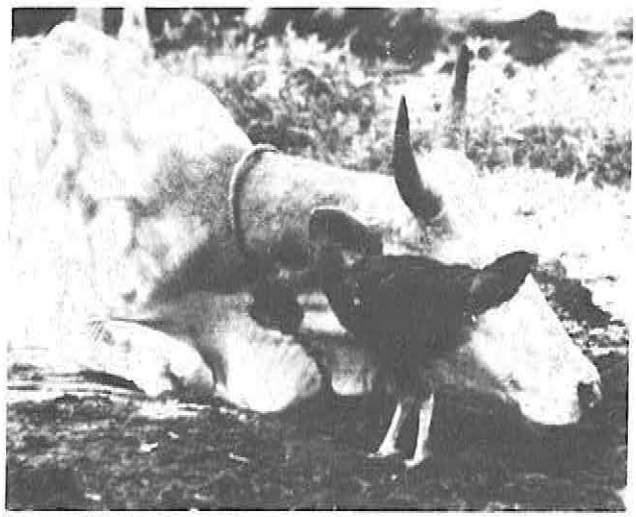

Figure 2.3 Recumbent cow with head lowered and right ear turned forward to enable a chicken to pick off ticks, Rusinga Island.

acknowledge the approach of a chicken by lowering its head and turning the ears in the direction of the bird. The cattle also helped the chickens because they usually closed their eyes and exposed the eyelids for the chickens' attention. Feeding was also easier when cattle were recumbent early in the morning, making the ears and eyelids more accessible (Figure 2.3).

It is apparent that predation of ticks by chickens is a potential component of integrated tick management that should be investigated further.

2.13 ACARICIDES FROM LOCALLY AVAILABLE NATURAL PRODUCTS

O. O. Dipeolu, J. N. Ndungu and A. Hassanali

Within the context of resource-poor farming in Africa, tick control through the application of commercial acaricides is outside the reach of most farmers. It is an external

input which is not affordable by this category of farmers because of the high purchase cost. Even though community dips in some East and Central African countries offer the possibility to resource-poor farmers of acaricide application to their livestock, socio-economic and logistical factors have rendered such dips non-functional or ineffective. These factors include distance of diptanks from homesteads, lack of water especially during the dry season, vandalism when roofing materials are removed, irregular availability of acaricides due to high cost, and lack of manpower for efficient dip management.

Resource-poor farmers in various parts of Africa have substituted commercial acaricides with those made locally from natural products. These substitutions however do not have a scientific basis. The goal of our investigation is to screen natural products with a view to selecting those which are cheap and efficient. Any chosen natural product will be expected to be used within the context of integrated tick management.

Three products have been screened so far. These are (1) sodium chloride solution which was reported to have an acaricidal effect against *Amblyomma variegatum*, *Boophilus decoloratus* and *B. geigyi* (Dipeolu, unpublished data), (2) a product from Nigeria which was also demonstrated to have an acaricidal effect against the same ticks (Dipeolu, unpublished data) and (3) a natural product from Kenya. Results so far indicate that the Kenyan product has the greatest potential.

In vivo tests using the ears of rabbits and calves showed that the Kenyan product inhibited primary detachment, and the female growth, mating and feeding phases of *Rhipicephalus appendiculatus*. The rapid feeding sub-phase of female *R. appendiculatus* was especially suppressed. When the product was applied to ticks shortly after they had engorged on rabbit ears, many of them died and the survivors laid significantly fewer eggs compared with control ticks (Table 2.6). A test of the residual effect of the Kenyan product showed that it retained its acaricidal activity for at least 5 days after application (Table 2.7).

Table 2.6 Oviposition of engorged female *R. appendiculatus* which survived treatment with a natural acaricide from Kenya

Conc.	No. survived	Mean wt. (mg)	Mean no. of eggs laid
100%	8/50	342	1025
50%	19/50	351	998
Untreated control	46/50	381	4724

The natural product from Kenya is available locally in markets for non-acaricidal domestic use and it can be bought very cheaply. Bioassay of the product has started.

Table 2.7 Residual effect of a saturated solution of a natural acaricide from Kenya when adult *R. appendiculatus* (25 males:25 females) were applied to each ear of a treated calf at intervals of 24–144 hours later

Interval (hours)	No. of ticks that attached (both ears)
24	0
48	0
72	0
96	0
120	13 (all attached, very weak; detached and died within 24–48 hours)
144	Approx. 20:18 on each ear (*c.* 80% engorged)

2.14 EPIDEMIOLOGICAL-BIOLOGICAL MODELLING OF AFRICAN TICKS OF LIVESTOCK

O. O. Dipeolu, J. N. Ndungu and A. O. J. Amoo

Much attention has been devoted to studies on tick biology because of the economic importance of tick infestation of livestock in Africa. Most of these studies have, however, created very little impact in terms of tick control. The methodology adopted for many of them was questionable; studies were often made with different tick strains on different occasions. Even though such experiments were not strictly comparable, conclusions made from them were usually regarded as valid. One of our objectives is to produce experimental designs which will eliminate these limitations. Another is that our studies will produce the knowledge base for the modulation of integrated pest management (IPM) components of the tick control technology which the Programme is developing. Our studies will also demonstrate the advantages of the application of a systems analytical approach to research on the biology of African ticks. They complement field ecological studies by providing valid explanations for the fluctuations or stabilisation of tick population sizes, and serve as a springboard for successful statistical and/or mathematical population and computer simulation modelling of African ticks. *Rhipicephalus appendiculatus* is being used as the model.

Network diagrams were drawn to show the epidemiological-biological systems interacting to influence tick population dynamics, and the components influencing population dynamics of female and male ticks. In the latter, the life stages of ticks were linked with factors which could influence them and the biological parameters which are to be measured during the study of the effects

of any factor on each life stage. The standard experiment with which the results of effects of factors will be compared has been concluded. For the standard experiment, four climatic seasons were mimicked in the laboratory i.e. cool, hot, long rains and short rains. This was effected by rotating experimental ticks through different combinations of temperature every day. The optimal moisture was regarded as moderate moisture and simulated in the laboratory; optimal relative humidity was set at 85% for all climatic seasons. The methodology has been standardised; the same tick strain will be used for all experiments and the same experimental design will be applied to measure the effects of each factor.

Highlights of the results of the standard experiment include:

(a) Construction of the biological model of the feeding strategy of *R. appendiculatus* in which eight phases are recognised.
(b) Redesignation of the concept of "standard tick" of Australian workers with "potentially mature ticks".
(c) Elucidation of multiple mating of male ticks during feeding and the recognition of three types of mating.
(d) Showing for the first time the attraction of two males by one female for mating; the engorgement weights of such females are usually bigger than those females which have attracted only one male for mating.
(e) Concept of "critical engorgement weight" introduced into the oviposition strategy of ticks, with definitions of newly introduced terms such as "mature weight", "pre-mature weight" and "pre-mating weight".
(f) Description of the feeding strategy of larvae and nymphs of *R. appendiculatus*. Measurements of the effects of factors such as photoperiod, host type, flooding etc., and comparison of the results with those of the standard results, are continuing.

2.15 RELATIVE INDICES FOR MONITORING RESISTANCE OF CATTLE TO *R. APPENDICULATUS*

K. S. Nokoe, D. K. Punyua, A. A. Latif and P. B. Capstick

Twenty-five males, 25 females and 50 nymphs of the Rusinga Island strain of *Rhipicephalus appendiculatus* were applied (in an earbag) to the left ear of each of 17 East African zebu cattle selected from Rusinga Island. Three other tick strains—Ukunda, Intona and Muguga—were applied to the right ears of the cattle. The ears were examined twice daily after the sixth day for any engorged and detached ticks. These were counted and the adults were weighed individually, while the nymphs were weighed in groups.

We then computed the resistance index (I^j) for each strain using the relationship:

$$I^j = (0.2681\,NF^j + 0.0399\,FW^j + 1.6099\,NW^j)/21.8964$$

where: I^j = index for jth animal
NF = number of engorged female ticks
FW = mean female engorged weight
NW = mean nymphal engorged weight.

In the original study, an I value in excess of 1.31 was representative of susceptibility, while a value of less than 0.76 implied high resistance.

A relative measure was further established for animals receiving the same pair of tick strains. This was done by dividing the computed animal index value by the index value of the animal which had the highest index for the Rusinga stock (Table 2.8). The results indicate consistency and comparable values in relative indices for each pair of stocks. Although the formula for computation of the resistance index had originally been based on the Rusinga strain, these results have shown that resistance of zebu cattle to *R. appendiculatus* can indeed be assessed using the same formula and any of the above tick stocks.

2.16 THE KUJA RIVER PROJECT

O. O. Dipeolu, D. K. Manyasi, S. M. Hassan and D. K. Punyua

With the sharpening of the focus of the Livestock Ticks Research Programme on the resource-poor farmers who produce the bulk of livestock in Africa, the development of a field site has become a top priority. Suitable land has been found (three parcels totalling 204 ha) and is now being developed as the Kuja River Field Site, located in the Ndhiwa Division of South Nyanza District in western Kenya. Apart from the availability of a big area of land on which to develop paddocks for experimental purposes, the site is surrounded by a large number of resource-poor farmers for whom livestock is the primary enterprise. The site will therefore provide opportunities

Table 2.8 Relative resistance indices for four *R. appendiculatus* stocks feeding on 17 cattle, with Rusinga (R) on the left ear of each animal and Ukunda (U), Intona (I) or Muguga (M) on the right ear

Group 1			Group 2			Group 3		
No.	R	U	No.	R	I	No.	R	M
1	0.82	0.84	7	0.65	0.71	12	0.73	0.84
2	0.70	0.70	8	1.00	1.00	13	0.85	0.84
3	0.78	0.82	9	0.59	0.48	14	0.68	0.65
4	1.00	1.00	10	0.92	0.95	15	0.90	1.00
5	0.73	0.81	11	0.88	0.87	16	1.00	0.91
6	0.97	0.94				17	0.73	0.81

for interaction in which to involve the farmers in experiments designed to validate components of integrated tick management practices, and also to transfer the technology developed for tick control.

Virtually all the surrounding farmers keep livestock, including cattle, sheep and goats. A few also keep donkeys for domestic transport. Cattle range in number from 30–100 per farm, and are kept mainly for sale when money is urgently needed, and for draught power and milk production. A tick survey was carried out between September and November on these cattle. Tick numbers were low at this time, both on cattle and pasture. However, *Rhipicephalus appendiculatus* was the predominant species and *Amblyomma variegatum* was also found. Lice were commonly seen on calves.

Management practices are uniform among the farmers. Milking is performed within every homestead in the morning. The whole herd grazes from late morning till early afternoon, followed by drinking at the Kuja River, and then returns to the homestead in the early evening.

Extensive investigations on the prevalence of ticks at the site will begin early in 1990.

2.17 EFFECT OF NUTRITION ON THE RESISTANCE OF INDIGENOUS ZEBU CATTLE TO TICKS

H. Oranga, K. S. Nokoe and O. O. Dipeolu

The hypothesis tested was that good nutrition helps to improve the resistance of cattle to high tick infestation, using indigenous East African zebu (*Bos indicus*) cattle and the ticks *Rhipicephalus appendiculatus* and *Amblyomma variegatum*. In order to test this hypothesis a multivariate technique, canonical correlation, was used. This method involves the development of linear combinations of each subset of data such that the new variables (known as canonical variables) possess maximum correlations between themselves and are also orthogonal to one another. One key assumption was that the calves had efficient feed conversion capability so that the picture depicted by the pasture quality was similar to that in the animals.

In this study, two subsets of data were considered. The first subset consisted of the tick numbers as:

A. variegatum males (X_1)
A. variegatum females (X_2)
R. appendiculatus males (X_3)
R. appendiculatus females (X_4)
Total number of ticks (X_5).

The second subset comprised nutritional values for the pastures including:

Crude protein (Y_1)
Ether extract (fat content) (Y_2)
Phosphorus (Y_3)
Potassium (Y_4)
Calcium (Y_5).

The linear combinations may be given as:

$V_i = \alpha_i' X'$ and $W_i = \beta_i' Y'$

for $i = 1,2,3,4,5$, such that:

$$\text{Corr}\,(V_i, W_i) = \delta_i$$

for $i = 1,2,3,4,5$,

$$\text{Corr}\,(V_k, V_l) = \text{Corr}\,(V_s, W_m) = 0$$

for $k \neq l \neq s \neq m \neq 1,2,3,4,5$, and

$$\delta_1 > \delta_2 > \delta_3 > \delta_4 > \delta_5.$$

Further, α_i', β_i', X' and Y' are the sums of their component subsets.

The analysis was based on a sample of 72 calves aged 1–2 years. The results of this study revealed that the resistance of the cattle to *R. appendiculatus* is directly related to the the crude protein level of the pasture. As crude protein levels increase, the tick burden falls, implying increasing resistance by the animals. Secondly, the fat content and the level of phosphorus in the pasture seem to be inversely associated with cattle resistance. Thus, as these levels increase, the decreasing resistance of the calves is manifested by rising tick burdens.

2.18 EFFECT OF DIFFERENT TREATMENT REGIMENS ON THE PRODUCTIVITY OF RUSINGA ISLAND CATTLE

S. M. Hassan and D. K. Punyua

A great deal of data has been collected on Rusinga Island cattle in relation to ticks, tick-borne diseases, endoparasites and levels of production and reproduction (*ICIPE 1985–1988 Annual Reports*). Rusinga Island cattle reach maturity when they are about five years old; their breeding frequency is approximately two years and they are low milk producers. A study of the nutritive quality of the pasture on the island is under way.

There has been no study to identify factors which have a direct impact on the level of production and the reproductive performance of the cattle on the island. The role played by ticks, tick-borne diseases, parasites and poor nutrition in decreasing the potential production of these cattle is therefore unknown.

The current experiment is the first major intervention on Rusinga Island, designed to elucidate the role of different management regimens as factors limiting the production level of Rusinga Island cattle. This is a long-term experiment covering each calf from birth until it reaches maturity. Only calves born during 1989 are being used (about 80 in all are expected). They are allocated to one of the following groups:

(a) Maximum protection (free of ticks, tick-borne diseases and endoparasites; balanced nutrition).
(b) Free of ticks.
(c) Free of tick-borne diseases.
(d) Free of endoparasites.
(e) Balanced nutrition.
(f) Untreated control group.

Data that are collected weekly include liveweight, rectal temperature and a visual tick count; blood smears, lymph node biopsies and faecal samples are also taken; ticks are collected monthly.

2.19 SELECTION OF BORAN CATTLE FOR TICK RESISTANCE

A. A. Latif and M. M. Malonza

Mutara Ranch, in Laikipia District, is the location of the Kenya Boran National Stud. Cattle have been selected for productivity for many years and good records of all animals are available. Tick-borne disease prevalence is low and animals could be subjected to relatively high tick challenge without great risk. The process of selecting cattle for phenotypic characters indicative of tick resistance started three years ago, with the first collection of ticks being made in January 1987 (*ICIPE 1987 Annual Report*). The initial objective of the project was to investigate the inheritance of tick resistance by breeding from cattle whose resistance status to tick infestation had been defined (high or low). The second objective was to identify in the Boran breed the genes, or their markers, which control resistance to ticks.

Regular monthly tick collections were made on 60 heifers from September 1988–October 1989 to assess the levels of resistance before embarking on a breeding programme. This extended period was necessary to allow the study of the factors which may affect resistance e.g. season, nutrition and level of tick challenge. The results showed that the *Boophilus decoloratus* population on the cattle was very low and did not repeat the pattern observed in 1987. *Rhipicephalus pulchellus* and *R. e. evertsi* were present in higher numbers; however, these species are of no economic importance and were not used for ranking the cattle. On the other hand, *R. appendiculatus* was collected only a few times and in very low numbers. The failure of the attempt to rank the cattle for resistance, on account of the low natural tick challenge, was the prime reason for not starting the breeding programme in 1989, and the herd of 60 heifers was therefore discarded.

In November 1989 a new herd of 110 yearling heifers was selected for the same experiment. They were divided into three groups: 70 undipped, 20 dipped once every month and 20 dipped twice per month. The groups are being rotated in three neighbouring paddocks. The use of undipped cattle is to allow greater tick multiplication and hence to increase the tick population on the pasture. Thus it is hoped that selection for resistance to *B. decoloratus* will be possible. Based on the growth of dipped versus undipped cattle, the economics of tick control through dipping in this situation will be worked out.

2.20 STUDIES OF TICKS IN DIFFERENT ECOLOGICAL ZONES OF KENYA

D. K. Punyua, T. Yonow, R. M. Newson and F. Gigon

Ecological studies, including survival and development of *Rhipicephalus appendiculatus* and *Amblyomma variegatum* in three different biotopes (Nairobi area, Trans-Mara area and Mbita Point area), were started in 1987 (*ICIPE 1988 Annual Report*). In the Trans-Mara the seasonal dynamics of adult ticks present on cattle were also studied, including *R. appendiculatus, Boophilus decoloratus, A. variegatum* and *A. cohaerens*; the latter is primarily a buffalo feeder. These observations will be concluded in 1990.

2.20.1 Tick population studies

Monthly tick collections from a typical Maasai cattle herd (using the same 15 individuals each time) continued throughout the year. One ear of each animal was sampled for *R. appendiculatus* and one half of the body for *Amblyomma* species and *B. decoloratus*. A 15 cm x 15 cm neck scrape yielded nymphs and larvae of all the species under study. During the monthly visits, ten samples from each of three selected sites within the cattle grazing areas were taken by blanket dragging to obtain larval ticks from the vegetation.

The two and half years of data indicated that adult *R. appendiculatus* were most numerous on cattle during the period July–September (Figure 2.4). A smaller peak was observed in February/March, while ticks were least numerous between April and June. Although the area lacks a real dry season, the main period of adult *R. appendiculatus* activity seemed to coincide with the drier part of the year.

Adult *A. variegatum* showed a similar pattern of activity with the highest numbers on cattle during the months of July–October, and the least from April to June.

The results from the neck scrapes showed a major peak for *R. appendiculatus* larvae in September. There was no discernible seasonal pattern in the small number of nymphs that was recovered. Similarly, *A. variegatum* larvae showed their main activity in September and March. *Boophilus decoloratus* collected from neck scrapes gave three regular peaks in February, June and October. Results from the monthly ground collections showed differences in the number of larval ticks collected at the three dragging sites. The forest edge site had consistently more ticks than the other two open grazing areas. Although there was no distinct seasonality, *R. appendiculatus* larvae were generally more numerous in the wetter periods of the year, centred on April and October.

2.20.2 Tick survival

Large batches of newly moulted larvae, nymphs and adults of *R. appendiculatus* were positioned at each site in nylon gauze bags, and then sampled every month. All the observations have been completed. Three batches of ticks were put out (at 3-month intervals) at Mbita Point and two each at the Trans-Mara and Nairobi sites. The first batch of larvae in Trans-Mara survived for 4 months, nymphs for 10 months and adults for up to 16 months. The remainder of the results are being processed.

2.21 ECOLOGICAL STUDIES ON *AMBLYOMMA VARIEGATUM*

T. Yonow

Ecological studies on *A. variegatum* have now been in progress for about three years. These studies have been designed better to understand the ecology of this tick

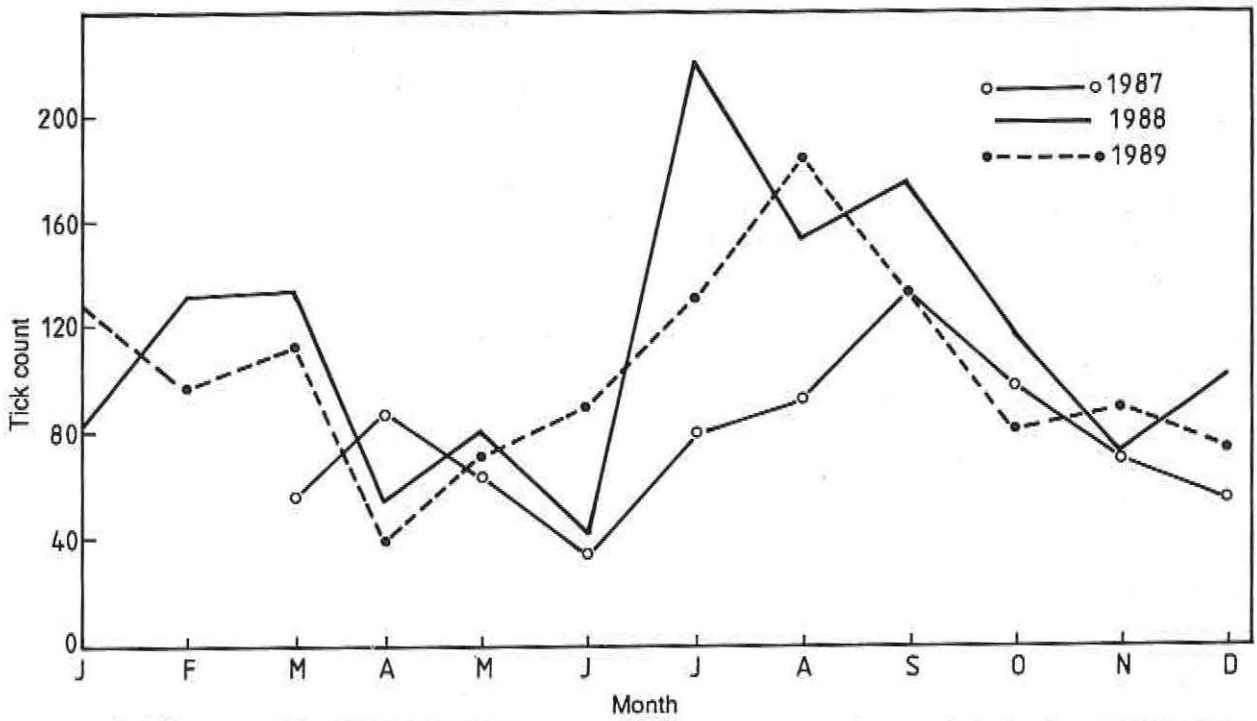

Figure 2.4 Mean monthly counts of adult *R. appendiculatus* on one ear of 15 cattle in the Trans-Mara study area, March 1987–December 1989.

species, and to relate various life-cycle parameters to climate. Once the ecology/biology can be described in terms of meteorological factors, it is possible to construct mathematical models that can accurately simulate population dynamics and fluctuations under different climatic conditions. Models that can accurately predict populations seasonally may also be used to test the effects of any combination of management and control strategies. The use of models can therefore eliminate the necessity for extensive field trials which are time-consuming and expensive.

Experiments to assess the survival of unfed adult and nymphal *A. variegatum* have been conducted in three contrasting biotopes in Kenya. Concurrently, meteorological data (temperature, relative humidity and rainfall) have been collected at the same sites. Four exposures of newly moulted ticks were made at each site at 3-monthly intervals. These experiments are now complete, except that at one site the last exposure had to be repeated due to damage caused by cane rats, and the observations in this series are still continuing. Although meteorological data have not been worked up fully for each site, it has nonetheless been possible to relate adult and nymphal survival times roughly to climatic factors.

The equations produced indicate that the critical factor for nymphs is soil dryness, with younger nymphs being more susceptible than older nymphs. For adults, it seems that soil moisture has no effect, but that high temperatures (>36°C) are the major limiting factor to survival, and that older adults are more susceptible to high temperatures than younger adults. In other words, it seems that adults are susceptible to high temperatures as they age, whereas nymphs are susceptible to dryness, especially when they are young. No data are yet available on larval survival; this is now a priority for further research.

A training visit to the CSIRO Long Pocket Laboratories in Brisbane, Australia, provided the opportunity to learn to use two models which have been developed there. Both of these models may be run for *A. variegatum*. One model, CLIMEX, predicts the potential geographical distribution of the tick as determined by climate, and indicates the overall suitability of a variety of locations for this species.

It is not yet possible to use all of the facilities available (e.g. to test the effects of various management strategies) with the second model, T3HOST, because essential information is still lacking on various ecological parameters of *A. variegatum*. At present, running T3HOST for *A. variegatum* produces seasonality patterns which do not correspond accurately to published data, but are nonetheless not too far off. Once additional data are acquired on the ecology of this species, the accuracy of the model may be greatly improved, and it should then be possible to use T3HOST to simulate the effects of different types of management strategy.

2.22 TICK DISTRIBUTION ON RUSINGA ISLAND

D. K. Punyua and S. M. Hassan

In an attempt to explain the observed farm-to-farm differences in tick infestation levels, an experiment was designed in which ticks were sampled on the vegetation from three areas (homestead, lakeside, roadside) by blanket dragging. When comparisons were made it was shown that, in general, most ticks were collected from the roadside and least from the homestead. Significant farm-to-farm differences were still observed. The small number of ticks collected from the homestead may be due to prolonged and frequent host-tick contact. Probably due to the wider grazing area on the roadside there is a higher tick concentration in this habitat. More cattle from various

homesteads daily converge on the lakeshore for grazing and watering, thus reducing the number of ticks on the vegetation. Studies are under way to determine the tick drop-off rhythm, which may also explain tick distribution relative to host behaviour.

2.23 DIURNAL AND SEASONAL ACTIVITY OF IMMATURE TICKS ON THE VEGETATION ON RUSINGA ISLAND

S. M. Hassan, O. O. Dipeolu and D. K. Punyua

The population dynamics of ticks on Rusinga Island cattle have been studied (*ICIPE 1987 Annual Report*). However, tick activity off-host has not been thoroughly investigated. Some preliminary data collected in 1988 were not adequate to reflect diurnal and seasonal activity.

The aim of the current experiment is to describe and measure these activities. Ticks are collected monthly by the blanket dragging method from three sites: homestead, roadside and grazing areas. Each site is sampled at three times during the day (i.e. 0800–0900, 1200–1300 and 1600–1700 hours).

The experiment was started in June and will be continued throughout 1990. The ticks collected are almost entirely larval stages, with very few nymphs. Early indications are that ticks are most abundant on the vegetation during morning hours.

2.24 EFFECT OF CATTLE MANAGEMENT ON RUSINGA ISLAND TICK POPULATIONS

D. K. Punyua and S. M. Hassan

As reported earlier (*ICIPE 1988 Annual Report*), an experiment conducted during the low tick season (September–October) has now been repeated during the high tick season (February–March). The results obtained have confirmed our hypothesis that the traditional patterns of husbandry and management play a major role in the observed tick population dynamics. Significant differences between two groups of animals grazing for short periods each day (group I, 6 hours) and long periods (group II, 10 hours) were observed for the adults of four tick species (Table 2.9). *Rhipicephalus appendiculatus* also showed significant differences between seasons but, due to their low numbers, *Amblyomma variegatum*, *Boophilus decoloratus* and *R. e. evertsi* did not. An identical result was also obtained for nymphs and larvae of the four species.

It may be concluded that the group of cattle remaining in the homestead until midday (group I) not only collected fewer ticks from the pasture, but may also have lost large numbers of their attached ticks to domestic chickens, as shown elsewhere in this report.

2.25 DROP-OFF PATTERN OF ENGORGED *RHIPICEPHALUS APPENDICULATUS*

E. N. Mwangi

The objective was to establish whether *R. appendiculatus* shows a daily rhythm in the time of dropping off the host after engorgement. Nine Friesian calves were used and were kept in an open field. Each animal was infested with 200 adults held on the ears in nylon gauze bags, and 800 nymphs and 4000 larvae confined in nylon gauze patches glued on to the body.

Engorged females showed a definite rhythm of drop-off, with 31% dropping between 0600–0800 hours and the largest proportion of the ticks (38%) dropping between 0800–1000 hours. For tick-sensitised animals, the greatest adult drop-off also occurred at the same time in the morning, but started 24 hours later than for first infestations. Of engorged nymphs, 55% dropped between 1600 and 1800 hours, thus also showing a definite rhythm. There was, however, no discernible drop-off rhythm for larvae.

The results from this study indicate that for cattle that are confined at night, most engorged females could be made to drop off in an area unfavourable for tick survival by delaying the release of the animals until 1000 hours each morning.

2.26 COMPARISON OF *RHIPICEPHALUS APPENDICULATUS* STRAINS: SURVIVAL PATTERNS

J. W. Chiera

A series of experiments was started in 1988 to investigate the ecological characteristics of *R. appendiculatus* field strains in relation to survival. The strains under study

Table 2.9 Mean numbers of adult ticks on two groups of cattle under two management regimes, during high and low tick seasons on Rusinga Island

Tick season	Treatment group†	*n*	*R. appendiculatus*	*R. e. evertsi*	*A. variegatum*	*B. decoloratus*
High	I	24	157.3	3.8	8.3	6.3
High	II	24	564.5	9.3	45.0	36.6
Low	I	18	90.1	3.8	5.3	7.6
Low	II	18	121.5	6.4	16.5	23.5
Diff. between seasons			$P < 0.001$	n.s.	n.s.	n.s.
Diff. between groups			$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$

†I = 6 hours grazing per day; II = 10 hours grazing per day.

strains in relation to survival. The strains under study were from: Rusinga Island (RS) near Mbita Point Field Station; Kikuyu (KS) in Kiambu District; Intona (IS) in the Trans-Mara Division of Narok District; Ukunda (US) in Kwale District on the coast; and the long-established Muguga laboratory strain (LS). The survival was assessed of eggs, and of unfed larvae, nymphs and adults exposed to constant temperatures of 18°C, 22°C and 28°C. Constant humidities were provided by saturated solutions of the salts K_2CO_3 (44% r.h.), NaCl (75% r.h.), KNO_3 (93% r.h.), and certain concentrations of K_2CO_3 (55% r.h. and 65% r.h.). Some of the findings have already been reported (*ICIPE 1988 Annual Report*) and the present report is intended to highlight the remaining aspects.

2.26.1 Survival of unfed larvae

The survival of the larval strains was assessed at constant 65% r.h., 75% r.h. and 93% r.h. and at the temperatures listed above. Larval survival was best at a combination of the highest humidity and lowest temperature, but was reduced ten-fold at the lowest humidity and highest temperature. There were obvious differences in the survival of the various strains. In general, the survival of US and RS larvae was poorer than that of KS and LS. The poorest survival under all treatments, particularly at the lowest humidity, was shown by the US larvae (Figure 2.5).

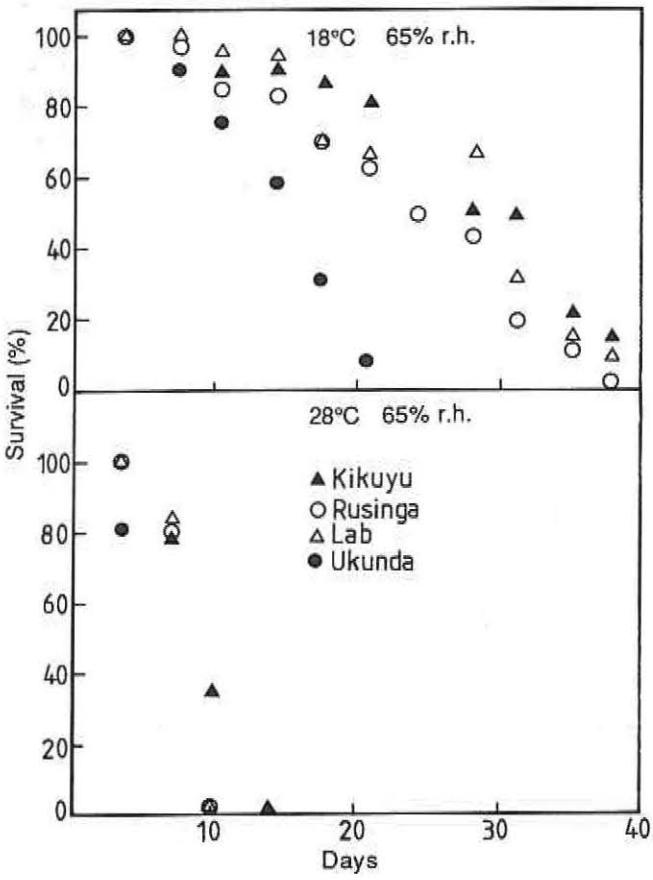

Figure 2.5 Survival patterns of larvae of four strains of *R. appendiculatus* at 18°C and 28°C at a constant 65% relative humidity.

2.26.2 Survival of unfed nymphs

Nymphal survival was also assessed over the whole range of temperatures and humidities detailed above, except 65% r.h. At 93% r.h. all the nymphs had excellent survival for at least 6 months, after which mortality steadily increased depending on temperature. The LS nymphs had the best survival at this high humidity. The survival of KS nymphs was the poorest of all the strains at the highest temperature and humidity, but improved at the lower temperatures. It was, however, at 75% r.h. that the combination of humidity and temperature appeared to affect the nymphs of each strain differently, and the strains switched places at low and high temperatures. Thus, LS survival was better than that of US and KS at 28°C, but poorer at 18°C; RS nymphs had the poorest survival at 75% r.h. Strain differences occurred also at the lower humidities, with KS survival being the best and that of US and IS the poorest.

2.26.3 Survival of unfed adult ticks

Adult ticks were assessed under all the treatments detailed above, except 65% r.h. At 93% r.h. adults all had excellent survival for at least 9 months, after which mortality increased at every temperature. The survival patterns of all strains at this humidity were fairly similar. Some differences in adult survival also occurred under other treatments, although this was not as marked as with larvae and nymphs.

These results show that the survival patterns of field strains of *R. appendiculatus* do differ. However, the full impact of these differences can only be realised under field situations where conditions are changing all the time.

MARIAKANI TICK PROJECT

East Coast fever (ECF) caused by Theileria parva, *a protozoan parasite transmitted by the tick* Rhipicephalus appendiculatus, *is the most prevalent of the tick-borne diseases (TBDs) present in Kilifi District, Coast Province, Kenya. Cattle are generally protected by dipping once or twice per week. Not only is this exercise expensive, but dip management is often poor. Extensive trials of ECF immunisation (using the method of infection and treatment) by the Kenya Government and other research institutes have shown great promise and it might, therefore, be possible now to create a regional herd of cattle that are not at risk from this deadly disease. Enzootic stability in TBDs, induced either naturally or artificially, plays a big role in the complex relationship between parasites and hosts, and must be maintained. Thus, the ICIPE Mariakani Tick Project came into being with two specific objectives:*

- *To investigate alternative methods of controlling ticks in cattle populations not at risk, or shielded from, TBDs (especially ECF) by the use of immunisation and/or drugs.*
- *To develop a model for the cost-effective control of ticks in East Africa over a wide range of biotopes and climatic conditions.*

2.27 EFFECTS OF VARYING THE INTENSITY OF CATTLE TICK CONTROL ON TICK NUMBERS AND MILK PRODUCTION

A. O. J. Amoo, O. O. Dipeolu, P. B. Capstick, T. R. Odhiambo and L. N. Gichuru†

This study is being conducted at the Mariakani Livestock Productivity Sub-Centre (LPC) of the Kenya Agricultural Research Institute. The aim is to find the most cost-effective level of dipping for the control of ticks on cattle that have been immunised against East Coast fever (ECF). Unless such animals remain exposed to a degree of tick infestation, the desirable state of enzootic stability, induced artificially by the immunisation, will not be maintained. The opportunity has therefore been taken to use high grade Sahiwal x Ayrshire cattle at the LPC, in order to observe the effects on ECF-immunised cattle of varying the intensity of tick control by the use of acaricide, and also to determine the economic threshold of tick damage.

Thirty lactating cows and 30 weaners, all immunised against ECF, were divided equally into six groups and dipped at the following intervals (in weeks): 1 (control), 2, 4, 6, 8 and undipped, respectively.

All groups are kept under the same extensive management procedures and all routine vaccinations and prophylactic medications are done. Productivity in terms of milk yield and liveweight gain are being compared. Ticks are sampled monthly by whole body collections from all the lactating cows. Data will be collected for 2 years. The results for the first 6 months of the experiment are presented for the cows (Figure 2.6), and show that the tick challenge was generally low. This might be as a result of the prolonged period of intensive dipping that has been practised on the farm. Analysis of the tick data shows that although the tick load in Group 1 was the same as in Group 2, it differed from all the other groups (Table 2.10). The milk yields of animals in Groups 1–4 did not differ appreciably, but they were significantly lower than in Groups 5 and 6 (Table 2.10).

It will also be necessary to gather information on calving interval, days in milk, milk offtake, incidence of clinical disease (especially other TBDs like babesiosis and anaplasmosis) and whether immunisation alters susceptibility to trypanosomiasis.

Data generated during the course of the study will also be compared to all relevant data from the previous 1–2 years for the experimental animals. Finally, since the experimental animals are not all the same age, age effects on production under different dipping regimes will be examined by comparing tick load and milk production of animals of the same age under different dipping regimes, as well as animals of different ages under the same regime.

†*National Veterinary Research Centre, Kenya Agricultural Research Institute, Kabete.*

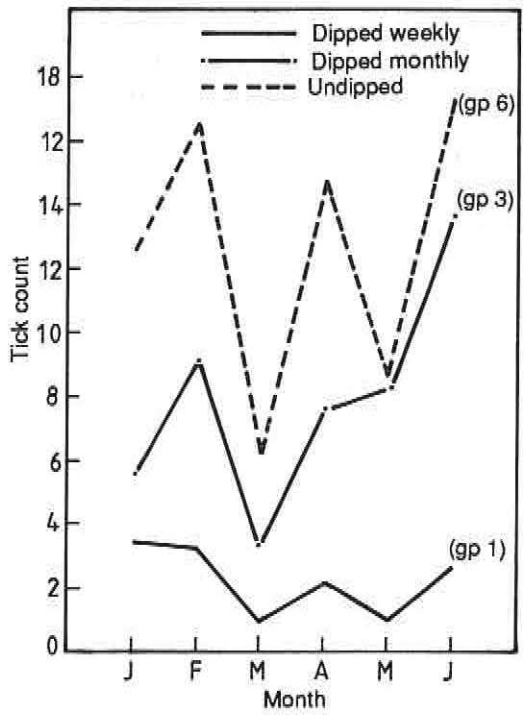

Figure 2.6 Mean monthly counts of ticks on the whole body of five cows under three tick control regimes at Mariakani Livestock Productivity Sub-Centre, January–June 1989.

Table 2.10 Mean monthly tick load and mean milk yield for six groups of five cows each at Mariakani LPC under different dipping regimes, January–June 1989

Experimental group	Dip interval (weeks)	No. of ticks	Milk yield (kg)
1	1	2.3^{a}	151.8^{a}
2	2	4.8^{ab}	141.7^{a}
3	4	7.9^{bc}	134.5^{a}
4	6	11.3^{cd}	136.9^{a}
5	8	11.4^{cd}	113.7^{b}
6	no dipping	12.5^{d}	112.9^{b}

Means in each column followed by the same letter do not differ significantly ($P > 0.05$).

2.28 EFFECT OF TICK INFESTATION ON GROWTH OF CATTLE UNDER RANGE CONDITIONS

A. O. J. Amoo, O. O. Dipeolu and L. N. Gichuru

This study again examines the possibility of changing from the current intensive use of acaricide to a more cost-effective alternative, without necessarily impairing productivity, and certainly without causing high mortality in animals that are not immunised against East Coast fever. The animals are kept under rangeland conditions on a ranch in Taita-Taveta District and are dipped weekly. Routine preventive medications include regular deworming and quarterly prophylactic use of Samorin against trypanosomiasis. Vaccinations against common viral

diseases are given.

A total of 30 cattle—all Sahiwals 11–12 months old at the start of the experiment—were divided into five groups of six animals each. Group 1 serves as the control and is dipped weekly; Groups 2–4 are dipped every 2, 4 and 6 weeks, respectively; Group 5 is not dipped. Every 2 weeks all animals are weighed; every month the ticks are sampled by whole body collection and blood is taken for parasitological examination.

Results for the first 8 months show that mean weights (Figure 2.7) and mean tick counts (Figure 2.8) of Groups 1 and 2 do not differ, but Groups 3, 4 and 5 differ when compared to Group 1. The tick counts show a very similar pattern to the mean weight gains. The blood examination revealed that all groups are infected with theilerial piroplasms to varying degrees, but only two clinical cases of theileriosis have occurred so far. It is too early to arrive at any firm conclusions, but the indications of a likely alternative to regular weekly dipping are already beginning to appear.

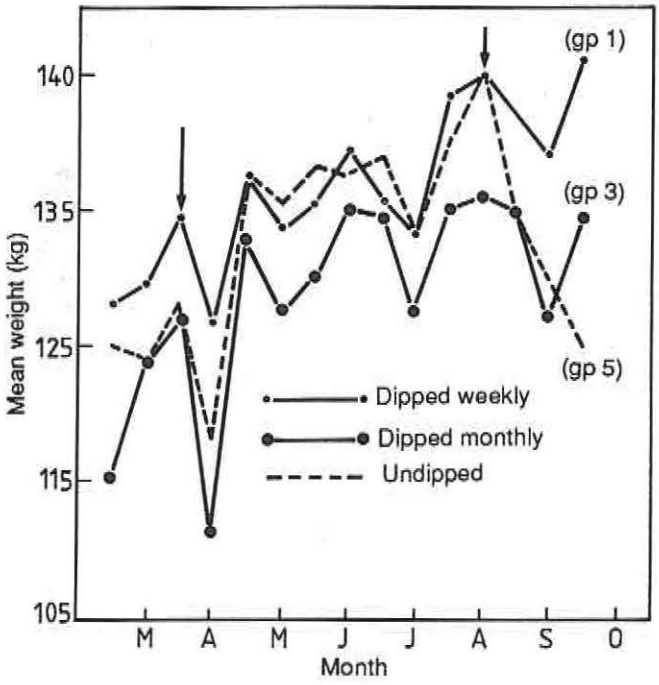

Figure 2.7 Mean weights of three groups of six cattle at monthly intervals under three tick control regimes on a ranch in Taita-Taveta District, March–October 1989. The vertical arrows indicate Samorin treatment.

2.29 POPULATION DYNAMICS OF LIVESTOCK TICKS IN COAST PROVINCE, KENYA

A. O. Amoo, O. O. Dipeolu, D. K. Punyua and L. N. Gichuru

Data on population dynamics, including survival and development, are essential for building a satisfactory model for prediction of tick numbers on the pasture and for developing the integrated control strategies and tick management packages discussed in section 2.1.

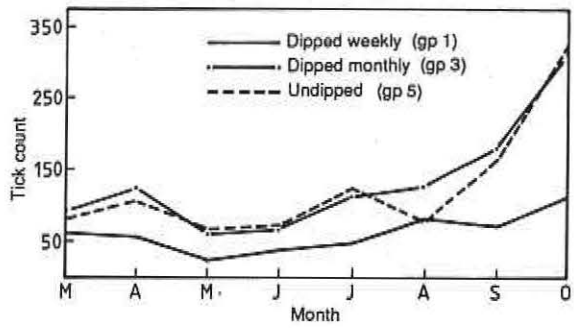

Figure 2.8 Mean counts of all ticks on the whole body of six cattle at monthly intervals under three tick control regimes on a ranch in Taita-Taveta District, March–October 1989.

2.29.1 Seasonal dynamics of ticks on cattle

On-host population data are presently being collected on selected herds in Kaloleni Division, a farm at Mariakani, and on two private ranches in Taita-Taveta District. These three areas represent different ecosystems and thus fit one of the aims of LTRP, to gather information on the seasonality of ticks in different biotopes and climatic conditions.

Kaloleni Division lies principally in the Coconut Belt and is currently the site of an extensive trial of East Coast fever immunisation of cross-bred dairy cattle belonging to smallholders. The animals in our survey, however, are East African zebu. Mariakani is in the Transitional Zone, while the ranches are in Dry Rangeland, bordering on Tsavo East National Park. These two locations have cross-bred Sahiwal x Ayrshire and Sahiwal animals, respectively. The sample is 12–15 animals for each location.

Only data on the seasonal fluctuations of *Rhipicephalus appendiculatus* in Kaloleni are ready for presentation yet, but the picture of the distribution pattern of the various ticks in the three ecoclimatic zones is emerging. Although *R. appendiculatus* is present in all three zones, it is second in abundance to *R. pulchellus* in the Dry Rangeland which is barely suitable for *R. appendiculatus*.

Amblyomma variegatum also disappears as one moves inland from the coast. It is present only in the Kaloleni collections, and is replaced by *A. gemma* in the Transitional and Dry Rangeland Zones.

Both *Boophilus decoloratus* and *B. microplus* are present in the Coconut Belt, but very few *B. decoloratus* have been collected on cattle at Mariakani. This is particularly important when considering the diseases that these species transmit. No boophilid has yet been encountered in the Dry Rangeland.

The population of adult *R. appendiculatus* on cattle over a 12-month period in Kaloleni showed peaks in March and September, while the rainy season of March–June was accompanied by a decline in numbers (Figure 2.9). This observation is contrary to what might be expected, but is similar to what was seen on Rusinga Island and might be connected with agricultural and husbandry practices (see section 2.24). The annual activity pattern of this tick thus appears to be bimodal, with a second peak that is higher than the first. Nymphal activity was also bimodal with peaks in March and June.

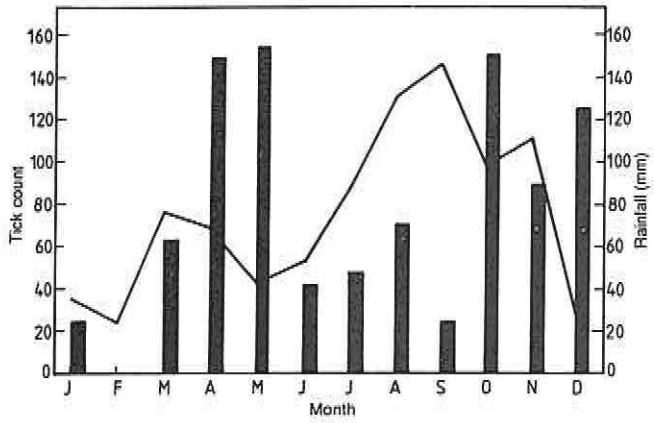

Figure 2.9 Mean counts of adult *R. appendiculatus* on the whole body of 12 undipped cattle at monthly intervals at Kaloleni, Kilifi District, during 1989; histogram shows monthly rainfall.

2.29.2 Development and survival of R. appendiculatus *and* A. variegatum *at Mariakani*

Engorged females, nymphs and larvae were put out in April and August 1989 at the Veterinary Investigation Laboratory, Mariakani, in order to determine the parameters listed in Table 2.11. For the survival studies, eggs and batches of fed nymphs and larvae were put out in nylon bags or cones; sampling is done monthly, the first sampling date being dependent on the corresponding ticks put out for development. A thermohygrograph is installed in the pasture at the specially demarcated study site.

Table 2.11 Development of *R. appendiculatus* and *A. variegatum* at Mariakani from exposures of ticks made in April and August 1989

	R. appendiculatus		*A. variegatum*	
Parameter	Apr.	Aug.	Apr.	Aug.
Larval-nymphal moult (days)	6	11	16	17
Nymphal-adult moult (days)	8	15	20	23
Females laying eggs (%)	94	92	70	< 10
Pre-oviposition period (days)	3	2	10	9
Pre-eclosion period (days)	24	> 90	> 45†	> 90

†More than 70% mortality thereafter.

The first results confirmed that *Rhipicephalus appendiculatus* is able to develop successfully in the environmental conditions of Mariakani, but *A. variegatum* cannot, and is therefore absent from the regular tick collections. This is because less than 70% (April) and 10% (August) of engorged females laid eggs, followed by high mortality during the larval development period which greatly reduced the crop of larvae that would be available for host pick-up. Another species, *A. gemma*, is relatively abundant and is known to be better adapted to dry environments than *A. variegatum*. For both species, egg hatching has been almost negligible in the second release, with most of the egg batches drying up.

The survival results are still incomplete, but the indications are that both species suffer relatively heavy mortality at Mariakani.

2.30 LARVAL AGGRESSIVENESS AND COMPETITION, AND HOST PICK-UP RATES OF TICKS

A. O. J. Amoo, O. O. Dipeolu, K. S. Nokoe, D. K. Punyua and L. N. Gichuru

There is no information on aggressiveness in terms of host-finding of the larvae of any species of tick present on the coast of Kenya. There is also no information on the rate of host pick-up of unfed adults of either *Rhipicephalus appendiculatus* or *Amblyomma variegatum* in the same region. This study is investigating the relative aggressiveness and interspecific competition on the pasture of larvae and adults of these two species, and also larval *Boophilus decoloratus*.

The study site is a pasture plot of 0.85 ha, planted with improved grasses, and used in an agronomy trial for the preceding two years. Daily blanket dragging for 8 weeks prior to the start of the experiment yielded no ticks. The site was divided into four paddocks of equal size by post and barbed wire fences.

In the first part of the experiment, different combinations of the species of larvae, and different numbers of *R. appendiculatus*, were deployed. Six bait cattle (3 tick-susceptible crosses and 3 tick-resistant zebus) were grazed in each paddock for 3–4 days in every test. The larvae were then sampled from the neck only.The second part of the experiment will be conducted with adults of *R. appendiculatus* and *A. variegatum*.

2.31 EFFECT OF VARYING TICK CONTROL ON CATTLE FERTILITY

A. O. J. Amoo, D. K. Punyua, O. O. Dipeolu, S. J. Munyua† and L. N. Gichuru

Information on the effect of ticks on fertility, especially of bulls, is lacking. An experiment on this topic has just begun, using two groups of animals kept in a zero-grazing unit; one group will be completely tick-free, while the second group will be artificially infested every month with known numbers of adult *Rhipicephalus appendiculatus* and *Amblyomma variegatum* and *Boophilus decoloratus*. A second experiment will have grazing animals (cross-bred and zebu) subjected to various dipping regimes, and to high and low tick challenge.

†*Faculty of Veterinary Medicine, University of Nairobi.*

MEDICAL VECTORS RESEARCH PROGRAMME

3

Medical Vectors Research Programme

The MVRP continued research activities geared to protecting rural populations from two major vector-borne diseases through integrated vector management. The activities centred on sandflies and leishmaniasis and mosquitoes and malaria. Furthermore, work on animal reservoirs of leishmaniases was intensified. Mosquito behaviour studies were also carried out in the Mwea-Tebere Rice Irrigation Scheme. Sandfly and leishmanial parasite characterisation work was continued using various techniques. Efforts were made to identify other parasites which affect the same hosts infected in nature by leishmanial parasites, as part of an approach to vector-disease epidemiology based on multi-parasite studies. This effort resulted in the identification of new species of haemoprotozoa in lizards, and opened new areas of future research on understanding the effect of these parasites in enhancing or protecting the affected host against further infection by Leishmania *or other blood parasites.*

3.1 FEEDING INTENSITY OF *SERGENTOMYIA INGRAMI* ON SELECTED PLANTS

J. B. Kaddu, M. J. Mutinga, K. S. Nokoe, R. M. Musyoki and M. P. Nyamori

Previous studies (*ICIPE 1988 Annual Report*) on the feeding of a species of sandfly, *Sergentomyia ingrami*, on selected common indigenous and exotic plants in its Kenyan habitat indicated that *S. ingrami* not only feeds on many different species but prefers certain ones. In the present study we continued the work at three intensities of feeding to find out whether differences observed in the amount of plant-derived sugars in the sandflies are statistically significant.

Totals of 1693 female and 1012 male unfed laboratory-reared sandflies were caged in replicates and offered shoots of nine indigenous plants (*Asystasia schimperi, Bidens pilosa, Conyza floribunda, Dyschoriste radicans, Ficus natalensis, Galinsoga parviflora, Neonotonia wightii, Solanum incanum* and *Vernonia lasiopus*) and nine exotic plants (*Chrysanthemum coccineum, Lycopersicon esculentum, Morus alba, Musa paradisiaca, Phaseolus vulgaris, Solanum tuberosum, Tagetes minuta, Tipuana tipu* and *Vigna unguiculata*). These species belong to six families of Kenyan plants (Acanthaceae, Compositae, Moraceae, Musaceae, Papilionaceae and Solanaceae). Each test lasted 16 hours at 25 ± 1°C and 90% r.h. Controls were kept under the same conditions but without plants. The sandflies were then dissected. The gut and the rest of the body were immersed in 0.05 ml Anthrone solution and examined for blue staining.

Flies showing faint blue staining were counted as feeding rate level 1 (FRL 1), increasing to those showing deep blue staining (FRL 3). The feeding rate of the sandflies on each plant was estimated using the following formula:

% feeding rate (FR) = $100\ (b + c + d) / (a + b + c + d)$

where a = number of sandflies which failed to feed, and b, c and d are the numbers of FRL 1–3, respectively. The number of males and females which fed at each of the three levels was recorded separately. An analysis of variance was performed and the mean FRs compared using Duncan's multiple range test.

Sergentomyia ingrami fed more on the exotic than on the indigenous plants at FRL 3. Evaluation of FRL 2 indicated no difference between exotic and indigenous species but the males consistently fed more heavily than the females. There were some significant differences between species at each of the three feeding rate levels on the exotic plants and a highly significant sex difference existed at FRL 2. Evaluation of feeding performance on the indigenous plant species indicated highly significant differences between species at all three FRLs.

The distinction between the three feeding levels assumes that the differences in staining intensity in the Anthrone test reflect real differences in the amount of plant-derived sugar in the sandfly gut. Three possibilities emerge from this assumption:

1. The staining intensity relates to the size of the meal taken by the sandfly. This would indicate that some sandflies failed to take full meals on certain plants owing perhaps to exogenous and/or endogenous factors, including any of plant origin.

2. The three FRLs represent a progression in the digestion of the sugar meal in the gut, and FRL 1 and FRL 2 sandflies merely indicate that residual, undigested sugar was detected in the tests. If this is true it would indicate that the previously starved sandflies sucked plant juices at widely different times, although they were all exposed initially to the plants at the same time. A lack of uniformity in the feeding schedule would equally indicate that there were factors (exogenous and/or endogenous) which influenced the feeding pattern.

3. The sugar content of the juices of the tested plants varied.

Given these differences, it would be valuable to analyse these plants chemically to find out their interaction with the biology of sandflies in relation to their vectorial potential. Studies on the rate of digestion of plant-derived sugars in sandflies would also be valuable in elucidating the phenomenon of feeding level.

3.2 SEASONAL PREVALENCE OF *SERGENTOMYIA GARNHAMI*

A. E. Onyido

Sandflies are of world-wide importance as the only vectors of leishmaniasis. In the Old World, only species of the genus *Phlebotomus* have been incriminated. Sandflies of the genus *Sergentomyia* were previously only known to feed on reptiles and transmit the reptilian form of leishmaniasis, but work by MVRP in Kitui District has showed that *S. garnhami* not only feeds on man but could also be involved in the transmission and maintenance of leishmaniases. Detailed ecological investigations have therefore been needed in order to clarify the role of *S. garnhami* in the epidemiology of leishmaniases.

Sandflies were sampled at bi-weekly intervals in nine different biotopes: termite hills, animal burrows, animal enclosures, open spaces, inside and outside walls of houses, rock crevices, plant bases and tree holes. The flies were washed in 1% detergent saline, mounted in gum chloral, examined under the stereomicroscope, then identified and counted.

Of the total sandfly yield from the nine biotopes, 29% were *S. garnhami*. Termite hills, animal burrows and rock crevices were found to be major sandfly habitats (Table 3.1), and termite hills (59%) and animal burrows (24%) also constituted the main habitats for *S. garnhami*.

Table 3.1 Comparative yields of sandflies from nine biotopes in Kitui District

Site	Total sandfly yield (%)	Distribution of *S. garnhami* (%)
Termite hill	35.4	58.8
Animal burrow	19.9	23.9
Animal enclosure	0.9	0.1
Open space	2.1	0.7
Inside house	6.0	0.5
Outside house	7.1	0.4
Rock crevice	22.5	9.6
Plant base	4.1	3.9
Tree hole	2.3	2.0

The seasonal prevalence of *S. garnhami* appears to be similarly influenced by climatic factors, mainly temperature and rainfall, in all nine biotopes studied. Peak numbers in October–December and April–June appear to be associated with the rainy seasons as the major influence.

Rainfall leads to an increase in the sandfly population because it supplies moisture to the habitat for the development of eggs, larvae and pupae, raises ambient humidity and lowers the temperature to the optimum of 25–35°C and thereby also enhances adult survival.

3.3 NATURAL HOST PREFERENCES OF WILD-CAUGHT SANDFLIES

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

Sandflies are known as the major vectors of visceral, cutaneous and mucocutaneous leishmaniases, but very little is known about their natural feeding habits. This is mainly because of their small size and highly selective and somewhat secretive resting and breeding sites. Moreover, the flies are very fragile and it is not easy to handle them for marking and releasing in the field for behavioural investigations under natural conditions.

A focus for both visceral and cutaneous leishmaniases at Marigat in Baringo District, Kenya, was chosen for the investigations. Blood-meal analysis was used as a tool to investigate natural host preferences in order to incriminate vectors of leishmaniases and identify animal reservoirs.

Female sandflies were sampled from their normal resting sites in animal burrows, termite hills, tree holes, tree canopies, inside and outside walls of houses, soil crevices, chicken coops and open areas. They were trapped using sticky traps made of polythene sheets coated with castor oil, fan suction traps, modified CDC light traps and mouth aspirators. In order to capture freshly fed sandflies, the traps were set in the evening and the flies collected in the early morning. The results are summarised in Table 3.2.

Two species of *Phlebotomus* and five species of *Sergentomyia* were encountered blood-fed and resting in the nine habitats which were investigated. Analysis of the blood meals revealed distinct host preferences between the genera, with further distinctions between species. Furthermore, certain resting sites appeared to be favoured by particular species. It was observed that such wild hosts as lizards and rodents shared the same resting habitats as the sandflies. It was also observed that the man-biting species preferred to rest outdoors after feeding. Domestic animals (i.e. the ruminants and canids) and man were the favoured hosts of those species which vector visceral and cutaneous leishmaniasis. It has become apparent that prophylactic treatment of domestic animals might be a factor to consider in controlling leishmaniases in this focus.

Table 3.2 Host preference from blood meal analyses in seven species of phlebotomine sandflies, expressed as percentage distribution

	Phlebotomus		*Sergentomyia*				
Host	*duboscqi*	*martini*	*africanus*	*antennatus*	*bedfordi*[1]	*ingrami*	*schwetzi*[2]
Man	15.4	14.9	7.1	13.0	7.0	4.3	8.9
Ruminant sp.	30.8	75.9	50.0	28.4	11.5	6.4	14.4
Carnivore sp.	15.4	0.0	7.1	1.9	4.1	8.5	2.2
Bird sp.	0.0	5.6	0.0	0.6	2.1	40.4	48.9
Hippopotamus	0.0	0.0	0.0	6.8	4.5	4.3	1.1
Rodent sp.	38.5	1.9	7.1	9.9	7.4	6.4	3.3
Lizard sp.	0.0	1.9	28.6	39.5	63.1	29.8	20.0

[1]Includes 1 mixed bird/ruminant bloodmeal (0.4%).
[2]Includes 1 mixed rodent/canid bloodmeal (1.1%).

3.4 SANDFLIES FROM SOME NATURAL MICROHABITATS IN NAROK DISTRICT

M. J. Mutinga, C. C. Kamau, F. M. Kyai and A. M. Lohding[†]

This area attracted interest when two clinical cases of leishmaniasis in goats belonging to pastoralists in the vicinity of the Trans-Mara Veterinary Research Sub-Centre were reported in 1987 (*ICIPE 1988 Annual Report*). This part of the Western Escarpment of the Rift Valley has only been reported to harbour *Leishmania aethiopica*.

The sandfly fauna of the area was investigated in November–December which is a dry period when the sandfly population was assumed to have stabilised. Sticky castor oil traps were placed overnight in four habitats (termite hills, tree holes, animal burrows and caves). Similar traps 1 m x 1 m in area were also set in the place where the goats were reported to have been grazing. The traps were set before sunset and the sandflies were collected from the traps the following morning.

The collected sandflies were identified as described in Section 3.2.

Termite hills and tree holes were the most productive habitats. The two most abundant species (accounting for 97.5% of the catch) were *Sergentomyia schwetzi* and *S. bedfordi*. Only occasional specimens of the genus *Phlebotomus*, *P. rodhaini*, were encountered, but the studies were not exhaustive.

[†]*Ministry of Livestock Development, Trans-Mara Veterinary Research Sub-Centre, Lolgorien.*

3.5 EPIDEMIOLOGY OF CUTANEOUS LEISHMANIASIS IN KITUI DISTRICT

M. J. Mutinga, M. Basimike, C. C. Kamau, D. M. Omogo and F. M. Kyai

Investigations of animal reservoirs of both visceral and cutaneous leishmaniasis in Kitui District have led to the isolation of leishmanial parasites from lizards and carnivores. Parasites recently isolated from genet cats were characterised using isoenzymes and shown to be similar to the human *Leishmania major* type. Studies were consequently carried out on the sandflies from the area which led to the isolation of *Leishmania* parasites from *Sergentomyia garnhami*, an anthropophilic sandfly previously implicated as a vector of *L. donovani* in Machakos District. The isolate was likewise characterised by isoenzyme techniques as *L. major*.

Recent investigations have now led to isolations of *Leishmania* from a rodent (gerbil) and their behaviour in an animal model seems to be like that of *L. major*.

This is the first report of *L. major* to the east of the Rift Valley in an *L. donovani* focus and with *S. garnhami* implicated as a possible vector. It is also the second instance of the two diseases, *L. donovani* and *L. major*, occurring in the same focus in Kenya. This double focus is situated on plains traversed by the Tana River which are earmarked for future irrigation development. The presence of cutaneous leishmaniasis therefore raises epidemiological questions which the Programme is endeavouring to answer.

3.6 TAXONOMY OF SANDFLY SPECIES

H. Mahamat

Isoenzyme analysis and pattern analysis of cuticular components were used to characterise sandfly species collected from the field and reared in the laboratory. The following sandfly species were used during the investigations: *Phlebotomus duboscqi, P. elgonensis, P. martini, P. pedifer, Sergentomyia africanus, S. antennatus, S. bedfordi, S. garnhami, S. ingrami* and *S. schwetzi*.

3.6.1 Isoenzyme analysis by thin layer starch gel electrophoresis

Histograms were developed to express banding patterns for different sandfly species based on the following enzymes: glucose phosphate isomerase, malate dehydrogenase and phosphoglucomutase. The banding patterns were specific and could discriminate between the different species of sandflies. Phylogenetic relationships between the species based on Jaccard matching indicated two

groups which correspond to the genera *Phlebotomus* and *Sergentomyia*. It was noted, however, that *S. garnhami* was grouped in the genus *Phlebotomus*, a particularity to be further investigated.

3.6.2 Isoenzyme analysis by isoelectric focusing
Eighteen isoenzymes were assayed to determine which of them could be of practical use in the identification of sandflies. Isoelectric focusing was carried out, and only two isoenzymes (glucose phosphate isomerase and phosphoglucomutase) were found to give banding patterns visible to the naked eye.

3.6.3 Pattern analysis of cuticular components
Cuticular components of single sandflies were extracted in 20 µl of double distilled hexane for 15 minutes. The extract was then injected into a Hewlett Packard 5890A gas chromatograph equipped with a fused capillary column (25 m x 0.32 mm ID) and a flame ionisation detector. Cuticular components of sandflies showed both quantitative and qualitative differences among species. Each species had a unique pattern of peaks, which was discernible visually. Classification based on different characteristics of the peaks (e.g. area, width and area percent) was carried out and found to be equally useful in differentiating between species. Peaks of females and males of the same species also showed significant quantitative differences. These results showed that cuticular component analysis could be used as a rapid and simple technique for the identification of sandflies.

3.7 SANDFLY PARASITIC MITES

M. J. Mutinga, F. A. Amimo, C. C. Kamau, D. M. Omogo and F. Kyai

Mites have been found attached under the wings of sandflies and thereby introduced into insectary colonies where they have proved detrimental to the immature stages, if left unchecked. Little is known of the impact of mites on the sandfly population at large, but their apparent predatory tendency identifies them as possible natural enemies of sandflies. A study was therefore started with the following objectives: (a) to identify the mites, (b) study their biology and ascertain the stages in the life cycle which are predatory, and (c) determine their parasitic capacity.

Immature stages were obtained from sandfly rearing dishes in the ICIPE sandfly colony. They were mounted and examined under a compound microscope. Observations were made on the plate ornamentation and setae, the chaetotaxy of the dorsum and appendages, the body segmentation and the structure of the mouthparts. The morphology of the immature stages and their relative sizes were also considered. Measurements of eggs, larvae, nymphs and adult males and females were taken from living specimens in water mounts. Ten mites were considered in each series.

Studies on the life cycle, experimental feeding and the susceptibility of the sandfly immatures to the mites were undertaken. The mites were cultured at 25–30°C and 60% r.h. in standard petri dishes pierced with a hole at the bottom to allow the entry of moisture, and half-filled with plaster of Paris. Larval sandfly diet containing rabbit faeces, sandfly eggs and larvae and resultant fungal growths was constantly available to the mites. The stages of post-embryonic development were observed and timed in pure cultures introduced into cylindrical plastic vials half-filled with plaster of Paris and maintained as above.

The consumption rates of the mites were monitored on eggs and larvae of *Sergentomyia ingrami* and *S. schwetzi* which were introduced to vials containing mites of a pure line. Sandfly larval food was also provided.

Two species of mites have been isolated from the laboratory sandfly colony. One belongs to the sub-order Mesostigmata and the other to the Astigmata. The mesostigmatid is parasitic on the eggs and larvae of sandflies. We are now looking to see whether other soil fauna might form part of its diet.

3.8 PILOT CONTROL OF MALARIA AND LEISHMANIASES IN BARINGO DISTRICT: PREPARATIONS

M. J. Mutinga, C. M. Mutero, M. Basimike and A. M. Ngindu†

The aim of the Medical Vectors Research Programme is to develop appropriate control measures against disease vectors for use by the rural community that are sustainable, affordable and safe.

In late 1988, a joint pilot project was initiated at Marigat in Baringo District by ICIPE and the Kenya Government to evaluate the impact of Permethrin-impregnated screens on vectors of malaria and leishmaniases.

Very good results have been shown by the use of insecticide-impregnated bednets to protect people against mosquito bites. The intention now is to protect the household as a whole rather than the individuals, by the use of the "ICIPE *mbu* cloth" screens hung on house walls—an approach tried with success in the use of the ICIPE sticky trap to control sandflies round the homestead.

3.8.1 Preparatory phase
This involved the selection and marking of 2000 houses in the Marigat area in which Permethrin-impregnated screens were to be fixed. The houses were distributed within Marigat town and in adjoining settlements which are part of the Perkerra Irrigation Scheme. A census of people living in the houses was also conducted. Several public meetings to provide information were held with the assistance of the local administration, particularly the District Officer and Chiefs. In addition to the selection of an experimental area, a separate settlement, Ngambo, was chosen as a non-treated control area. A barrier zone of one kilometre separated the experimental and control areas.

A sample of the local human population was screened for malarial parasites. Schools were chosen for this purpose. Clinical records were also examined to establish the incidence of malaria and leishmaniasis.

3.8.2 Insecticide-impregnated cloth screens

Selection of the study sites and marking of houses was followed, in February 1989, by collection of baseline data on mosquitoes and sandflies for six months. Preparation and fitting of the cloth screens were then carried out over a period of one and a half months.

The cloth is white cotton supplied in bulk by Kisumu Cotton Mills. The cloth was provided in specified sizes. The pieces of cloth were impregnated with Permethrin using standard World Health Organisation procedures. They were individually soaked in Permethrin solution and spread out to dry. Treated screens were then secured on the inner bedroom walls with strings, nails or strips of wood.

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3.9 PILOT CONTROL OF MALARIA AND LEISHMANIASES IN BARINGO DISTRICT: MOSQUITOES

C. M. Mutero

The conventional method of evaluating the success of vector control operations is by assessment of certain population parameters before and after the application of intervention measures. The mosquito parameters that were studied included: relative and absolute densities in houses and in selected outdoor resting sites, average survival rates, and the movement of fed mosquitoes out of houses (exophily).

Appropriate data were then collected following a standard study design which incorporated several mosquito-collecting and sampling techniques. These included removal of mosquitoes from walls using battery-powered aspirators, exit traps, up-draft suction traps and CDC light traps. The catches were examined and identified. Medically-important species were, in addition, grouped according to their abdominal appearance and unfed females were dissected to determine parity.

Results to date show that *Culex quinquefasciatus* is the predominant species in Marigat town. *Anopheles funestus, A. gambiae* (*sensu lato*) and *Mansonia uniformis* were collected from various settlements within the irrigation scheme but only rarely in the town. A proper assessment of the impact of the screens is not possible on the basis of only two months post-treatment data. Nevertheless, the available research results, coupled with reports of greatly reduced mosquito nuisance received from many people in the treated area, indicate that this technology is a highly promising control device.

3.10 PILOT CONTROL OF MALARIA AND LEISHMANIASES IN BARINGO DISTRICT: SANDFLIES

M. Basimike

In order to evaluate the effectiveness of the Permethrin-treated screens for controlling sandflies in the Marigat leishmaniasis focus, studies on sandfly population levels and their bionomics were needed before and after deployment of the screens. Sandflies were sampled on a weekly basis from six experimental and two control villages chosen in the Marigat area. Six houses were randomly selected in each village. Sticky traps made of polythene sheeting (1 m x 1 m) coated with castor oil were used to sample sandflies from the selected houses. Eleven sandfly species have been collected and identified, namely: *Phlebotomus duboscqi, P. martini, P. rodhaini, Sergentomyia adleri, S. affinis, S. africanus, S. antennatus, S. bedfordi, S. clydei, S. ingrami* and *S. schwetzi.*

Sandfly numbers fluctuated seasonally in both villages. Low populations were observed during the dry period (February to March) and the beginning of the wet weather (April). High sandfly densities were recorded during months with moderate rainfall (May and June), but heavy rain in July decreased the sandfly population.

In August–September, approximately 2000 houses were fitted with Permethrin-impregnated screens. The number of sandflies feeding on man inside the treated houses was assessed from detailing the physiological status of the females caught. The ratio of the number of engorged females to the total number of females caught inside the treated houses is known as the engorgement rate. *Sergentomyia adleri, S. africanus* and *S. schwetzi* were found to feed mainly inside human dwellings.

Preliminary results show a significant sandfly reduction in the treated villages, while no significant sandfly reduction was observed in the control area.

3.11 ISOLATION OF LEISHMANIAL PARASITES FROM AN *ANOPHELES GAMBIAE* MOSQUITO

C. M. Mutero, M. J. Mutinga and R. M. Musyoki

As a follow up of previous experiments on the laboratory infection of mosquitoes with *Leishmania* promastigotes, wild mosquitoes were collected and dissected for leishmanial parasites at Marigat, Baringo District. *Anopheles gambiae (sensu lato)* comprised 91% of the catch; the rest were *A. funestus* and *Culex quinquefasciatus*. One female *A. gambiae* was found to be infected with leishmanial promastigotes. These, when subsequently inoculated into Balb C mice, caused skin lesions resembling those due to *Leishmania major*. The average size of the parasites when grown in RPMI culture medium was body length 11.7 ± 0.2 μm, width 1.3 ± 0.4 μm and flagellum length

15.5 ± 0.3 µm. Biochemical characterisation of the parasites is being undertaken by the MVRP Molecular Biology Unit.

3.12 CHARACTERISATION OF *LEISHMANIA* SPECIES FROM KENYA BY CELLULOSE ACETATE ELECTROPHORESIS

B. N. Odero

Identification of *Leishmania* parasites continued during the year. Field isolates were compared with WHO marker strains of *Leishmania* species which parasitise man. These included *Leishmania aethiopica, L. donovani, L. infantum L. major* and a lizard-infecting species, *L. adleri*. The isoenzyme band patterns of the markers were matched with those of wild isolates to identify them, using five enzyme systems, i.e. malate dehydrogenase (MDH), mannose phosphate isomerase (MPI), glucose-6-phosphate dehydrogenase (G6PD), phosphoglucomutase (PGM) and glucose phosphate isomerase (GPI).

Thirty-eight wild isolates were screened against the reference species. The results showed that 12 isolates typed as *L. major*, seven as *L. donovani*, five as *L. adleri*, one as *L. aethiopica* and 13 did not match any of the markers. More markers will be used to screen these unknown strains.

3.13 MOLECULAR KARYOTYPE ANALYSIS OF *LEISHMANIA* SPECIES

V. C. Nyambati

There are several species of leishmanial parasites affecting both man and animals which are transmitted by sandflies. Although these parasites are morphologically similar, they produce different types of disease in man. The identification of the species is of great importance for epidemiological and disease control purposes.

The characterisation of *Leishmania* is based on clinical manifestations, response to treatment, geographic distribution, behaviour in laboratory or wild animals and development in different species of sandflies. In addition to these, a variety of molecular and biochemical techniques have been used. In this study chromosomes were analysed from different species of WHO reference strains and various wild *Leishmania* isolates. The application of pulsed field gel electrophoresis techniques allowed the separation of the entire chromosomes or large DNA molecules. This technique is capable of separating DNA molecules in the size range 50–2000 kilobase pairs, which is well above the resolving power of conventional gel electrophoresis. The DNA molecules present in the chromosomes are resolved into a series of bands of different sizes.

The chromosome profiles of six WHO reference strains used as controls fitted into three distinct groups. Chromosomes were analysed from 25 cloned wild isolates. The majority of these isolates had chromosome banding patterns similar to those found in the control WHO strains. The other wild isolates had chromosome profiles that differed from all three groups of reference strains. They could be divided into further groups according to their banding patterns.

Work is in progress to isolate particular chromosome fragments useful for species identification and for the preparation of a chromosome DNA library for molecular hybridisation. This should make it possible to generate a panel of chromosome-specific probes useful for identifying the corresponding chromosomes in different isolates.

3.14 ECOLOGICAL AND BEHAVIOURAL STUDIES OF MOSQUITOES IN THE MWEA RICE IRRIGATION SCHEME

B. A. Rapuoda

Human activities such as irrigation schemes increase the potential for malaria transmission through vector propagation. This is mainly due to the existence of vast networks of irrigation channels which, if not properly maintained, enhance the breeding potential of vector species. In April 1989 studies on the relationship between irrigation and malaria transmission were initiated in the Mwea-Tebere Irrigation Scheme which lies approximately 110 km north-west of Nairobi near the foothills of Mt. Kenya.

The objectives of the field study were, firstly, to determine the impact of rice irrigation practices on: (a) variation in mosquito species composition and their relative population density, (b) malaria infection rates in both the human and mosquito populations; and secondly, to compare the attractiveness of various hosts to different mosquito species.

Mosquitoes were sampled from the villages of Mathangauta and Mbui Njeru. Mbui Njeru lies in the centre of the scheme and is thus surrounded by irrigated paddies on all sides. It has a population of 268 tenant farmers. Mathangauta, on the other hand, lies on the periphery so it is not completely surrounded by irrigation, and has a population of approximately 500 tenant farmers.

Mosquito sampling was carried out for seven days every month in four houses per village. Hand collections were made from both indoor and outdoor resting sites using battery-powered aspirators.

The collected mosquitoes were identified to species. Female *Anopheles arabiensis* and *A. funestus* were then separated, depending on the physiological state of the abdomen. The salivary glands and midgut were dissected for the detection of malarial parasites, i.e. sporozoite and oocyst stages, respectively. The gut contents of fully fed females were individually collected on filter paper for blood meal analysis. Blood samples were also collected from the human population for malarial parasite examination by preparing smears from peripheral finger blood.

Mosquitoes identified from the irrigation scheme included *A. arabiensis, A. funestus, A. maculipalpis, A.*

pharoensis, A. praetoriensis, A. rufipes, Culex annulioris, C. quinquefasciatus and *Mansonia fuscopennatus.*

The most abundant species was *A. arabiensis.* The adults were present throughout the year and exhibited a strong endophilic tendency, in spite of having fed on bovine hosts outdoors. The mosquitoes showed a marked preference for bovine hosts. *Anopheles funestus* was initially recorded in low numbers which later increased sharply during the months of December and January. This rise coincided with draining the paddies and harvesting. During the draining period, water from the paddies is channelled into canals with a lot of vegetation which form suitable breeding sites for *A. funestus.* The parasite rate in the human population ranged between 0.3–7.6%. The infection rate in the mosquitoes was found to be 0.1–8.3% in *A. arabiensis* and 0–5.3% in *A. funestus.* These infection rates were considerably lower than those observed for irrigation schemes elsewhere in Kenya. Factors contributing to these low rates are being investigated in order to understand their significance in malaria epidemiology at Mwea.

3.15 SAURIAN MALARIA IN KENYA: NEW SPECIES OF PARASITES IN LIZARDS IN W. POKOT DISTRICT

M. J. Mutinga and O. O. Dipeolu

In the course of investigations on the malaria parasites of lizards in West Pokot District, we also found other sporozoan parasites in the peripheral blood of a large percentage of the lizards examined. Even though most of these parasites are morphologically distinct from the malaria parasites, many of them, especially the *Pirhemocyton*-like organisms, have identical taxonomic characters. The infection rate of lizards with these parasites was high in our study area and it was not uncommon to find two or three of them accompanying two or three *Plasmodium* species in an individual lizard. It became apparent to us that in our future epidemiological, haematological and pathological investigations on saurian malaria in this study area, concomitant infections with these other parasites must be taken into consideration.

There is, furthermore, a general scarcity of information on these groups of parasites throughout the world and especially in Africa.

Detailed investigations have shown that some of these are new species and we have now described them. The newly described species are *Haemoproteus mungitii* (a haemoproteid), *Karyolysus poleensis* and *Schellakia mabuyai* (haemogregarines), *Haematractidium omogoi, Pirhemocyton kongelai, Sauroplasma kachelibaensis* (*Pirhemocyton*-like organisms) and *Aegyptianella elgonensis* and *Eperythrozoon ngokai* (*Anaplasma*-like organisms). *Karyolysus poleensis* and *S. mabuyai* are regarded as the first reports of these genera in lizards in Africa, while *A. elgonensis* is regarded as the first report of the genus *Aegyptianella* in lizards.

3.16 SAURIAN MALARIA IN KENYA: EPIDEMIOLOGY IN LIZARDS IN W. POKOT DISTRICT

M. J. Mutinga and O. O. Dipeolu

During investigations into the prevalence of malarial parasites among lizards in West Pokot District, 179 lizards comprising eight species were caught. Examination of Giemsa-stained blood smears showed that 34 were infected with *Plasmodium* species; 15 were infected with a single species of *Plasmodium* and 19 carried multiple infections; the maximum, in four lizards, was four species. There were 19 combinations of parasite infections. Seventeen *Plasmodium* species were identified, the commonest being *P. icipeensis.* Only two of the eight lizard species were infected: the skink *Mabuya striata* and the agamid *Agama agama.* Eight of the *Plasmodium* species infected both; another eight species infected *M. striata* only, but three of these have been described from different lizard families elsewhere in Africa. *Plasmodium robinsoni* infected *A. agama* only, although it too was first described from another lizard family elsewhere in Africa.

Thirty-four (19%) of the lizards examined were infected with *Plasmodium.* Few data exist with which this infection rate can be compared; it appears to be one of the highest reported so far in Africa.

3.17 SAURIAN MALARIA IN KENYA: REDESCRIPTION OF SOME *PLASMODIUM* SPECIES

O. O. Dipeolu and M. J. Mutinga

Plasmodia of reptiles have received little attention compared with those of other animals and man. By 1986, only nine species of lizard malaria had been reported in Africa. The criteria used for avian and human malaria were not applicable to saurian malaria because of the distinct peculiarities of the latter. Telford (1974)[1] suggested a set of criteria that can be used to distinguish saurian malaria in stained blood smears in America. During our investigations in West Pokot District, we found that these criteria were fundamentally applicable for distinguishing saurian malaria in stained smears, but certain modifications were needed to suit the peculiarities of the species we encountered. These modifications, which are generally suitable for the identification of lizard plasmodia in Africa, have been described (Dipeolu and Mutinga, 1989)[2] and a key provided for the identification of all species reported in Africa (including 10 new species recorded in our study).

We hope to stimulate interest in research on saurian malaria in Africa because the importance of a better understanding of saurian malaria as an eventual tool for the control of human malaria is now recognised. Lizard malarias are the earliest forms on the evolutionary scale and are especially well suited for studies on the evolution and epidemiology of natural infections.

Very careful examination of Giemsa-stained smears made from the peripheral blood, liver and spleen of hand-caught lizards, captured between 1975 and 1987, showed the presence of seven out of the nine *Plasmodium* species of lizards which have been previously described in Africa. We have redescribed these species using a set of biological characters and procedures which enabled a large quantity of each stage of any species to be studied, measured and compared. The utilisation of these characters and procedures was a reaction to the multiple infections in individual lizards and a wide host range of each species among lizard species. These are: *Plasmodium adunyinkai, P. bowiei, P. gloriai, P. icipeensis, P. kachelibaensis, P. kadogoi, P. kaninii, P. kyaii, P. odhiamboi* and *P. sapaaensis. Plasmodium adunyinkai* is related to *P. maculilabre; P. kaninii* is related to *P. minasense* (*sensu* Telford); and *P. sapaaensis* was found to be related to *P. kadogoi, P. mabuyai* and *P. rhadinurum. Plasmodium kachelibaensis* and *P. kyaii* have distinct characteristics which distinguish them from the other *Plasmodium* species in the *tropiduri* group reported so far.

Four species (*P. bowiei , P. gloriai, P. icipeensis,* and *P. odhiamboi*) exhibited peculiar characteristics, most especially their effect on the white cells. They were therefore constituted into the "Kenyan" group.

[1]*Telford S. R. (1974) The malarial parasites of* Anolis *species (Sauria:Iguanidae) in Panama. International Journal for Parasitology 4, 91–102.*

[2]*Dipeolu O. O. and Mutinga M. J. (1989) Saurian malaria in Kenya: Redescription of some* Plasmodium *species of lizards in Africa and a key for the identification of all reported species. Insect Science and its Application 10, 531–544.*

TSETSE RESEARCH PROGRAMME

4 Tsetse Research Programme

The main goals of the programme are to contribute to the alleviation of constraints in livestock development and to the improvement of human health. In order to achieve these objectives, emphasis has been placed on pest management strategies that are environmentally safe, socially acceptable and within the means of resource-poor rural communities living in the neighbourhood of tsetse infestation. Particular attention has focused on the reproductive biology and factors related to the very low population densities of tsetse in their habitats. These sparse populations require a complex system of communication between the males and females to enable mating to take place. It is in their host location behaviour that tsetse assume importance as transmitters of African trypanosomiasis. Studies carried out this year have included population dynamics, diversity between populations, the role of wild life as reservoirs of African trypanosomiasis, hormonal control of reproduction, and an evaluation of biological control agents of tsetse. This report highlights the major findings.

The study areas in Kenya included a site at the foot of the Nguruman Escarpment in Kajiado District where there is an ICIPE field study site, Ruma National Park in the Lambwe Valley and Rusinga Island in South Nyanza Province in western Kenya, and Muhaka Forest and the Shimba Hills in Kwale District, Coast Province.

4.1 SUPPRESSION OF *GLOSSINA PALLIDIPES* AND *G. LONGIPENNIS* POPULATIONS AT NGURUMAN

R. D. Dransfield, R. Brightwell and B. G. Williams

The experimental suppression of tsetse populations on the Olkeramatian Group Ranch at Nguruman, using odour-baited NGU traps has continued through 1989 with tsetse numbers within the suppression zone reduced by 90.0–99.9%. Work has concentrated on mark-release-recapture studies in order to quantify absolute size of tsetse populations, length of the feeding cycle, and rate of movement between sub-populations.

We were especially interested to determine whether the NGU traps that we were using to monitor tsetse numbers in the suppression zone, were also giving us a good estimate of population size. Flies were marked at the beginning of each month and population size was estimated by regressing log-corrected recapture rate on time, and extrapolating to time zero. Figure 4.1 shows the population estimates. The very close relationship between catches in the NGU traps over one year and the absolute population estimates is shown in Figure 4.2. We can therefore use the NGU traps to monitor accurately changes in tsetse population size.

4.2 SEASONAL DISPERSAL OF *G. PALLIDIPES* IN RELATION TO REINVASION OF CONTROL AREAS

R. Brightwell, R. D. Dransfield and B. G. Williams

Reinvasion into "cleared" areas is the single most important factor governing the success of any tsetse control campaign. It not only determines whether eradication is really possible, but also the additional mortality required to suppress to a given level (e.g. to 90% or 99% reduction). Surprisingly, very little effort has gone into understanding what governs this process—least of all when fly numbers are reduced, when such processes are most important. During the last year we have been examining in detail both the spatial and temporal aspects of *Glossina pallidipes* invasion into the suppression zone at Nguruman, where fly numbers have been artificially reduced using baited NGU traps. Preliminary results show high rates of reinvasion associated

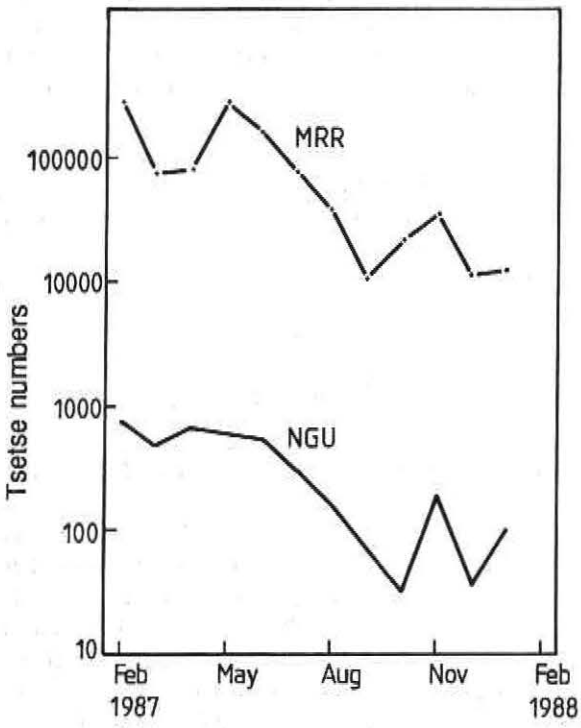

Figure 4.1 Absolute population size given by mark-release-recapture (MRR) and apparent density (given by NGU traps) over one year for female *G. pallidipes* at Nguruman.

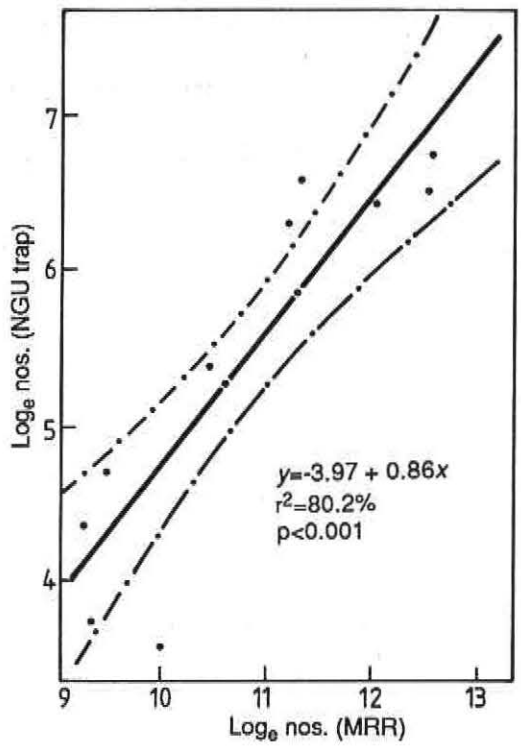

Figure 4.2 Relationship between log$_e$(numbers in traps) and log$_e$(absolute population size) for female *G. pallidipes* at Nguruman with 95% confidence limits.

with rain, and much lower rates at other times of year. Although both sexes reinvade, females do so consistently more than males, an observation confirmed from mark-release-recapture studies. Invasion down the escarpment appears to be much faster than from the north of the suppression zone, perhaps because temperatures are higher in the lowland areas.

Our initial hypothesis was that reinvasion was related to the seasonal spread of flies into more open areas. To correlate changes in spread with climatic and environmental factors we examined unbaited biconical trap data both pre- and post-suppression. Spread was correlated primarily with temperature, with the proportion of flies in open areas increasing as temperatures decreased. However both males and females showed an extremely similar degree of spread into open areas, in contrast to the invasions.

A full understanding of the factors responsible for fly movement is obviously essential in planning trap deployment, specifically whether to restrict reinvasion or to cope with its effects.

4.3 FURTHER DEVELOPMENT OF TSETSE CONTROL TECHNOLOGIES

R. Brightwell and R. D. Dransfield

Servicing constitutes by far the largest component of the costs in trapping control. There are three approaches to reducing this: improving trap efficiency, improving reliability and optimising trap placement.

We felt that the use of vertical shelves and targets would simplify trap construction and maintenance, and possibly improve the catch by providing a greater area of visible black to an approaching tsetse. Various experiments have now shown the shelf and target orientations used at present to be optimal compared to those tested. The further addition of black, high within the body of the trap, may however be advantageous for *Glossina longipennis*. Spectral transmittance data suggest that the colour of materials inside the trap may be less important than previously supposed, opening the way for the use of materials that are less likely to fade.

Various approaches to increasing trap reliability have been examined. Most noteworthy is an improved cage design which prevents aggregation of dead flies around the entrance hole, and also much reduces ant damage at the top of the cage. We have been able to change from a monthly to a two-monthly servicing schedule by using larger, locally manufactured odour containers for urine and acetone, and our own new long-life octenol dispenser. Also, a different trap orientation has radically reduced fading of the targets by the sun.

4.4 STUDIES ON THE DENSITY AND BEHAVIOUR OF TSETSE AND OTHER BITING FLIES AROUND CATTLE

R. D. Dransfield, R. Brightwell and P. Stevenson[†]

The aim of these studies, carried out in close collaboration with Kenya Trypanosomiasis Research Institute (KETRI) scientists, has been to determine how well our normal sampling techniques (biconical and NGU traps) reflect the density, species and age composition of biting flies attacking cattle in the Nguruman area. In addition, the behaviour of flies around cattle has been studied,

biconical traps were operated in similar sites, replicated over several days, for comparison of catches with those around the cow.

Preliminary results show that there is a clear relationship between numbers coming to the cow and numbers in the trap, but this relationship may not be linear and may change seasonally. Feeding success rates tend to be very low in some species (e.g. *Glossina pallidipes*) but quite high in others (e.g. *Musca crassirostris*). There is considerable evidence of circumnavigation with multiple interrupted feeds, especially in the case of *G. longipennis*.

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4.5 EXTENDED USE OF COW URINE ODOUR AS TSETSE ATTRACTANT

F. O. Oloo

This study concentrated on components of tsetse control which would ease financial constraints in community-based, odour-bait, trapping programmes. It was carried out at the ICIPE Nguruman Field Station, where NGU traps are currently used to control *Glossina pallidipes* and *G. longipennis* in a community-based programme with members of the Olkeramatian Group Ranch.

Cow urine, acetone and 1-octen-3-ol were used simultaneously as tsetse attractants during *G. pallidipes* and *G. longipennis* control trials at Nguruman. They were dispensed at the rate of approximately 1000 mg/hour, 150 mg/hour and 20 mg/day, respectively. Cow urine was left to mature for 3 weeks before being dispensed from 2-litre plastic containers at the trapping sites, and was topped up every 4 weeks with urine diluted 50% with water to compensate for evaporation. After 3 months, the odour attractant was replaced with more 3-week-old cow urine.

Preliminary trials, run for 6 months, showed that there was no significant difference in effectiveness of the 3-month-old urine compared with 3-week-old urine. Males and females of both *G. pallidipes* and *G. longipennis* responded similarly, and catches more than doubled when compared with acetone and octenol as controls.

Cow urine was collected from various animals over a 2-day period, mixed and divided into four batches, each in four 2-litre containers. The first batch was kept in a refrigerator at about 4°C for 6 months. The second and third batches were kept at a typical trapping site under deep shade and topped up with water and 50% cow urine, respectively, every month to compensate for evaporation. The fourth batch was kept at the trapping site, but topped up with its own stock. The potency of the three batches from the trapping site was compared, with the one from the refrigerator as control, after 1, 2, 4 and 6 months in a 4 x 4 Latin square design replicated twice. The data were subjected to analysis of variance after log $(x + 1)$ transformation.

All the urine treatments significantly increased the catch of both male and female *G. pallidipes*, except the batch topped up with water, in which the catch decreased steadily after the fourth month, yielding significantly fewer flies at the end of 6 months. However, the four treatments had no apparent influence on the catches of both sexes of *G. longipennis*.

Thus it appears that cow urine remains an effective *G. pallidipes* attractant for up to 6 months when topped up with either 50%, or undiluted, urine, but it is effective for only 4 months when replenished with water. It was also noted that the urine matures steadily when kept at about 4°C.

4.6 ECOLOGY AND VECTORIAL CAPACITY OF *G. F. FUSCIPES* AROUND LAKE VICTORIA

M. I. Mwangelwa, R. D. Dransfield and L. H. Otieno

Studies on population dynamics of *Glossina fuscipes fuscipes* and on odour baits continued throughout the first half of 1989. Apparent population densities of both males and females were stable over time but dropped during the rainy season. It is considered that flooding following heavy rains is a significant source of fly mortality. Reproductive abnormalities including abortion, follicular degeneration and egg retention were, in general, rare and did not exceed 2%. About 57% of the teneral females in the age category OA had been inseminated, indicating that *G. f. fuscipes* mates quite early in life and probably near the host animal.

None of the trap odour baits tested, either singly or in combination, including cow and human urine, acetone, 1-octen-3-ol, *p*-cresol, 3-n-propylphenol and *m*-cresol was found to raise catches of males significantly. The combination of acetone and cow urine produced inconsistent results for females, alternately slightly attracting and repelling them. Containers of cow urine, 1-octen-3-ol, acetone and a cocktail of 8 parts *p*-cresol, 4 parts 1-octen-3-ol and 1 part 3-n-propylphenol were placed together and were found to repel females significantly. Studies extended to body washings of indigenous goats and monitor lizards (*Varanus niloticus*) which are likely animal hosts of *G. f. fuscipes*, indicated that odours from these washings did not raise fly catches. It is therefore suggested that further studies should concentrate on the breath of these animals, placed in pits, since the attractive components may not be from the skin.

Field and laboratory studies of trypanosome infection showed that *G. f. fuscipes* did not acquire *brucei*-type and *congolense*-type infections as efficiently as did *G. pallidipes*. Of the 2009 wild *G. f. fuscipes* that were dissected, only one fly (0.05%) was found to be infected with *congolense*-type trypanosomes. None of the 1003 wild flies dissected from Rusinga Island was infected, despite four cases of cattle trypanosomiasis being diagnosed. Cattle were not, however, observed to be preferred hosts of these flies. When *G. f. fuscipes* were offered blood meals infected with *brucei* and *congolense*-type trypanosomes not more than 1% picked up infection, whereas 2–23% of *G. pallidipes* fed on the same blood became infected.

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4.7 POPULATION ECOLOGY OF *G. PALLIDIPES* IN THE LAMBWE VALLEY

L. H. Otieno, P. A. Onyango and E. Mpanga

Past attempts to control *Glossina pallidipes* in the Lambwe Valley have met with very short-lived success. It has therefore been necessary to repeat the control campaigns—an exercise costly in both time and money. All these attempts have involved intervention with chemical insecticides. The latest attempt to eradicate *G. pallidipes* has involved a mass deployment of insecticide-impregnated targets in the Ruma National Park. Since we had been monitoring the population of *G. pallidipes* inside and outside the Park, it was important to see the impact of the targets on the tsetse population.

The relative density and age structure of the *G. pallidipes* population were monitored in the Ruma Thicket of the Lambwe Valley National Park throughout 1988. In August 1988 insecticide-impregnated screens were deployed in the National Park by the Kenya Trypanosomiasis Research

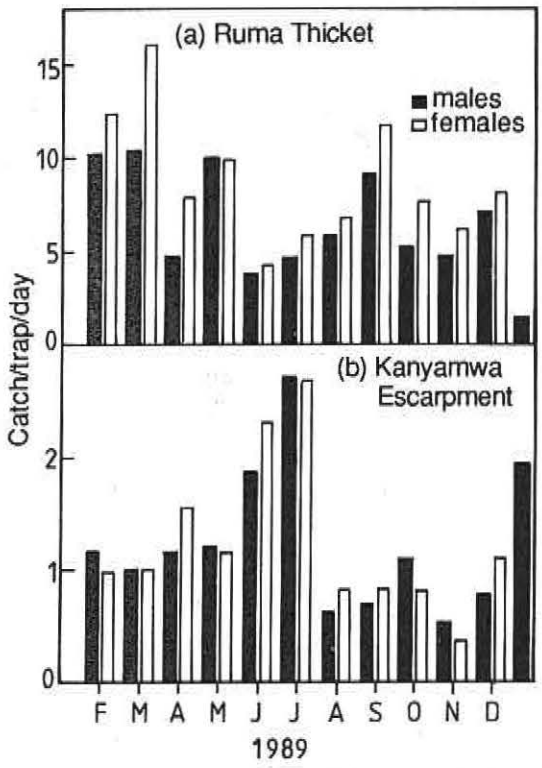


Figure 4.3 Comparison of *G. pallidipes* populations in (a) target area (Ruma Thicket) and (b) untreated area (Kanyamwa Escarpment).

Institute in conjunction with the Ministry of Livestock Development of the Kenya Government. As expected, the targets reduced the tsetse population quite rapidly. The effect however was more dramatic on the female than the male population (Figure 4.3). Previously, female flies had dominated the catch, but after the targets were placed, equal numbers of males and females were caught (Figure 4.4). The age structure of the captured flies also

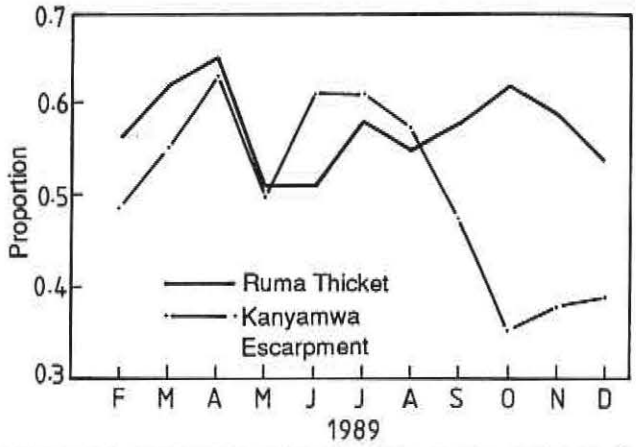


Figure 4.4 Proportion of female flies in the catch of *G. pallidipes* from (a) target area (Ruma Thicket) and (b) untreated area (Kanyamwa Escarpment).

changed when the targets were deployed, and many more young than old females were caught. These observations suggest that the targets were quite effective against the female tsetse population.

Reports elsewhere show that targets can suppress tsetse populations for a distance of up to 5 km from the placement site. Monitoring of the tsetse population 4 km outside the National Park was started in February 1989. Spot checks had earlier given a catch of 5–30 flies per trap per day. Figure 4.3 shows the trend of flies caught in this area compared with those caught in the Ruma Thicket where the targets were deployed. The samples from outside the Ruma Thicket contained far fewer flies compared with those from inside. It was, however, interesting to note that during the months of June and July, when the lowest numbers of flies were recorded inside the thicket, there was a sharp increase in the numbers of flies recorded outside the thicket, although the cause was not apparent.

4.8 GENETIC DIFFERENTIATION IN NATURAL POPULATIONS OF *G. PALLIDIPES*

A. Kence,[1] L. H. Otieno and N. F. Darji

Glossina pallidipes is known to exhibit considerable genetic diversity in many behavioural and physiological traits, as well as in isoenzyme loci, when geographically isolated populations are compared. Knowledge on the spatial structuring of genetic variation in tsetse populations occupying a given region with diverse habitats, however, is very scarce. Do tsetse flies occupying a large area behave as a single panmictic unit, or exist in many sub-populations showing various degrees of genetic differentiation? It is imperative to answer this question in order

design strategies to control this pest. This study was carried out to obtain information on the genetic differentiation of *G. pallidipes* across its distribution, within and between geographically isolated regions.

Thoraces of flies were homogenised in distilled water and analysed by thin layer gel electrophoresis. The enzymes studied were phosphoglucomutase (PGM) and glucose phosphate isomerase (GPI) which were shown to be polymorphic[2]. Flies were collected from three geographically isolated areas of Kenya: the Lambwe Valley, Nguruman and the Shimba Hills near the coast. In western Kenya sampling was done at three different sites. Similarly, three different localities were chosen for the coastal samples.

The allele frequencies of the enzyme loci studied were analysed using nested analysis of variance. There is significant genetic differentiation between the three study areas and also within each locality. When the total variation in gene frequencies is partitioned, 85.1% is found between the study areas, while the differences between localities within the study areas account for 9.5%, and differences between samples in a given locality are responsible for only 5.4% of the total variation.

When the gene frequencies for males and females are compared they are found to be significantly different ($P < 0.01$) only in samples from Lambwe Valley. It is most probable that the differences in PGM alleles seen in the Lambwe Valley population could be due to migration of large numbers of females into the area which has disturbed the equilibrium gene frequencies. This is likely if the females were coming from a population with a different gene frequency. The widespread distribution of *G. pallidipes* in South Nyanza District lends support to this suggestion.

[1]*Visiting Scientist from Turkey, left ICIPE November 1989.*

[2]*Agatsuma T. and Otieno L. H. (1988) Isoenzyme studies on two field populations of* Glossina pallidipes *in Kenya. Insect Science and its Application 9, 527–530.*

4.9 ELECTROPHORETIC STUDY OF ENZYMES IN A *G. F. FUSCIPES* POPULATION FROM WESTERN KENYA

G. F. Rajendram,[†] N. F. Darji and L. H. Otieno

Starch gel electrophoresis was carried out on adults of *Glossina fuscipes fuscipes* from Rusinga Island, near Mbita Point Field Station. Of the ten enzymes analysed, esterase (EST), glucose-6-phosphate dehydrogenase (G6PDH), malate dehydrogenase (MDH) and xanthine dehydrogenase (XDH) appeared to be monomorphic. Hexokinase (HEX) and isocitric dehydrogenase (IDH) manifested two bands with very close mobilities and appeared to represent single loci. Malic enzyme (ME) and phosphoglucose dehydrogenase (PGDH) appeared to be polymorphic. Glucose phosphate isomerase (GPI) and phosphoglucomutase (PGM) were highly polymorphic. At the GPI locus three alleles and six genotypes were seen, while PGM showed a double band. These findings are in general agreement with previously reported polymorphism in *G. m. morsitans* and *G. pallidipes.*

[†]*Visiting Scientist from Sri Lanka, left ICIPE October 1989.*

4.10 IMMUNE RESPONSES OF WILDLIFE TO TRYPANOSOMIASIS

S. Mihok and E. N. Munyoki

Although wildlife species tolerate infection with trypanosomes, very little is known about the mechanisms of immunity. An understanding of these mechanisms may lead to novel developments in the therapeutic control of trypanosomiasis in humans or livestock. In collaboration with the National Veterinary Laboratories at Kabete, we have been studying the responses of waterbuck, buffalo, and Boran cattle to infection with *Trypanosoma congolense*. Individuals were challenged by cyclical transmission through *Glossina morsitans morsitans* with two parasite clones, IL 2895 and IL 1180. Haematological and immunological responses were monitored for two months. Preliminary results indicate that many of the pathological effects in cattle, as opposed to wildlife, are due to the high levels of parasitaemia in the blood. Parasitaemia dramatically reduces platelet levels in cattle, contributing to the severe anaemia that is characteristic of African trypanosomiasis. Wildlife species respond minimally to infection, largely as a result of their ability to inhibit the initial wave of replication of trypanosomes, both in the skin and in the blood. Waterbuck, especially, have efficient immune mechanisms for dealing with parasites before they reach the peripheral blood.

4.11 TSETSE VECTORIAL CAPACITY

S. Mihok and E. N. Munyoki

Tsetse are partially resistant to infection with trypanosomes but the mechanisms underlying this resistance are poorly understood. In conjunction with research on wildlife immune responses to trypanosomiasis, we have been studying the ability of tsetse to pick up infections of *Trypanosoma congolense*. These studies have the goal of defining tsetse species differences in susceptibility as well as characterising the relationships between parasitaemia, immune response and transmissibility. Our initial work has been done with two clones of *T. congolense* transmitted to two species of tsetse (*Glossina morsitans morsitans* and *G. fuscipes fuscipes*), in two species of wildlife (buffalo and waterbuck) and cattle. Preliminary results indicate that immune factors in wildlife may contribute to poor transmissibility to tsetse. Xenodiagnosis with tsetse has also proved to be a useful technique in the detection of extremely low levels of infection in wildlife. The parameters calculated in these studies will be used in the future to determine the levels of tsetse control required to interrupt disease transmission cycles through epidemiological modelling.

4.12 SEXUAL RECEPTIVITY IN *GLOSSINA PALLIDIPES* AND *G. MORSITANS MORSITANS*: AN OVARIAN FACTOR

M. F. B. Chaudhury

Most females of *Glossina pallidipes* become sexually receptive about eight days after emergence, whereas the females of *G. morsitans morsitans* and other species become receptive on the second or third day after emergence. Preliminary experiments using 20-hydroxyecdysone suggest that the application of hormone on virgin females 1–2 days old results in early receptivity. It is well known that the ovaries of some insects produce ecdysone, but it is not known whether the ovaries of *Glossina* species do so. If the ovaries of tsetse produce ecdysone it would be interesting to see what happens to female receptivity if the ovaries are removed surgically and the ovariectomised females allowed to mate.

The present report describes the results of some experiments to determine the effect of ovariectomy and the application of 20-hydroxyecdysone on the receptivity of female *G. pallidipes* and *G. m. morsitans*.

The females (15–20 flies per experiment) were ovariectomised when they were 1 day old. During an operation under cold saline both ovaries were removed through an abdominal incision by snipping them off at the base of the common oviduct. The incision was sealed with petroleum jelly. The sham-operated females had an incision through which some fat body was removed. Several experiments were also conducted in which the ovaries were removed and then reimplanted in the same individual. Post-surgical mortality averaged 6% (range 1–15%).

4.12.1 Effect of ovariectomy

Surgical removal of the ovaries from 1-day-old females resulted either in disappearance of receptivity or delay in becoming receptive in more than 80% of both *G. pallidipes* and *G. m. morsitans*. About 30% of operated females of both species never became receptive although they fed well and looked otherwise normal. More than 50% of the females of both species showed willingness to mate at various ages beyond their normal age of receptivity. In *G. pallidipes*, this extended from day 10 to day 21, and in *G. m. morsitans* from day 4 to day 17. About 20% of the operated females and about 90% of the sham-operated females mated at their maximum age of receptivity (8 days old for *G. pallidipes* and 3 days old for *G. m. morsitans*).

4.12.2 Effect of ovariectomy and re-implantation

Re-implantation of the ovaries in ovariectomised females did not significantly change their behaviour. In spite of re-implantation, about 25% of female *G. pallidipes* and 35% of *G. m. morsitans* did not mate even after repeated trials; further females (about 60% and 55%, respectively) showed delayed receptivity. The remaining 15–20% showed receptivity within the normal age range for the species.

4.12.3 Application of 20-hydroxyecdysone

Application of 20-hydroxyecdysone (2 ng/fly on day 2 following emergence) on ovariectomised flies produced interesting results. Most of the *G. pallidipes* females were receptive one or two days earlier than the normal time and a few were found to be receptive even on day 3 after emergence. Only about 20% of the treated *G. m. morsitans* females showed delayed receptivity while the remaining females were receptive at the normal age, i.e. 2–3 days after emergence.

Although these results are only preliminary and further work is under way, they clearly indicate that receptivity is somewhat under hormonal control. It is not known whether the tsetse ovary produces ecdysone. The preliminary results, however, indicate that ovariectomy influences female receptivity either by delaying it or blocking it completely. It was further noticed that males which should have been capable of inseminating ovariectomised females, did not produce a normal spermatophore. In such cases the spermatophore in the uterus was a gelatinous mass in which only a few sperm were interspersed.

4.13 SOME FACTORS AFFECTING MATING IN *GLOSSINA PALLIDIPES*

J. O. Davies-Cole

Studies were conducted on the mating behaviour of *G. pallidipes* from the Nguruman study site. The aim was to improve current laboratory rearing methods. The typical premating behaviour of the male fly is an attempt to make hypopygeal connection with the female; if rejected, it flies away. The same behaviour is repeated with the same, or other, females until the male finally succeeds.

Males were less aggressive and rather lethargic when young. It was rare to see males younger than 7–9 days coupling in the mating cages, especially during the first 20 minutes of observation (some pairs were seen after a few hours). Most males aged 13–15 days were very aggressive. Although males of 7–9 days were generally lethargic, those that successfully copulated inseminated well. However, 15% had a mean spermathecal value (MSV) of less than 1.50. Females that mated with males within age group 13–15 days had full spermathecae and an MSV of 1.91. It was common to find a few such males mating within a few minutes of being introduced into female cages. Eighty percent of 12-day-old females were inseminated when group-mated, compared to 50% observed in single matings. Small laboratory holding cages measuring 18 x 8 x 4 cm gave better results than large cages measuring 21 x 16 x 18 cm (Figure 4.5). There was no significant difference in the degree of insemination between female flies kept with males under a regimen of 12 hours dim light:12 hours darkness, and those kept in total darkness ($\chi^2 = 4.18$, $P < 0.05$).

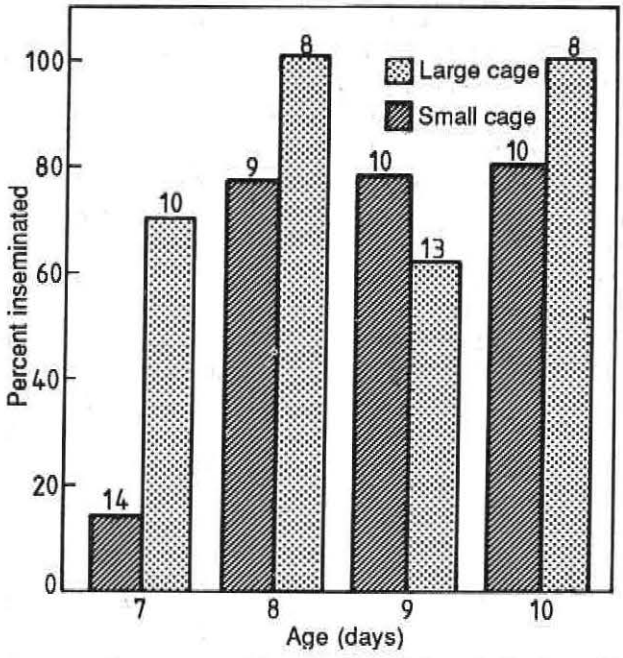


Figure 4.5 Percentage of female *G. pallidipes* 7–10 days old inseminated when kept with males in large or small cages for 72 hours. The sample size is indicated on each bar.

4.14 ECO-BEHAVIOURAL CHARACTERISTICS OF *GLOSSINA AUSTENI* ON THE SOUTH KENYA COAST

M. L. A. Owaga, C. O. Machika and D. Uvyu

Studies on aspects of *G. austeni* ecology in Muhaka Forest began in late 1988. Particular attention was paid to identification of an effective method of sampling this species and to the study of eco-behavioural characteristics. After an initial survey to map the general distribution of *G. austeni* in the study area, experiments were conducted to compare the efficiency of biconical, ICIPE NGU and pyramidal traps. Odour sources screened as baits included acetone, cow urine, buffalo urine and phenols derived from buffalo urine. Fly density was expressed as catch per trap per day for each month.

The results showed that *G. austeni* catches were generally very low and the response to odour baits was non-significant (Figure 4.6). The pyramidal trap yielded significantly

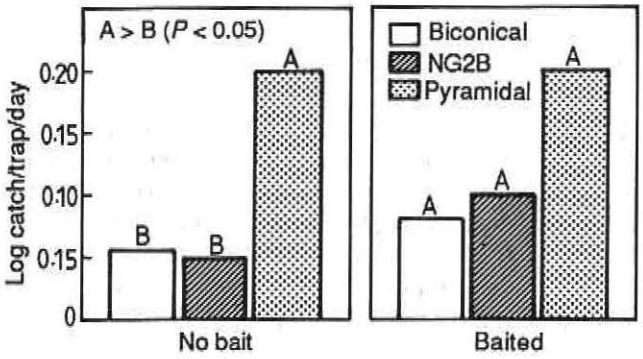


Figure 4.6 The numbers of *G. austeni* caught in coastal forest at Muhaka according to trap type and use of odour baiting.

higher catches than the other two types tested. The apparent density also fluctuated significantly over the year as shown in Figure 4.7, with the highest densities recorded in March–April. It is too early to draw firm conclusions regarding seasonal changes, but further studies are under way to explore the relationship between increased apparent densities and relative humidity and other factors.

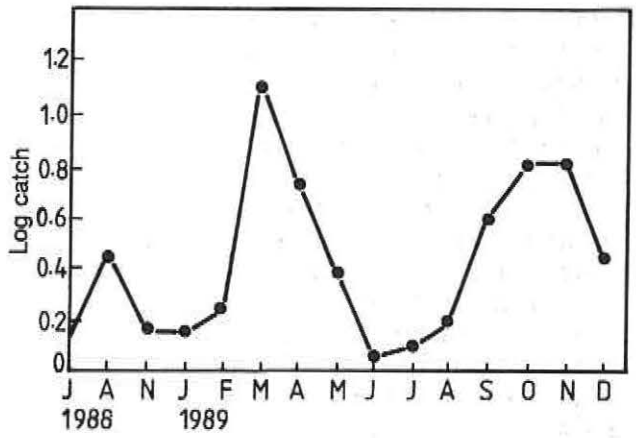


Figure 4.7 Mean catch per trap per month of *G. austeni* at Muhaka Forest with results for all trap types pooled.

4.15 DEVELOPMENT OF AN EFFECTIVE TRAP/ODOUR BAIT SYSTEM FOR THREE TSETSE SPECIES IN THE MUHAKA AREA

C. A. Kyorku and J. Cheruiyot

Three species of tsetse occur in the Muhaka area, *Glossina pallidipes*, *G. brevipalpis* and *G. austeni* and the little work done previously indicated that the two latter species are not readily trapped. Studies were therefore undertaken to improve trapping efficiency for these species through research on trap design and odour bait technology, with particular emphasis on *G. brevipalpis*.

The first objective was to test the performance of odour attractants and trap designs that were already known to be effective for other tsetse species elsewhere, and then progressively introduce new/modified trap designs and odour attractants towards the improvement of trap efficiency. Various combinations and dose rates of acetone, 1-octen-3-ol (octenol), cow urine and pig urine have so far been tested as odour attractants using the ICIPE NG2B trap as the standard. The performance of five modifications of the NG2B trap and the blue biconical trap has also been tested using cow urine (c. 1000 mg/hour) plus acetone (150 mg/hour) as the standard bait.

The results, so far, indicate that acetone is an effective attractant for both *G. brevipalpis* and *G. pallidipes*. When dispensed alone, it effected a seven-fold increase in catch over an unbaited trap for both species. Cow urine alone caused no significant increase in *G. brevipalpis*, but doubled the catch of *G. pallidipes*. The combination of cow urine and acetone therefore showed no significant increase in catch over acetone alone for *G. brevipalpis*, but effected a 5–12-fold increase for *G. pallidipes*. The addition of octenol to cow urine alone, or to cow urine

plus acetone, did not have any significant effect on the catch of either species. Doubling the doses of the above substances in various combinations gave no apparent increase either, but this needs confirmation as the catches in the particular experiment were very low. Pig urine showed no attractive properties for either species and was in fact significantly inferior to cow urine for *G. pallidipes*.

The original NG2B proved to be more effective than all the other modifications or the biconical trap for *G. brevipalpis*. For *G. pallidipes*, however, a modification which increased the area of blue on one side of the entrance (the lop-sided NGU) doubled the catch.

4.16 PATHOGENS ASSOCIATED WITH TSETSE IN NATURE AND THEIR BIOCONTROL POTENTIAL

G. P. Kaaya and M. A. Okech

Little is known about micro-organisms associated with tsetse in nature or their potential as biocontrol agents for tsetse. During 1989 some effort was devoted to the isolation, identification and pathogenicity testing of fungi and bacteria obtained from tsetse collected in the field and from our laboratory colony.

Field-collected adults (*Glossina pallidipes*) were trapped at Nguruman, Lambwe Valley and Muhaka and were then maintained on rabbits for one week. During this period, fungi and bacteria were isolated from all tsetse dying of unknown causes. Likewise, bacteria were isolated from adult *G. morsitans morsitans* which died of unknown causes in our insectary colony. Attempts were also made to isolate bacteria from pupae produced by both field-collected and insectary females.

The following six fungi were isolated from the field: *Aspergillus flavus, A. niger, Aspergillus* sp. (unidentified group), *Fusarium* sp., *Penicillium* sp. and *Rhizopus* sp. The following bacteria were also isolated: *Aeromonas hydrophilia, Cedecea* sp., *Enterobacter amnigenus, Providencia alcalifaciense, P. rettgeri* (two strains) and *Serratia marcescens* (three strains based on biochemical reactions). One species of *Bacillus* was isolated from pupae.

The bacteria isolated from insectary-reared adults were: *A. hydrophilia, E. cloacae, P. rettgeri, S. liquefaciens* and *S. marcescens* (three strains), while *S. liquefaciens* and *S. marcescens* (two strains) were isolated from insectary pupae.

Pathogenicity tests in the laboratory revealed that all the field-isolated fungi had low pathogenicity for adult tsetse and were, therefore, most likely to be saprophytes. Using a spore concentration of 10^7/ml in distilled water, mortality ranged from 4–26% by 30 days post-exposure, compared to 100% for *Beauveria bassiana* and *Metarhizium anisopliae* in our other experiments.

Some of the bacterial isolates, however, were very entomopathogenic when mixed with blood at a concentration of 10^7/ml and administered by feeding through an artificial silicone membrane. By 14 days post-infection mortalities ranged from 60–100%. *Aspergillus hydrophilia* was by far the most pathogenic species, inducing 100% mortality in less than 24 hours, followed by *S. marcescens* and *S. liquefaciens* which induced 100% mortality by 5 days. Least pathogenic were the *Bacillus* sp. and *P. alcalifaciense* which induced mortalities of approximately 10% and 30%, respectively, by 14 days post-infection. The search for pathogens of tsetse will continue and experiments to study methods of transmission from infected to non-infected tsetse are now in progress to assess their potential for biocontrol in the field.

4.17 TSETSE CONTROL PROJECT IN THE KAGERA RIVER BASIN

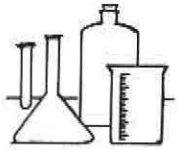
C. S. Tarimo, L. H. Otieno and S. Mihok

The Kagera River Basin Organisation (KBO) is a regional organization created in 1977 by the governments of Burundi, Rwanda, Tanzania and Uganda. In order to exploit some of the resources along the river course (water resources and agricultural and livestock developments), the authority drew up plans which included the reclamation of land from tsetse infestation. In response to a request from the KBO to the United Nations Development Programme, a preparatory assistance project was approved. The main objective of the project is to design an integrated management system to control tsetse and trypanosomiasis in the Kagera Basin. This project is executed by the United Nations Economic Commission for Africa and subcontracted to the ICIPE.

During this preparatory phase of the project, specific activities have been carried out in Rwanda in the Rusumo area of Kibungo Prefecture.

NGU traps were deployed on Rusumo Ranch and Mpanga Ranch at a density of 2 traps/km^2. Since April 1989, tsetse populations in these two experimental areas have been closely monitored to assess changes in density and age distribution, and to compare these changes with data collected from Nasho Ranch where no suppression has been carried out. The data show clearly that NGU traps can be used effectively to suppress *G. pallidipes* populations under different ecological conditions. It has also been demonstrated that the trap is effective against *G. morsitans centralis*. This trap can therefore be used as a component of an integrated tsetse management system during the implementation phase of tsetse and trypanosomiasis control in the entire Kagera River Basin.

CHEMISTRY AND BIOCHEMISTRY RESEARCH UNIT



5 Chemistry and Biochemistry Research Unit

The primary role of the CBRU is to undertake collaborative research with Core Programmes in areas of chemical ecology and biochemistry pertinent to their goals. The current research activities fall under the following three themes:

- *Chemical ecology of the ICIPE's target disease vectors and plant pests, currently focused on tsetse flies (in collaboration with TRP and SPRU), and the stem-borer* Chilo partellus *and the pod-borer* Maruca testulalis *(in collaboration with SPRU and CPRP); a project on the identification of banana semiochemicals was also started recently (in collaboration with SPRU and CPRP).*
- *Protein biochemistry focused on collaborative work with LTRP on the development of an anti-tick vaccine, and with CPRP on the diapause phenomenon in* Busseola fusca.
- *Exploratory studies on biochemical phenomena of special significance and interest (such as trypanosome transformation in the tsetse gut) and on selected anti-arthropod natural products from African plants.*

In addition, a taxonomic project based on pattern analysis of cuticular wax components of different species of sandflies is being undertaken by an ARPPIS student (in collaboration with MVRP).

5.1 SYNOPSIS OF CBRU'S MAIN ACTIVITIES AND ACCOMPLISHMENTS

A. Hassanali

5.1.1 Crop pest semiochemical studies

These studies were badly hampered by the breakdown of the Unit's VG 12250 gas chromatograph-mass spectrograph as a result of fluctuations and frequent interruptions in the electrical supply. The uninterruptible power supply (UPS) system for the Duduville laboratories was recently commissioned and linked to the instrument, and we now anticipate that the planned work on moth pheromones and banana weevil semiochemicals will have started by early in 1990.

Semiochemical studies during the year focused on the identification of *Chilo partellus* oviposition stimulants from sorghum, and on elucidating the allelochemical basis for differences in feeding preference of larval *C. partellus* shown between two maize cultivars. Two sorghum-derived phenols (*p*-hydroxybenzaldehyde and *p*-hydroxybenzoic acid) previously found to be phagostimulatory to the larva of *C. partellus*, were also shown to stimulate oviposition in the female. The aldehyde was the more potent phagostimulant, whereas the relative activity of the two phenols as oviposition stimulants was reversed. Unlike the sorghum cultivars examined to date, the maize cultivars (Inbred A and MP 704) contained relatively small amounts of these two phenols. The differences between the chromatographic profiles of the organic extracts of Inbred A and MP 704 were qualitative as well as quantitative. Bioassays suggested the presence of some inhibitory principles in MP 704. The identification of these compounds is now under way.

5.1.2 Biochemistry of diapause in Busseola fusca

There was significant progress in elucidating the biochemical basis of diapause in *B. fusca*. A protein described last year that was associated with diapause was shown to bind specifically with a photo-labile juvenile hormone mimic, suggesting that the protein may have a role as a carrier of juvenile hormones. In addition, if discs cut from young sorghum plants were treated with extracts from mature sorghum stems, this induced the production of the protein in non-diapausing *B. fusca* larvae that were fed on the discs. The indication was that diapause

in this insect may indeed be associated with specific allelochemical signals present in older food plants. Work on the identification of these signals is in hand.

5.1.3 Tick antigen research

With Dr S. Essuman's move to LTRP, the search for polypeptides from the tick *Rhipicephalus appendiculatus* of potential use in the production of an anti-tick vaccine is now being carried out mostly within the Tick Programme. The Unit's primary role henceforth will be to undertake fine-tuned separation, purification, characterisation and preparative production of components from fractions shown to be active by immunological monitoring. Work on one such fraction identified in LTRP is due to start early in 1990.

5.1.4 Tsetse-related research

Work on tsetse kairomones continued during the year on several fronts (in collaboration with SPRU) and two exploratory biochemical studies were initiated in collaboration with TRP, one on trypanosome transformation and another on milk gland constituents.

A Gram-positive diplococcus has now been shown to be primarily responsible for the conversion of the pro-kairomones present in buffalo urine into the final phenolic attractants. This microbe is also present in the body wash and faeces of the host animal. Interestingly, a methanolic wash of cow body was found to elicit a series of behavioural responses from *Glossina morsitans morsitans* in a wind tunnel (see SPRU report). Preliminary chromatographic examination shows the presence of a complex profile of chemicals which includes phenols. It remains to be established if these phenols are also formed by microbe-mediated processes on the skin of the host, and if they do play an effective role in location and recognition of the host by the fly. Identification of other behaviourally-active body chemicals is in progress.

An *in vitro* method has been developed of observing the transformation of trypanosomes from the form in the bloodstream of the vertebrate host to the form in the midgut of the tsetse. This has allowed the process to be studied outside the fly and the essential requirements to be delineated. The transformation has been shown to be associated with whole blood and to be inhibited either by exposure of midgut homogenates at 60°C or by a trypsin inhibitor. The stage is, therefore, set for a better understanding of the factors involved in the transformation, and this may ultimately suggest ways of interfering with the process.

The major protein of the milk gland secretions of female *G. m. morsitans* has been isolated, purified and characterised. The high aromatic amino acid content of this protein suggests that it may act as a reservoir, in developing larvae, of raw materials for making the puparium. Further studies will help to shed some light on this question.

5.1.5 Natural insect repellents

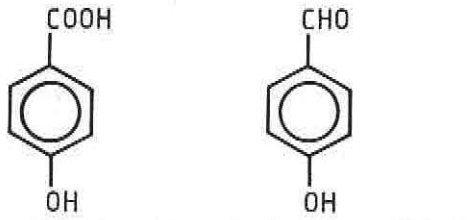
The use of plants with anti-insect properties has formed an important part of traditional pest management practices in Africa. They have been used either in intercropping and agroforestry systems, or processed for direct application against the pest. Last year we reported the identification of constituents of the shrub *Ocimum suave* that were repellent to the grain weevil *Sitophilus zeamais*. The constituents of another insect repellent plant, *Commiphora rostrata*, were reported in the *ICIPE 1987 Annual Report*. The major components of *C. rostrata* and some of their analogues were bioassayed during the year against the grain weevil and most have demonstrated significant repellent action. Ways of utilising these two plants are being explored in collaboration with scientists working in integrated pest management (IPM).

5.2 SORGHUM-DERIVED CHEMICALS AND OVIPOSITION BEHAVIOUR OF *C. PARTELLUS*

W. Lwande, I. O. Ogwayo, K. N. Saxena and J. D. Onyango

Chemical work was undertaken in collaboration with the Crop Pests Research Programme on the isolation and identification of sorghum semiochemicals that stimulate oviposition by *Chilo partellus* moths.

Ethyl acetate extracts were prepared of three cultivars: IS 18363 (susceptible to *C. partellus* attack), IS 18520 (tolerant) and IS 1044 (resistant). The constituents of the extracts were separated and monitored in bioassays for their effect on oviposition. This led to the identification of *p*-hydroxybenzoic acid (Figure 5.1) as the major ovipositional stimulant for *C. partellus*. The quantity present varied markedly between varieties. In addition, *p*-hydroxybenzaldehyde (Figure 5.1) also occurred and was earlier found to be the major feeding stimulant of the larvae (*ICIPE 1987 Annual Report*) it was less active as an oviposition stimulant than *p*-hydroxybenzoic acid. Further details of this work are given in the section on the CPRP.



p-hydroxybenzoic acid *p*-hydroxybenzaldehyde

Figure 5.1 Major constituents of ethyl acetate extract of sorghum plants.

5.3 PLANT CHEMICAL STIMULI THAT INDUCE DIAPAUSE IN *BUSSEOLA FUSCA*

E. O. Osir and N. ole Sitayo

We have described (*ICIPE 1988 Annual Report*) the identification, purification and physico-chemical characterisation of a protein of high molecular weight (500 kDa) that is

borer, *Busseola fusca*. Based on its high content of tyrosine and phenylalanine, we proposed that the *Busseola* diapause protein (BDP) could serve a storage function in these insects by providing the amino acids needed for the synthesis of pupal and adult structures.

We have subsequently shown that BDP binds specifically to epoxybifarnesyl diazoacetate, photo-affinity analogue of juvenile hormone 1 (JH 1). This finding would provide an explanation for the relatively high titres of JH 1 necessary to maintain the diapause state, since JH complexed with carrier proteins is less susceptible to degradation by haemolymph JH-esterases.

The overall aim of this project is eventually to identify plant chemical stimuli involved in inducing and/or sustaining diapause in *B. fusca*. The rationale behind this work is the finding that when non-diapausing larvae are fed on mature sorghum stems, they go into the diapause state. Interestingly, BDP is detectable by gel electrophoresis in the haemolymph of such insects only after four days. For this reason, therefore, the presence of BDP would be a good marker for diapause. In our initial experiments, we extracted mature sorghum stems with absolute methanol. Various concentrations of the extract were subsequently applied on thin discs (about 1 mm) cut from young sorghum stems. After evaporating the methanol, non-diapausing insects were fed on the discs for about six days after which their haemolymph was analysed by gel electrophoresis for the presence of BDP. Control insects were fed on discs to which only the solvent was applied. The results showed that BDP is induced by methanolic extract of mature sorghum stems. Further fractionation and testing of this extract are now in progress.

5.4 *CHILO PARTELLUS* ALLELOCHEMICS FROM MAIZE

E. Nyandat, P. E. W. Njoroge, A. Hassanali and K. N. Saxena

Studies on the feeding response of *C. partellus* larvae to major phenolic constituents of sorghum cultivars were reported in the *ICIPE 1987* and *1988 Annual Reports*. The difference in palatibility of the cultivars IS 18363 and IS 2205 to *C. partellus* larvae was shown to be largely due to quantitative differences in the various categories of phagostimulants present in these cultivars.

During the past year we have undertaken an exploratory examination of two maize varieties, Inbred A (susceptible) and MP 704 (resistant), to see if their allelochemistry and behavioural responses elicited would conform to the pattern observed with varieties of sorghum. Details of the behavioural studies undertaken are described in the CPRP section of this report. The surface chemicals of the two maize varieties were extracted sequentially with petroleum ether, ethyl acetate and methanol and the extracts were examined chromatographically. Major differences were observed in the ethyl acetate extracts of the two cultivars (Figure 5.2). Of particular interest is the presence of relatively small quantities of *p*-hydroxybenzaldehyde and *p*-hydroxybenzoic acid, the two prominent components in the sorghum varieties investigated previously. The

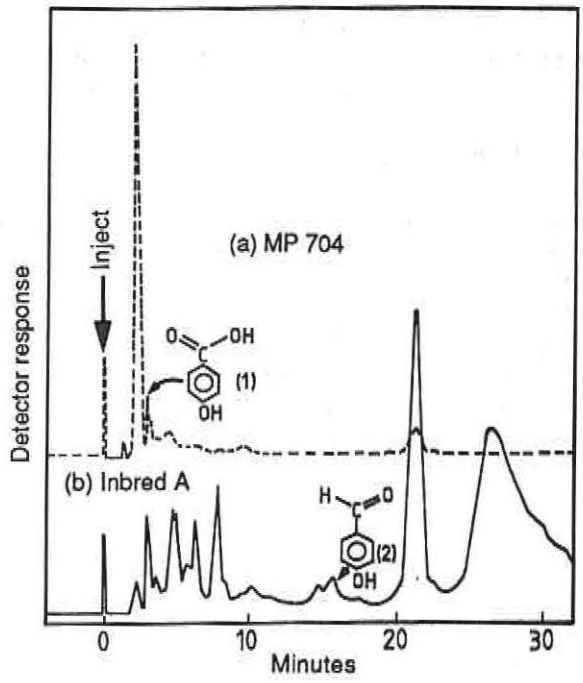


Figure 5.2 Reverse phase HPLC profiles of ethyl acetate extracts of surface chemicals of the seedlings of maize cultivars (a) MP 704 (broken-line) (b) Inbred A (solid line); 1 = *p*-hydroxybenzoic acid, 2 = *p*-hydroxybenzaldehyde.

difference in surface chemistry between the two maize varieties appears to be both qualitative and quantitative, and the relative resistance of MP 704 may be due to lower amounts of the kairomones as well as the presence of allomones. Fractionation and location of the active components, guided by bioassays, is in progress.

5.5 TSETSE KAIROMONE STUDIES

M. A. Okech, W. P. Ouma, E. Nyandat, A. Hassanali and R. K. Saini

During the year, investigations continued on the isolation and screening of microbes from buffalo urine involved in the hydrolytic formation of phenolic attractants from their precursors, and on structure-activity studies of selected analogues of these attractants. In addition, a study of host body washings was initiated in collaboration with SPRU with the objective of identifying any close-range or contact kairomones which may be involved in host location or recognition.

5.5.1 Microbial transformation of pro-attractants

We are interested in the microbe-mediated transformation of pro-attractants in buffalo urine to phenolic kairomones on account of their potential for use over extended periods in the field under conditions of controlled release in tsetse traps (see *ICIPE 1987* and *1988 Annual Reports*). The pro-attractants were shown to consist of glucuronates (80%) and sulphates (20%) of the corresponding phenols.

Only one of the microbial isolates, organism A (a Gram-positive diplococcus obtained from buffalo urine), was found to be an effective converter of pro-attractants to phenols (see *ICIPE 1988 Annual Report*). Another

isolate, organism L, also appears to have the requisite enzyme system for this conversion but dies off within 6 days, probably as a result of self-poisoning by accumulating phenols. Organism A is now a target for complete identification and further studies. A preliminary demonstration, of interest, is that this organism is present not only in contaminated urine, but also in buffalo body wash, faeces and in soil samples.

5.5.2 Structure-activity studies

Last year (see *ICIPE 1988 Annual Report*) the rationale for the synthesis and determination of the kairomonal activities of 3-alkylphenol derivatives was presented. In addition to the compounds listed then, three more analogues were synthesised during this year. Unfortunately, a breakdown in the supply of *G. pallidipes* made it difficult to continue with EAG and antennal movement assays with this tsetse fly. Plans to use flies from the field are now in hand, and it is hoped that this study can be completed and the results reported next year.

5.5.3 Close-range and contact kairomones

Close-range and contact kairomones may mediate tsetse behaviour in the vicinity of, and on, the host animal respectively. Such kairomones may be important in host recognition and in the host selectivity of different tsetse species. A study of host body extracts and their chromatographic fractions was initiated during the year in collaboration with SPRU, to determine if they would elicit any observable behavioural responses in a wind tunnel. The results of some of these studies are described in the SPRU section of this report. Examination by HPLC of a methanolic washing of cow body shows a complex profile of compounds. This washing has been separated into six groups of varying polarity by reverse phase HPLC as well as into phenolic, acidic, neutral and basic fractions by the standard partitioning procedure. Wind tunnel assays have shown that active compounds are present in each of the HPLC fractions and in phenolic, acidic and neutral fractions (see SPRU report). Further fractionation and identification of these components are in hand. Of particular interest is the preliminary detection of 4-cresol in the phenolic fraction, suggesting that the kairomones from buffalo urine may also be formed on the skin of the host animal. If so, this source of the kairomones may be playing just as important a role as urine in host location by tsetse. Further studies on the phenolic fraction and its origins should shed some light on this question.

5.6 TSETSE FLY MIDGUT FACTOR THAT MEDIATES TRANSFORMATION OF BLOODSTREAM TRYPANOSOMES

E. O. Osir, N. F. Darji and L. H. Otieno

Studies have recently been initiated with the aim of identifying the factor, or factors, within tsetse fly midgut that induces transformation of host bloodstream forms of *Trypanosoma brucei brucei* into tsetse midgut forms. In order to carry out these studies, we developed an *in vitro* system in which crude midgut homogenates of *Glossina morsitans morsitans* are incubated with parasitised blood under different conditions. At intervals, aliquots are removed from the incubation mixture and the proportion of the parasites which have transformed is determined in stained thin smears. The parasites are classified morphologically as typical bloodstream, or midgut forms, and transition forms.

Using this assay, we have shown that whole blood appears to be a requirement for activating the transformation activity. No activity resulted from feeding flies on plasma, serum, haemoglobin or saline. Heating the midgut homogenates at 60°C for 30 min prior to the assay led to a complete loss of activity. Furthermore, no transformation was evident when incubations were carried out at 4°C. The addition of soybean trypsin inhibitor to the incubation mixture also resulted in loss of activity. These results suggest that midgut factors activated by the bloodmeal play a role in the transformation of trypanosomes into midgut forms. Work is now in progress to identify the factor, or factors, involved as well as the mode of action. A thorough understanding of this process might suggest avenues for interrupting the transmission of these important parasites.

5.7 TSETSE MILK GLAND PROTEINS

E. O. Osir, M. O. Kotengo and M. F. B. Chaudhury

The milk gland secretions of female *Glossina morsitans morsitans* contain an abundant low molecular weight protein, as shown by polyacrylamide gel electrophoresis. Since the milk protein (MP) accounts for more than half of the total milk proteins, we are studying its possible role in larval nutrition. The MP was purified to homogeneity by a combination of gel permeation (Sephadex G50) and FPLC anion exchange chromatography, and it is a single polypeptide with an approximate molecular weight of 20 kDa (Figure 5.3). It is non-glycosylated and appears to have no complexed lipids.

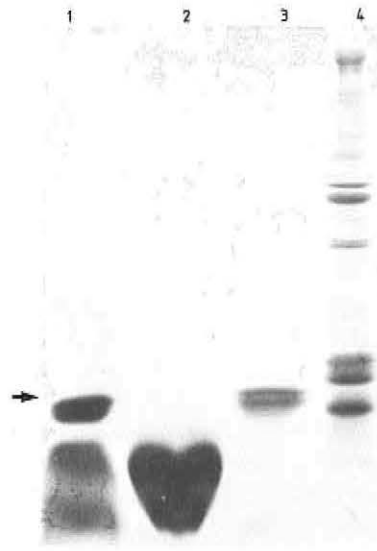


Figure 5.3 Purification of tsetse milk gland proteins by gel permeation chromatography; (1) whole milk proteins, (2) peak 1 proteins, (3) milk protein (MP) and (4) Pharmacin molecular weight markers (the arrow indicates 20 kDa).

Amino acid analysis showed unusually high amounts of the aromatic amino acids, tyrosine and phenylalanine. This suggests that MP provides the developing larva with these amino acids for making the puparium. We have also shown the presence of intact MP in larval haemolymph by immunological methods. It is therefore possible that MP diffuses into the haemolymph through the larval gut as an intact protein, thereby becoming available for cuticle formation.

Amino acid sequencing of part of the MP is being undertaken in collaboration with the Division of Biotechnology, University of Arizona, Tucson, USA. The N-terminal 20-amino-acid sequence is:

1 2 3 4 5 6 7 8 9 10
NH_2-Phe-Pro-Phe-Leu-Arg-Glu-X-Thr-Asn-Val-

11 12 13 14 15 16 17 18 19 20
Lys-Val- Y-Glu-Asn-Phe-Asn-Leu-Asp-Lys...

Starting with residue 14 of this sequence, a 14-mer oligonucleotide is being synthesised. This will then be labelled and used as a probe to screen a milk gland cDNA library.

The MP also forms very distinct crystals in physiological buffered saline at 4°C. An X-ray crystallographic analysis will be undertaken at the University of Arizona. A complete sequence of the protein will also be obtained.

5.8 CONSTITUENTS OF *COMMIPHORA* RESIN AS MAIZE WEEVIL REPELLENTS

W. Lwande, A. Hassanali and L. M. Moreka

Commiphora rostrata (Burseraceae) is a small deciduous tree that rarely attains a height of more than 3 metres. The smooth red-brown bark contains copious amounts of a clear pungent resin which appear to be retained under pressure. When branches or twigs are cut or bent, the resin is released as both a fine spray and as a free-flowing liquid which rapidly covers a considerable area around the point of damage. Most *C. rostrata* trees show signs of resin flow but are conspicuous by the absence of herbivore damage or pathogen attack on woody parts. During collection of the volatile resin of *C. rostrata*, it was noted that such insects as ants and termites in the vicinity of freshly cut wounds on the bark immediately became excited and moved rapidly away. These observations suggested that the resin may have a role to play in the defence of the plant against potential pests and pathogens. We previously reported the isolation and identification of 22 oxygenated lipophilic components from the stem bark exudate of *C. rostrata (ICIPE 1987 Annual Report)*. The major components were the ketones, 2-decanone (65%), 2-undecanone (24%) and 6-dodecanone (5%). The remaining components included trace amounts of other ketones, aldehydes and alcohols.

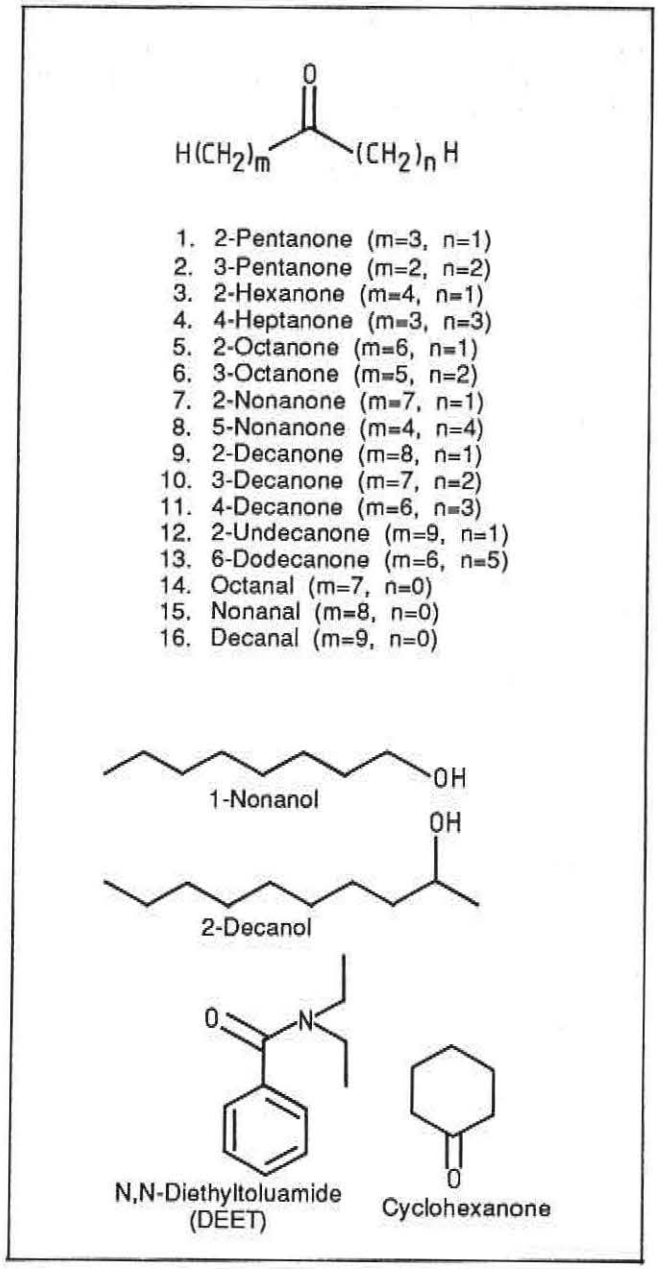
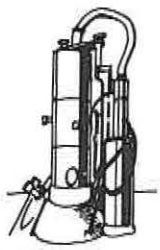


Figure 5.4 Constituents of *C. rostrata* and their analogues that were tested for repellency against *S. zeamais*, with N, N-diethyl toluamide as a standard.

Some of the ketone and aldehyde constituents of the resin of *C. rostrata* and their analogues (Figure 5.4) have now been shown to be highly repellent to the maize weevil *Sitophilus zeamais* using a Y-tube olfactometer bioassay. All the ketones and aldehydes (Figure 5.4) showed either similar, or stronger, repellent activity than N,N-diethyltoluamide (DEET), a commercial synthetic insect repellent, at various doses of the compounds. The highest repellency was shown by 4-heptanone and octanal. The activity of the straight chain ketones did not seem to be affected by the length of the carbon chain in the molecule. On the other hand, the alcohols 1-nonanol and 2-decanol showed slight attractancy to the weevils.

CELL BIOLOGY RESEARCH UNIT



6 Cell Biology Research Unit

As a support unit, the primary role of CRU is to carry out research and to provide answers to questions raised by ICIPE's core research programmes and units at the structural, cellular and molecular levels on the target insect crop pests and disease vectors.

In following the recommendations of the 1988 external review of its research activities, the CRU has been undergoing a process of change and modernisation in order to adapt to current methodology, technical expertise and the multidisciplinary aspects of cell biology research. The Unit's basic equipment has, for instance, been modernised by the acquisition of a new Philips CM12 transmission electron microscope and a scanning electron microscope.

A very progressive and ambitious training programme for scientific and technical staff has been initiated. One of our scientists has just completed a ten-month training course in modern and advanced techniques in cell biology at the Royal Postgraduate Medical School of the University of London.

The training programme will continue during 1990–1991 on various aspects of research in cellular and molecular biology. It is also planned that technicians will undergo training in recently improved techniques of electron microscopy at Philips International, Eindhoven, The Netherlands.

6.1 CONCURRENT INFECTION OF SALIVARY GLANDS OF *G. MORSITANS* WITH RICKETTSIA AND VIRUS

E. D. Kokwaro

Rickettsia-like organisms have been previously reported to occur within the midgut cells of several tsetse species. This infection inhibits a trypanocidal factor and leads to the establishment of *Trypanosoma congolense* infection in the tsetse midgut. There have been no previous reports of rickettsia in the salivary glands of *Glossina*. The only documented micro-organisms found in tsetse salivary glands have been virus particles and trypanosomes. When infected by virus particles the glands are greatly enlarged and, microscopically, a hypertrophied proliferative epithelium filled with virus inclusions is seen.

In the present study, enlarged salivary glands, dissected from laboratory-bred *G. morsitans*, were prepared and examined by light and electron microscopy to determine the cause of the severe gland deformation and enlargement, and also to describe associated morphological and functional changes.

Electron micrographs of enlarged glands showed that they contained large rickettsia-like micro-organisms (RLM) lying at random in the epithelium (Figure 6.1). In addition, the same organisms were observed in the lumen of the gland. There was a clear lytic area without any surrounding membrane around the RLM. In the salivary gland cells the RLM were rod-shaped organisms up to 1.9 µm long x 0.5 µm diam., and some were undergoing binary fission. The cells containing RLM were also heavily infected with virus particles. These were scattered within the predominantly degenerate cytoplasm and were also randomly dispersed in the nucleus where granular clumps of chromatin indicated advanced stages of necrosis. Functional organelles involved in protein synthesis (i.e. rough endoplasmic reticulum, ribosomes, Golgi complexes, mitochondria) were not readily detected in infected gland cells, suggesting that the normal cellular function of the gland is impaired. The degenerating cytoplasm was vacuolated and contained groups of membrane-bound vesicles. The incidence of combined infections of *G. morsitans* salivary glands by rickettsia and virus particles was estimated to be about 0.2%.

This is the first report on RLM in association with virus particles in hypertrophied *Glossina* salivary glands. The infection causes cellular proliferation, lysis of glandular cells and degeneration of intracellular organelles. The infection further interferes with the adaptive capability of the cells, and as a result the cells proliferate (Figure 6.2) so that the heavy microbial load is shared among a

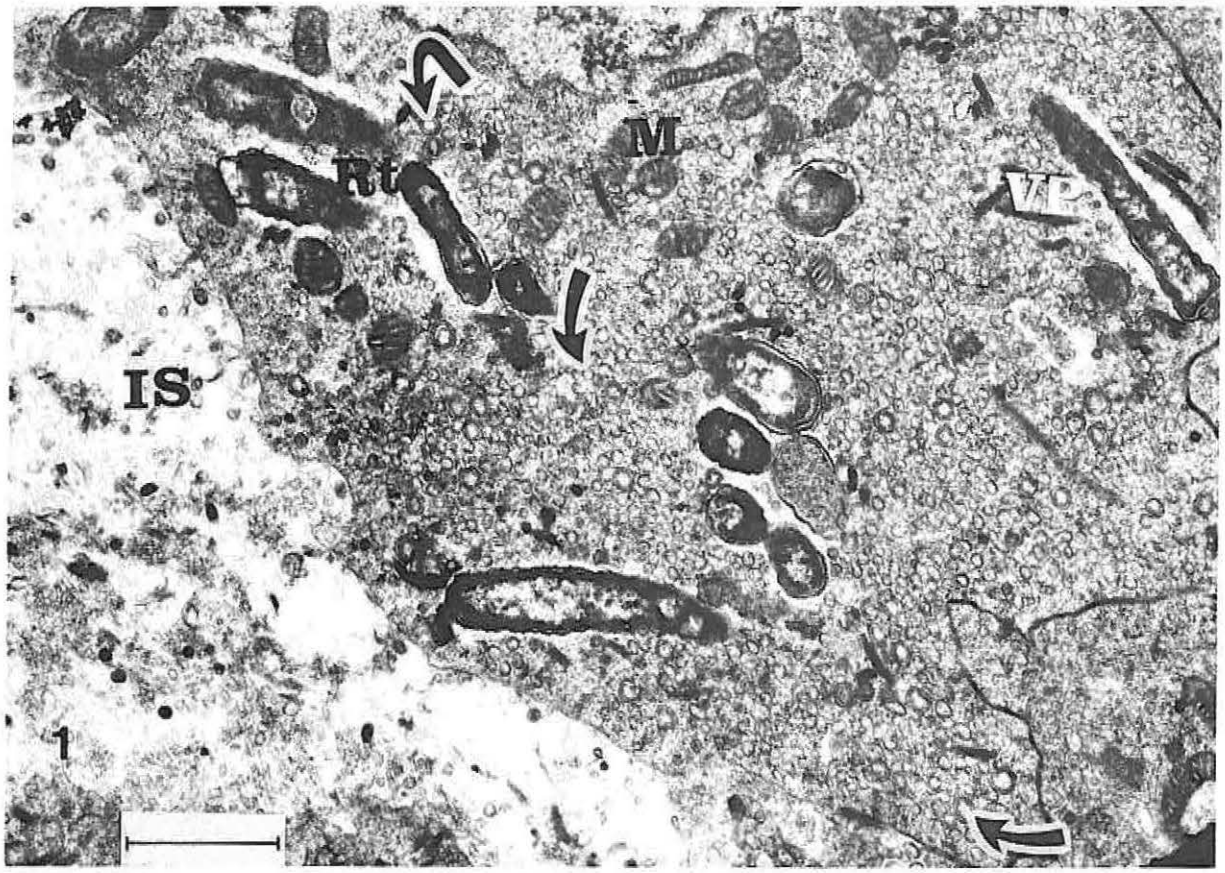


Figure 6.1 Electron micrograph of the glandular epithelium of *G. morsitans* salivary gland with combined rickettsial and viral infection, depicting extensive vesiculation (arrows), rickettsia (Rt), virus particles (VP), degenerating mitochondria (M) and intercellular spaces (IS); bar=1μm.

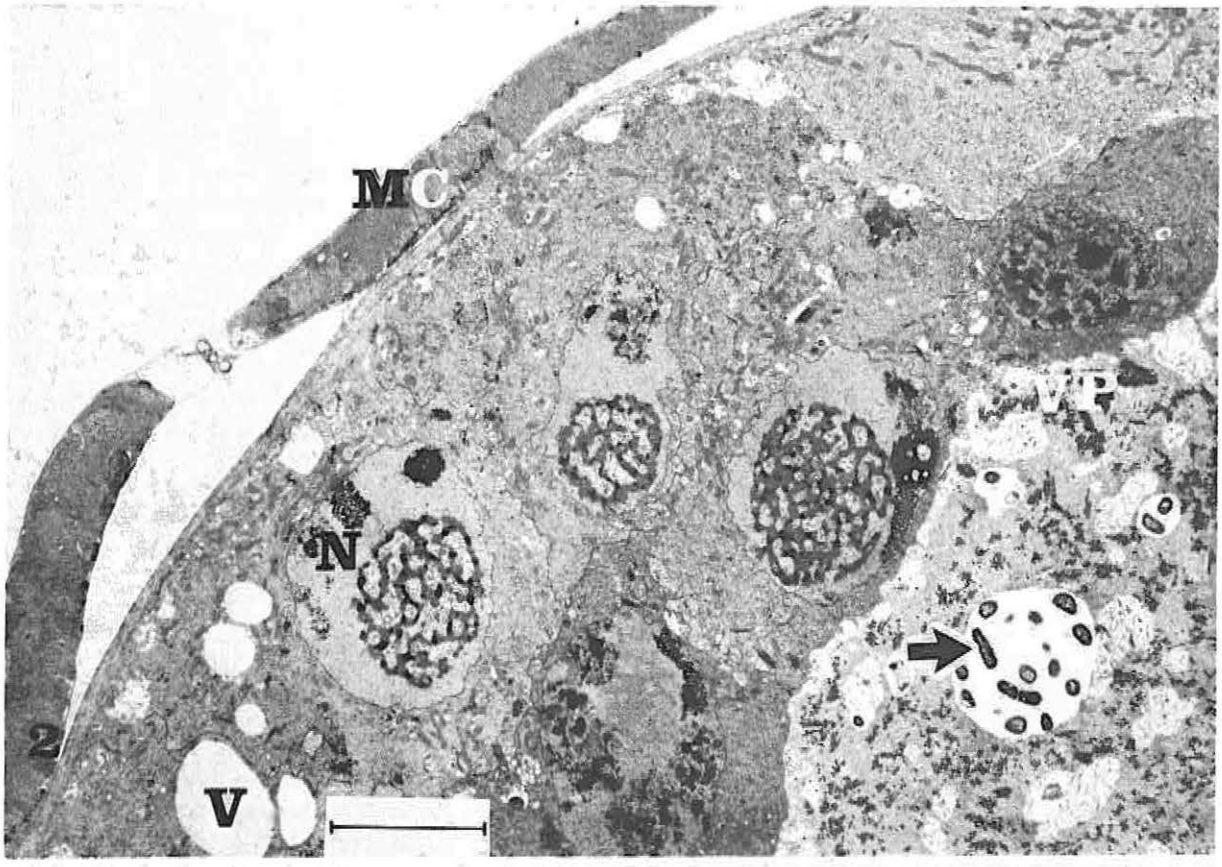


Figure 6.2 Electron micrograph of rickettsia-virus infected salivary gland cells of *G. morsitans*, showing many nuclei (N), degenerating muscle (MC), vacuoles (V) and the lumen filled with rickettsia (arrow) and virus particles (VP); bar=4μm.

greater number of cells. The severe damage caused to the salivary gland tissue suggests that the infection is parasitic.

Because the salivary glands of tsetse flies play an important role in the development of infective forms (metacyclics) of trypanosomes in the *T. brucei* group, we speculate that interference in the normal development of the glands, particularly of the epithelium, by a combination of virus and rickettsia, would lead to impaired vectorial capacity of infected flies. The low incidence of flies with the combined viral and rickettsial infection suggests that their survival is severely reduced.

6.2 NEUROPEPTIDE CHANGES ASSOCIATED WITH CHRONIC ARTHRITIS IN THE RAT

W. G. Z. O. Jura, S. Kar,† S. J. Gibson,†
R. G. Rees,† D. A. Brewerton† and J. M. Polak†

The dorsal horn of the spinal cord is the site of the first synapse in pain pathways, and is the main centre for processing information on pain. Three neuropeptides, namely, calcitonin gene-related peptide (CGRP) and two tachykinins (substance P and enkephalin) are thought to be involved in the modulation of pain transmission. In the ventral horn of the spinal cord CGRP is also localised within motor neurones where it is thought to have a role in muscle contraction. Rats with adjuvant-induced arthritis are considered to be good models for the study of chronic pain. The present study examined possible changes in the distribution of these neuropeptides in the spinal cord and the corresponding dorsal root ganglia, and also whether interruption of the pathways which supply noxious information results in an altered response. Three groups, each of five rats, were used as follows: (a) non-arthritic controls, (b) rats with widespread arthritis 28 days after injection with adjuvant and (c) rats with similar lesions, but with one sciatic nerve sectioned. Variations between the groups of rats were established by estimating the numbers of CGRP-immunoreactive motor neurones in the ventral spinal cord, and substance P- and CGRP-immunoreactive cell populations in the dorsal root ganglia.

In comparison with the controls, both sides of the L4 segment of the spinal cord of polyarthritic rats showed increased immunostaining of CGRP- and substance P-immunoreactive fibres, and in the deeper laminae large enkephalin reactive cell bodies also appeared. The raised levels of CGRP and substance P in the dorsal horn fibres were consistent with their increase in those neurones in the corresponding dorsal root ganglia which produce the two neuropeptides. In these dorsal root ganglia, the numbers of substance P- or CGRP-immunoreactive sensory neurones increased significantly in polyarthritic animals (Figure 6.3). Similar, but less pronounced, changes were seen on the intact (contralateral) side of the L4 segment of the spinal cord of rats in group (c). On the denervated (ipsilateral) side of the spinal cord in group (c) rats, however, consistent with interruption of the noxious input, the presence of substance P- or CGRP-immunoreactive fibres was markedly reduced and there were no enkephalin cell bodies present in the dorsal horn. On the ipsilateral side, also, the dorsal root ganglia contained fewer substance P- or CGRP-reactive cells (Figure 6.3). In the ventral horn of the spinal cord of the controls, CGRP-reactive motor neurones were abundant, but they were severely depleted in arthritic rats. Whereas on the ipsilateral side of the cord, the percent CGRP-reactivity increased markedly (Figure 6.4).

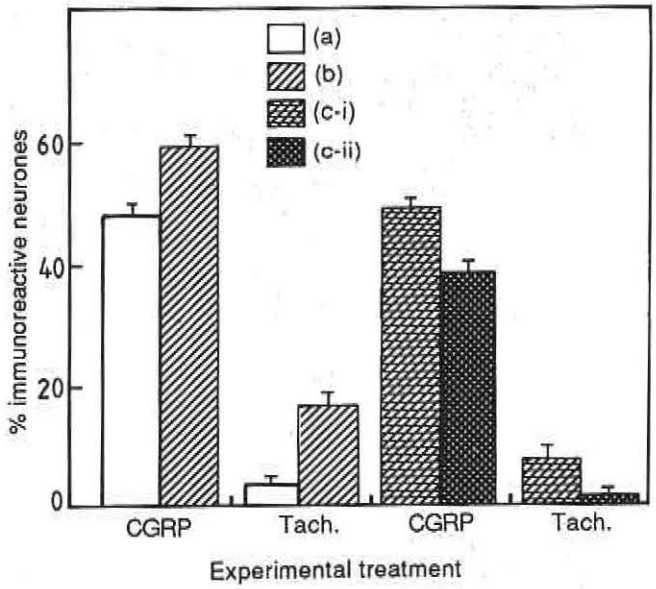


Figure 6.3 Mean percentages (+ 1 s.e.) of motor neurones immunoreactive to CGRP and tachykinins in dorsal root ganglion cells of rats: (a) normal controls (b) polyarthritic (c) polyarthritic with unilateral section of the sciatic nerve—(i) contralateral side (ii) ipsilateral side.

The data suggest that there is a complex interaction and interdependence between neuropeptides which are known to modulate sensory perception. The pain-associated

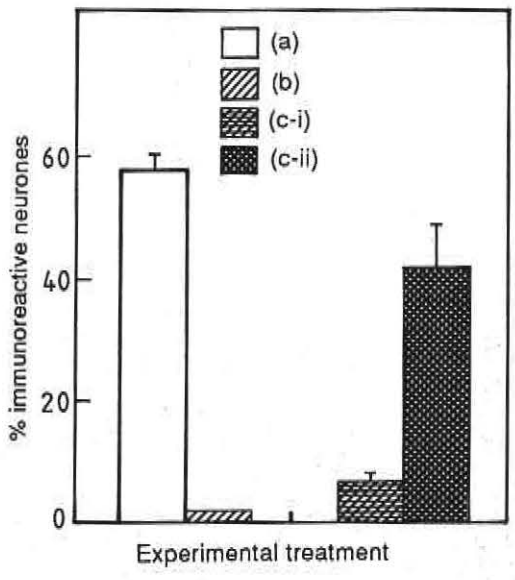


Figure 6.4 Mean percentages (+1 s.e.) of CGRP-immunoreactive motor neurones in the spinal cord of rats: (a) normal controls (b) polyarthritic (c) polyarthritic with unilateral section of the sciatic nerve — (i) contralateral side (ii) ipsilateral side.

changes observed in sensory pathways are dependent on an intact nerve supply to the spinal cord. Furthermore, the loss of CGRP-immunoreactive motor neurones observed in the ventral horn of the polyarthritic animals may reflect altered muscular activity associated with this condition.

†*Royal Postgraduate Medical School, University of London, UK.*

6.3 IDENTIFICATION AND CHARACTERISATION OF *LEISHMANIA* PARASITES

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

Identification of *Leishmania* strains has been hampered by deficiencies in the classical differentiating criteria, such as morphology, and the unreliability of clinical manifestations. Molecular biology techniques such as restriction endonuclease DNA analysis, southern blotting and molecular hybridisation offer greater powers of specificity because they can be used to detect subtle differences in DNA sequences between very closely related organisms. DNA analysis has the additional advantage over other identification methods in that individual genes, or parts of genes, are studied rather than their expressed products.

Total DNAs from WHO *Leishmania* reference strains, *L. infantum* IC-227, *L. aethiopica* IC-228, *L. major* Is IC-235, *L. major* Ke IC-236, *L. adleri* IC-244 and *L. donovani* IC-245 were digested with restriction enzymes BamHI, Dra I, EcoRI, Hind II, Hind III, Pst I or Taq I. This was followed by fractionation of the endonuclease digests using 0.8–1.0% agarose gel electrophoresis, and staining the gels with ethidium bromide. Visualization of the gels under ultraviolet light revealed characteristic bands ranging from 0.5–1.5 kilobases. Using as parameters the presence or absence of these specific bands and their size and number, we have grouped the six WHO *Leishmania* reference strains into three different genetic groups (Figure 6.5). The results were confirmed when DNA probes generated from these DNA fragment libraries were used in molecular hybridisation analysis (Figure 6.6).

Isoenzyme analysis using cellulose acetate electrophoresis continued during the year. The following

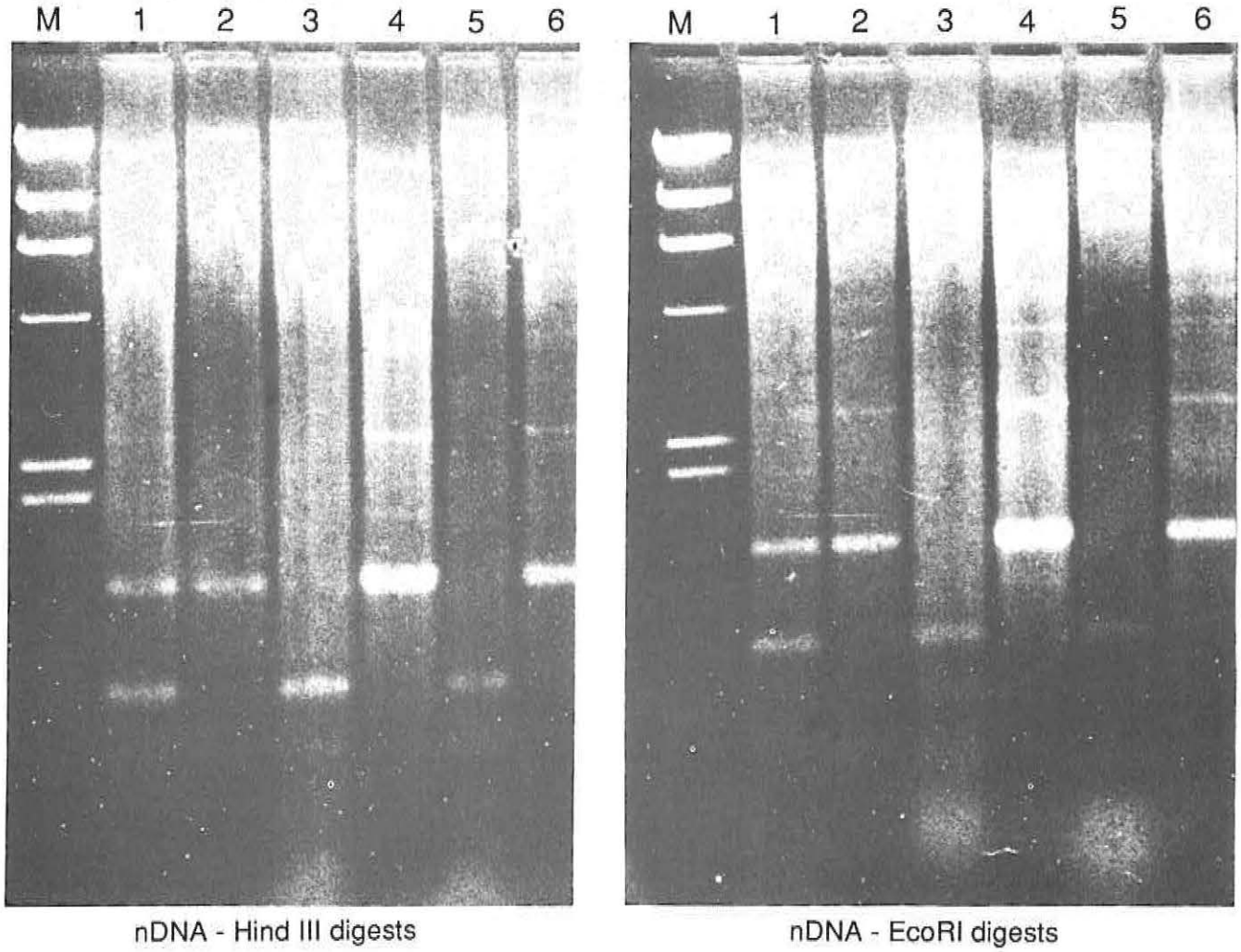


Figure 6.5 *Leishmania* DNA from WHO *Leishmania* reference strains: (1) *L. infantum* IC-227, (2) *L. aethiopica* IC-228, (3) *L. major* Is IC-235, (4) *L. major* Ke IC-236, (5) *L. adleri* IC-244 and (6) *L. donovani* IC-245 after digestion with restriction enzymes Hind III (left) and EcoRI (right). Molecular weight markers (M): λ DNA-Hind III digests. The method of preparation is described in the text.

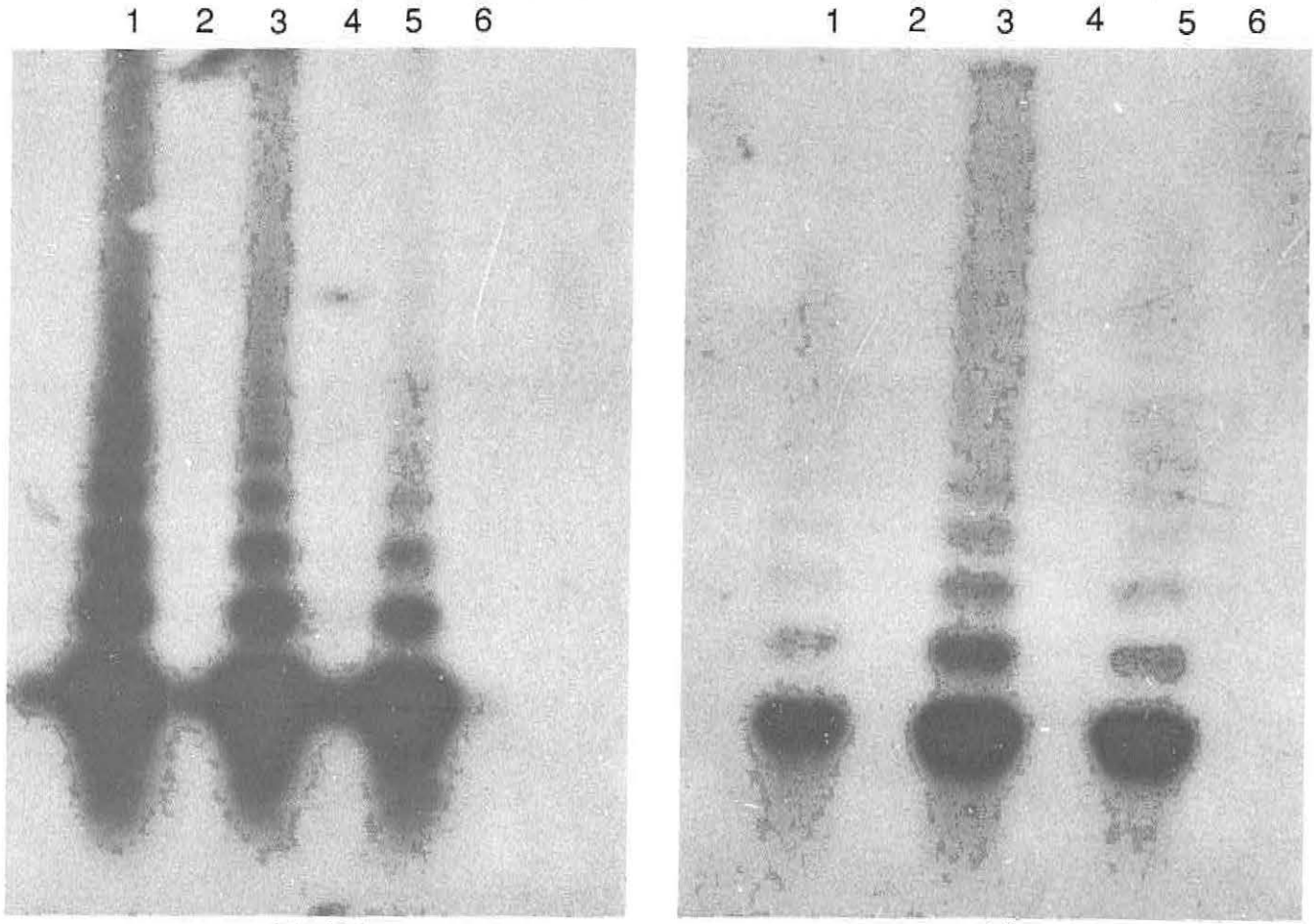
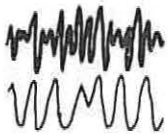


Figure 6.6 *Leishmania* DNA from WHO *Leishmania* reference strains: (1) *L. infantum* IC-227, (2) *L. aethiopica* IC-228, (3) *L. major* Is IC-235, (4) *L. major* Ke IC-236, (5) *L. adleri* IC-244 and (6) *L. donovani* were digested with restriction enzymes Hind III (left) and Hind II (right). The DNA fragments were electrophoresed on 0.8% agarose gels, blotted onto nitrocellulose filters and hybridised with a radiolabelled *L. major* Is IC-235 DNA probe. Differences in the hybridisation signals shown by the autoradiographs can be used for distinction of *Leishmania* species.

enzymatic systems were applied: malate dehydrogenase (MDH) EC 1.1.1.37, mannose phosphate isomerase (MPI) EC 5.3.1.8, glucose 6-phosphate dehydrogenase (G6PD) EC 1.1.1.49, glucose phosphate isomerase (GPI) EC 5.3.1.9 and phosphoglucomutase (PGM) EC 2.7.5.1. Forty wild *Leishmania* isolates were screened against the WHO *Leishmania* reference strains by comparing the isoenzyme banding patterns. Some of the wild isolates showed particular banding patterns which did not match the WHO *Leishmania* reference strains used in this study.

SENSORY PHYSIOLOGY RESEARCH UNIT

7



Sensory Physiology Research Unit

The Sensory Physiology Research Unit (SPRU) supports the ICIPE core programmes through research in behaviour and sensory physiology, in order to understand better the behaviour and biology of the target pest species. This knowledge is of crucial importance in formulating effective pest management strategies.

A combination of behavioural and electrophysiological studies are employed to investigate the factors and mechanisms involved in the stimulus-response activities which mediate such aspects of insect behaviour as host-finding, host-selection, feeding, mating and oviposition.

During 1989 the research focused on the following areas:

- *Feeding behaviour patterns of the maize stem-borer,* Chilo partellus
- *Feeding behaviour of the cowpea pod-borer* Maruca testulalis
- *Oviposition behaviour of* C. partellus
- *Responses of* M. testulalis *to oviposition stimuli*
- *Responses of tsetse,* Glossina morsitans *and* G. pallidipes, *to host-derived kairomones*
- *Mating behaviour of* G. morsitans *and* G. pallidipes
- *Artificial feeding of the tick,* Rhipicephalus appendiculatus.

Aspects of feeding behaviour of the cowpea pod-borer and tsetse mating behaviour are reported under the Crop Pests and Tsetse Research Programmes, respectively. The results of the other research projects are summarised below.

7.1 FEEDING BEHAVIOUR PATTERNS OF *CHILO PARTELLUS* LARVAE

P. G. N. Njagi

Two aspects of the feeding behaviour of neonate, first-instar *C. partellus* larvae are being investigated using Inbred A maize which is susceptible to attack. The aim is to analyse the feeding behaviour of the stem-borer, and then study those host-plant characteristics that elicit feeding. With the information acquired, resistant and tolerant cultivars of maize will be compared in order to determine which components of the feeding behaviour are disrupted by host-plant resistance.

7.1.1 Establishment and feeding activity of the first instar

In a laboratory assay on feeding activity, neonate *C. partellus* larvae were observed to spend most of the time feeding. There were short intervals of non-feeding activity during which the larvae rested, groomed their bodies or moved to other feeding spots. The number of larvae actively feeding (a measure of the time spent in feeding) increased throughout the day, reaching a maximum of about 80% at dusk (Figure 7.1). In the field, counts of pin-spot lesions, caused by larval feeding, started two hours after artificially infesting 2–3-week-old maize plants with neonatal larvae and showed an almost linear increase with time for the subsequent 9 hours. Although more larvae were observed to be feeding in the laboratory than in the field, especially after the initial 5 hours, the patterns were very similar (Figure 7.1). Disturbance during sampling in the field may have led to this variation. In both cases, fluctuations at the end of the observation period may have been due to a photoperiod effect on larval feeding activity. The number of pin-spot lesions declined because the larvae aggregated to feed at certain points, forming larger lesions.

Larvae do not feed whilst migrating from their hatching sites into the leaf whorl, but may resume feeding immediately after settling in the folds of the leaves, hence the observed foliar damage 1–2 days after larval infestation. More experiments will be done to determine: (a) time taken between location of food and commencement of

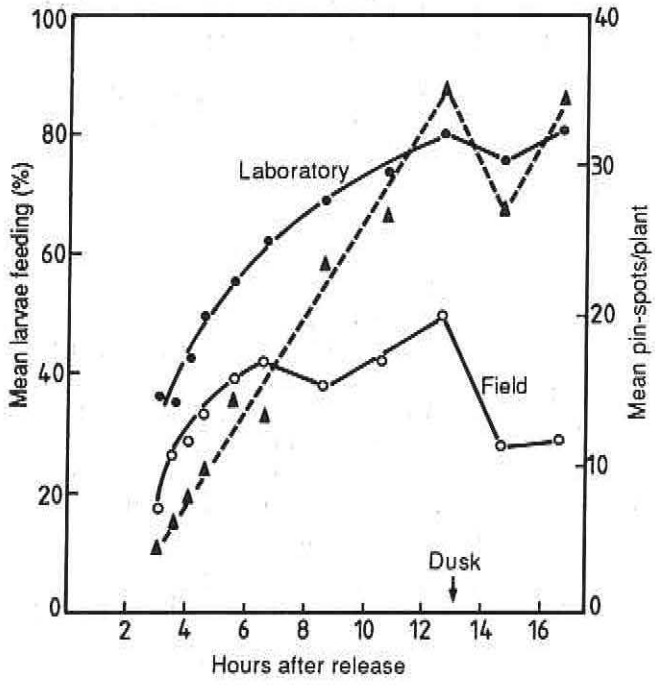


Figure 7.1 Feeding activity of neonate, first-instar *C. partellus* larvae in the laboratory and field (solid lines); damage was assessed as no. of pin-spot lesions per plant (broken line).

feeding, (b) duration of each meal, (c) inter-meal periods and (d) pattern of feeding activity of larvae over a longer period than one day.

7.1.2 Stem internode preference for tunnelling by larvae
Two sets of Inbred A maize plants, protected by screening, were artificially infested with neonate, first-instar larvae of *C. partellus* 14 days and 28 days after emergence (DAE). Plant samples were taken weekly to determine the location and extent of damage due to feeding by the larvae.

Tunnelling of stems was evident 14–21 days after infestation, though at very low frequency, especially for maize (Figures 7.2a and c). For 14 DAE maize, stem-tunnelling was concentrated in internodes 1–5 and the roll of whorl leaves. The frequency of tunnelling in 14 DAE maize was higher than in 28 DAE maize, in which a large proportion of the tunnels was in internodes 4–8 and the tassel axes (Figures 7.2a–c and e). The latter pattern was also obtained for 28 DAE plants harvested 35 days after infestation (Figure 7.2d).

For unprotected maize exposed to natural infestation there was a spread of tunnelling over internodes 2–10 and the tassel axes (Figure 2f). This pattern indicated a succession of overlapping infestations combining both of the patterns noted above, though at lower proportions.

The emphasis on tunnelling in the higher nodes and the terminal parts of the maize plant suggests that the texture of the stem material (rind, pith etc.) may be a

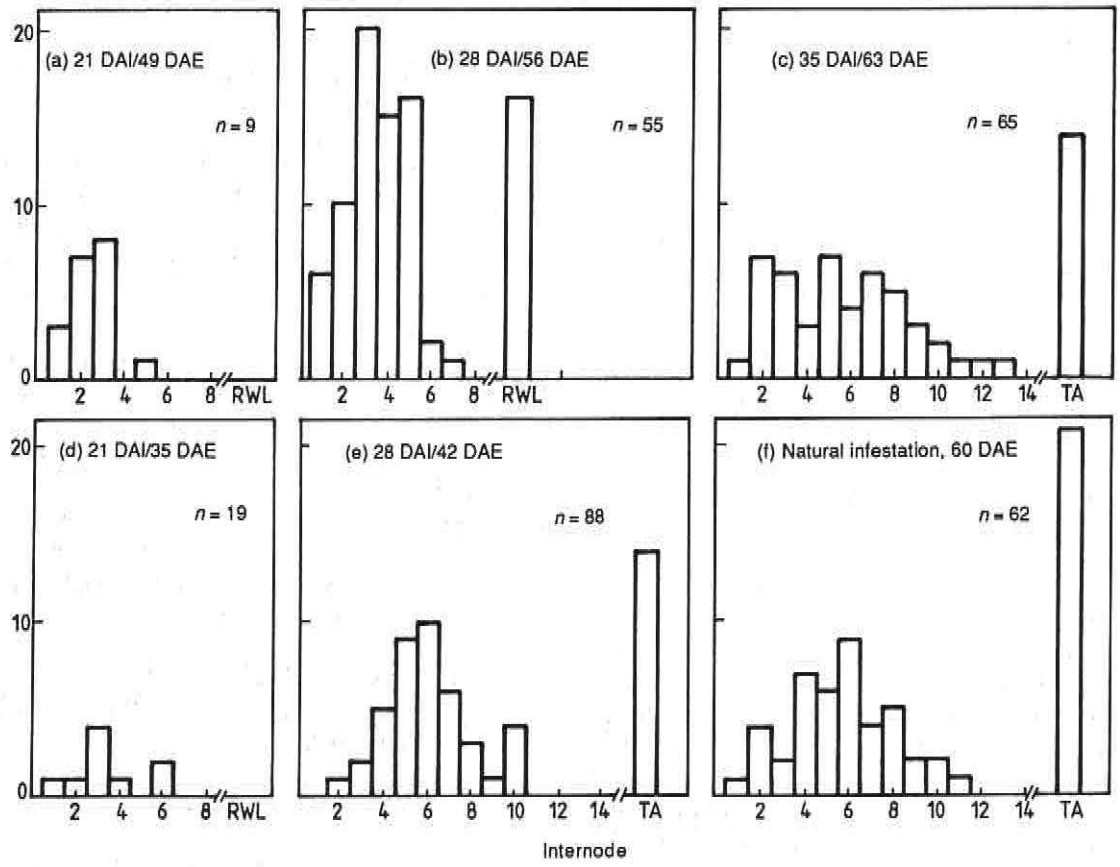


Figure 7.2 (a)–(c) Counts of larval tunnels in the internodes of the stems of maize plants infested artificially with neonate, first-instar *C. partellus* larvae 28 days after plant emergence (DAE) and (d)–(e) 14 DAE. Samples were taken at 21, 28 and 35 days after infestation (DAI). (f) Unprotected maize examined at 60 DAE. Internode no. 1 started just above the ground; *n* = no. of tunnels in sample; TA = tassel axis; RWL = roll of whorl leaves.

major factor influencing the tunnelling pattern by the stem-borer. Implicitly, chemical and nutrient reserves in the plant (though only after the larvae have entered the stem and started feeding), and the genetic make-up of the larvae may be other contributing factors. These hypotheses will be tested and the timing of the start of tunnelling and feeding activity of larvae in the tunnels will also be investigated.

7.2 OVIPOSITION BEHAVIOUR OF *C. PARTELLUS* IN A SORGHUM-COWPEA CROPPING SYSTEM

P. G. N. Njagi, S. M. Waladde, H. M. Kahoro and S. A. Ochieng'

Previous work at the ICIPE has shown that intercropping cereals and legumes suppresses the population of *Chilo partellus* on the cereals (*ICIPE 1986* and *1987 Annual Report*). Investigations were carried out to see whether the reduction in the stem-borer population brought about by intercropping occurs at the stage of host finding by the adult *C. partellus* female or at oviposition. The study also has the long-term objective of providing information on aspects of the underlying sensory mechanism of the insect/host-plant interaction in such a cropping system:

The intensity of oviposition was studied in field cages (2.0 x 2.0 x 1.8 m) on three cropping systems: sorghum (Serena) monocrop, cowpea (Vita 1) monocrop, and Serena-Vita 1 dicrop sown simultaneously using row displacement cropping. Mating of released moths occurred in all three systems. However, the number of mating pairs at 0100–0300 hours on the first day of release was higher on the Serena monocrop than on the others, which were almost equal. A large proportion of the eggs was laid on the sorghum and cowpea plants, but moth eggs were also found on weeds and on the wooden frames of the cages. The oviposition intensity on Serena in the dicrop was less than half (97.6 eggs/plant) that in the monocrop stand (216.2 eggs/plant). There was also a change in the order of oviposition site preference from: (lower leaf surface) > (upper leaf surface) ≥ (stem) on Serena monocrop, to (upper leaf surface) > (lower leaf surface) ≥ (stem) in the dicrop system. Vita 1 monocrop had 62.5 eggs/plant with a preference sequence: (stem) ≥ (lower leaf surface) > (upper leaf surface), compared to 64.1 eggs/plant in the dicrop, with the same preference sequence.

The work will be continued, while at this stage it is postulated that the presence of the cereal host provides arrestant cues for *C. partellus* females in searching for oviposition sites. However, the tarsal and/or ovipositor sensilla have low discriminatory ability and the moths possibly utilize such general stimuli as humidity, surface temperature and texture to locate an oviposition substrate/site. Eggs laid on cowpea seem to hatch normally and it is therefore possible that high mortality of first instar larvae occurs during dispersal on the non-host plant and thereby reduces the pest population. This may be augmented by reduced hatchability, through desiccation of eggs laid on sorghum in the dicrop due to reversed oviposition site preference.

Studies on the stimuli adequate for location of the oviposition site, dispersal of the neonate first-instar larvae on the non-host plant, and the ultrastructure and typology of tarsal and ovipositor sensilla will follow.

7.3 FEEDING BEHAVIOUR OF *M. TESTULALIS* ON HOST AND NON-HOST PLANTS

C. F. Mugoya

The feeding behaviour of the cowpea pod-borer *Maruca testulalis* on two of its host plants (cowpeas and beans) and a non-host plant (cotton) was investigated.

The activities observed were (a) feeding, (b) non-feeding movement (locomotion) and (c) non-feeding (resting). On the host plant, larvae spent most of the time feeding, especially at night. On the non-host plant, the larvae spent all the time in locomotion. No sustained feeding was observed on leaves, stems and flowers of cotton, even under severe prior starvation. First-instar larvae would, however, feed on the cotton bolls, and growth was supported up to the fifth instar, but mortality was high.

Freshly excised pods and flowers of host plants elicited the highest levels of larval feeding compared with other plant parts. Feeding activity on pods and flowers was higher on beans than on cowpeas, but feeding on bean leaves was heavily impeded by the presence of surface hairs. Powders of different host-plant parts (prepared by air drying) elicited lower levels of feeding when incorporated into agar diet. Among the pure compounds studied so far, sucrose and glucose were effective in stimulating feeding in *M. testulalis*. Response curves for both sugars showed that 0.2M was the optimum concentration for maximum feeding.

It appears that pods and flowers contain phagostimulants for *M. testulalis* larvae, and the lower levels of palatability of leaves, stems and seeds may be due to lower concentrations of such phagostimulants. The presence, in addition, of surface hairs on bean leaves may be an important factor in the resistance of beans to *M. testulalis*. On the other hand, the almost total lack of feeding on cotton plants suggests either the presence of feeding deterrents, or the absence of feeding stimulants.

These studies will lead to the identification of feeding stimulants and deterrents which could eventually be used in pest management programmes. Feeding stimulants would be particularly useful in baits incorporating biocontrol agents, while feeding deterrents might be used to prevent population build-up of the pest.

7.4 OVIPOSITION RESPONSES OF *M. TESTULALIS* AND SENSITIVITY OF THE OVIPOSITOR GUSTATORY SENSILLA

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

Laboratory rearing of *Maruca testulalis* relies heavily on eggs deposited on young cowpea plants, because there is no satisfactory artificial oviposition substrate since this moth has fairly specific oviposition behaviour. We

confirmed that in a cowpea-sorghum intercrop *M. testulalis* shows an overwhelming preference for oviposition on cowpea plants, in spite of the fact that females spend several hours feeding on the honeydew which is found on sorghum leaves. This suggests that cowpea plants provide specific oviposition stimulants for *M. testulalis*. We are therefore gathering detailed data on oviposition behaviour in order to develop an artificial oviposition substrate.

7.4.1 Oviposition tests

Four experiments were undertaken to examine *M. testulalis* oviposition responses on both natural and artificial substrates, treated with either known compounds or host-plant extracts as follows:

- Untreated host plants: (1) cowpea, (2) beans (*Phaseolus vulgaris*)
- Cowpea plants: (1) non-treated, (2) treated with 0.01M NaCl, (3) treated with 0.019M sucrose
- Cowpea plants: (1) non-treated, (2) treated with 0.01M NaCl, (3) treated with 0.125M sucrose
- Filter paper soaked in: (1) 0.01M NaCl, (2) 0.019M sucrose, (3) equal parts of solutions (1) and (2), and (4) aqueous extract from fresh cowpea leaves.

Although the bean plant can serve as an alternative host, *M. testulalis* did not lay as many eggs as on the cowpea (Figure 7.3). While plants treated with 0.019M sucrose augmented oviposition, plants treated with 0.125M sucrose received fewer eggs but the moths were stimulated to leak sugar on to the leaves (Figure 7.3). The females deposited 1–3 eggs at each spot, especially on the under surface of the host plant leaves. On the host plant, as well as on the filter paper treated with the host-plant extract, before oviposition the female either dragged the ovipositor firmly across the substrate, or moved it searchingly. These observations suggest that the ovipositor must detect suitable stimuli before releasing the eggs.

One hundred percent oviposition was obtained on filter paper treated with aqueous extracts from cowpea leaves (Figure 7.3) and this system has the following advantages:

- Eggs can be sterilised easily
- Hatchability is as good as that of eggs deposited on the host plant
- Newly hatched larvae can be easily transferred to the artificial diet.

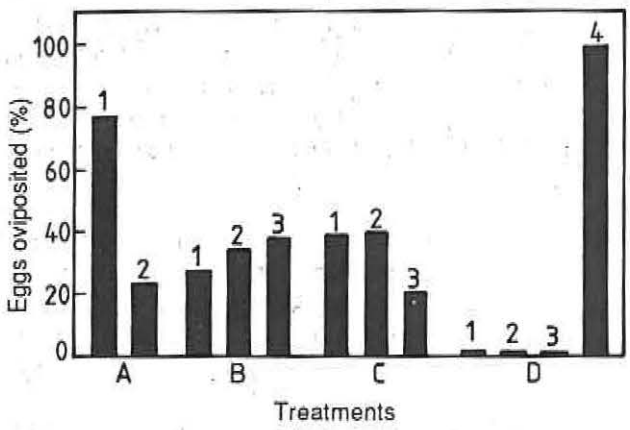


Figure 7.3 Eggs laid by *M. testulalis* in four experiments, expressed as percentages laid on each subtreatment; details given in text.

7.4.2 Ovipositor sensilla sensitivity

Electrophysiological tests are in progress to assess the sensitivity and coding properties of the gustatory cells in the ovipositor contact chemosensilla. Of the many bristles on the ovipositor, only twelve hairs, six on each valve, serve as contact chemoreceptors (Figure 7.4). The rest are possibly mere mechanoreceptors.

Data obtained using the tip-recording method showed that the ovipositor sensilla receptor cells are sensitive to a small range of compounds and they adapt fairly slowly. The threshold concentration for sucrose is 0.00118M while that for the cation salts (e.g. KCl) is 0.02M. Each sensillum has a cell responding vigorously to increasing concentrations of sucrose. Sucrose is the only active sugar and it stimulates one cell in each of the ovipositor sensilla, but it apparently deters oviposition at approximately 100-fold the threshold concentration. Stimulation with cation solutions and aqueous washes from cowpea leaves evokes

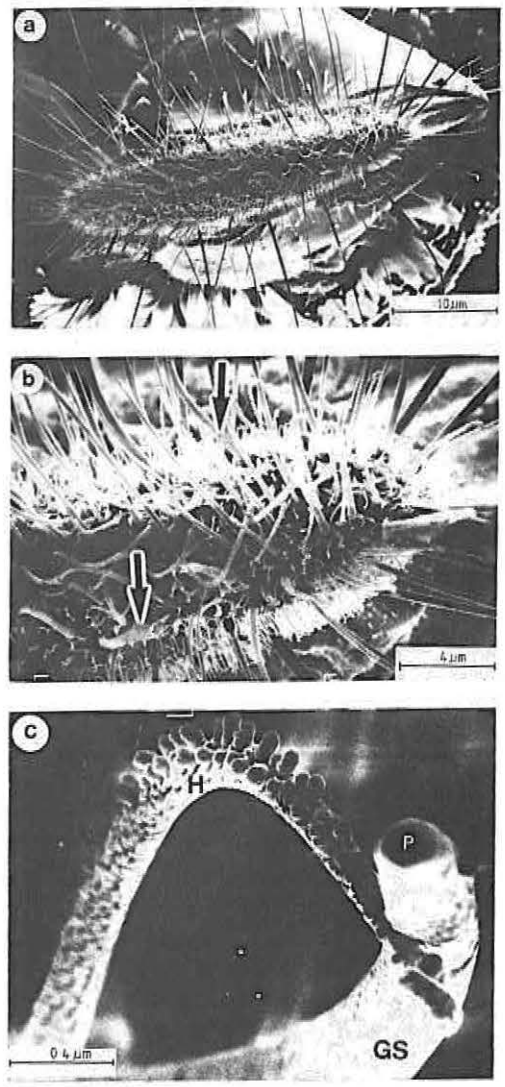


Figure 7.4 Scanning electron micrographs of *M. testulalis* ovipositor. (a) Displaying sensory hairs, (b) higher magnification with gustatory sensilla arrowed, (c) showing ovipositor hairs (H) with curved tips bearing globular features, and gustatory sensilla (GS) each with a conspicuous terminal pore (P).

polyneuronal responses. Increasing concentrations of cation salts stimulate at least four cells in each sensillum. The available data suggest that all six pairs of the ovipositor gustatory sensilla belong to the same category.

7.5 RESPONSES OF TSETSE FLIES TO PHENOLIC KAIROMONES

R. K. Saini and P. Ahuya

Investigations on how certain chemicals affect tsetse behaviour are important in providing a fuller understanding of the types and interplay of responses by tsetse to these chemicals, individually and in combination. These studies may suggest means by which odours can be used more effectively in tsetse control.

The responses of tsetse flies *Glossina m. morsitans* and *G. pallidipes* were observed in a wind-tunnel to a 4:1 mixture of 4-cresol and 3-n-propylphenol, phenolic kairomones responsible for conferring high activity to the "buffinol" mixture (see *ICIPE 1988 Annual Report*). For details of the wind-tunnel refer to the same report. In field studies, however, significantly fewer *G.m. morsitans* than *G. pallidipes* are attracted to this mixture.

Figure 7.5 shows the behavioural responses of tsetse flies on stimulation with the phenolic mixture. Both species exhibited activation behaviour (flight or walking in the release cage without any upwind movement) which was not significantly different. Only about 10% of the flies exhibited this behaviour on stimulation with the control (filter paper loaded with an equivalent amount of water). However, significantly more *G. pallidipes* flew

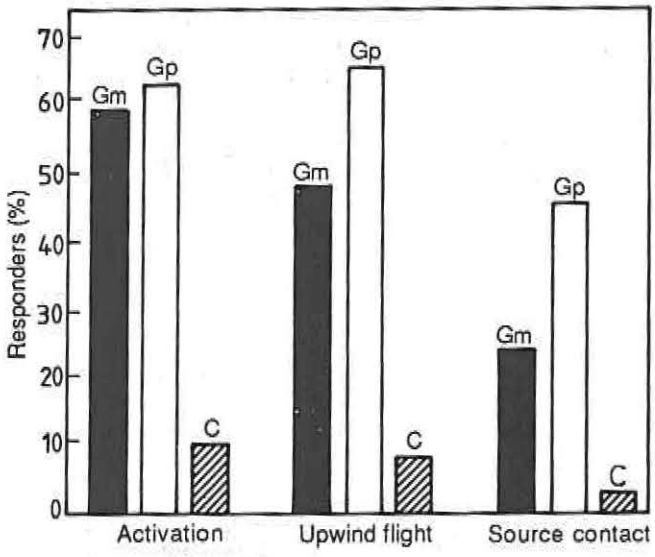


Figure 7.5 Behavioural responses in a wind-tunnel of *G. m. morsitans* (Gm) and *G. pallidipes* (Gp) to a 4:1 blend of 4-cresol and 3-n-propylphenol, and to a blank control (C).

upwind on stimulation with the phenolic mixture, and more also contacted the source (actual contact with the stimulus release device).

These observations suggest probable reasons why fewer *G. m. morsitans* than *G. pallidipes* are caught in the field in traps baited with this mixture. Additional kairomones may therefore be necessary to reinforce upwind flight and source contact behaviour in *G. m. morsitans*. The studies required to identify additional kairomones that mediate host-seeking behaviour of *G. m. morsitans* are now under way.

7.6 CLOSE-RANGE BEHAVIOUR OF TSETSE FLIES *(G. M. MORSITANS)* TO HOST ODOURS

R. K. Saini, A. Hassanali, J. A. Andoke, P. Ahuya and E. Nyandat

So far, two sets of kairomonal compounds derived from either the breath of host animals or their excretory products have been shown to mediate host-seeking behaviour of tsetse flies. Results of the experiments reported above suggest that additional kairomones may be involved in the host-seeking behaviour of *G. m. morsitans*. Hence, studies were initiated to investigate the behaviour in a wind-tunnel of these flies to a screen impregnated with body washings of cows, buffaloes and warthogs.

Figure 7.6 shows the behavioural responses of tsetse flies to body washings of cows. Since washings in hexane, ethyl acetate and methanol were equally stimulatory, the results were combined, and all subsequent washings were done using methanol, with pure methanol as the control.

Figure 7.6a shows that 40–80% of flies were activated (depending on dose) on stimulation with this body wash as compared to the control (only 10%). About 20–60% flies initiated upwind flight and actually flew up to the screen impregnated with the kairomones (Figures 7.6b and 7.6c). Flight past the screen was minimal (Figure 7.6d), while about 10–20% flies flew around the screen (Figure 7.6e). Significantly more flies (10–30%) landed

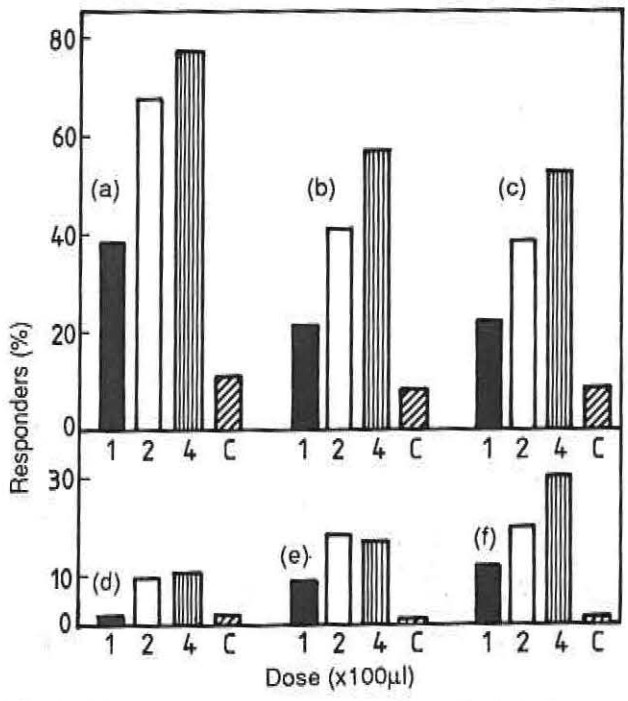


Figure 7.6 Behavioural responses in a wind-tunnel of *G. m. morsitans* to body washings in methanol of cows at three doses, and to a blank control (C). (a) Activation, (b) initiation of upwind flight, (c) flight up to screen, (d) past screen, (e) round screen and (f) landing on screen.

on the screen and initiated probing (Figure 7.6e) than on the control.

Figure 7.7 represents these behaviours schematically. It is clear that additional kairomones are present on the body of host animals and they not only increase activity around a target but also elicit responses which include alighting and probing. Body washings from warthogs, and the eye region of domestic pigs, also elicit similar responses. Experiments are in progress to identify the active compounds involved in the close-range behaviour of tsetse flies to host animals.

Preliminary chromatographic examination and behavioural assays of fractions of body washings suggest that a series of compounds of differing polarities may influence the close-range behaviour of the flies.

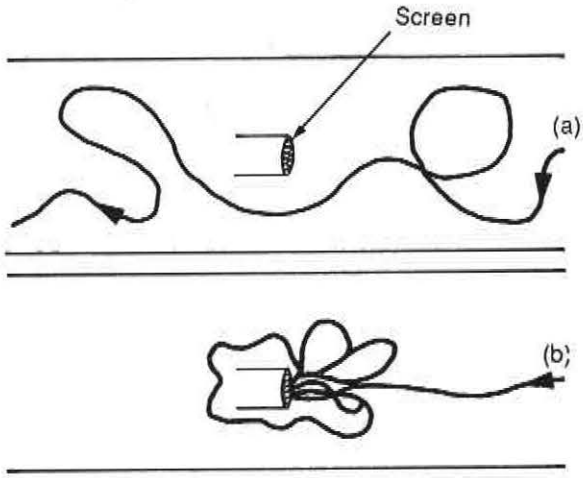


Figure 7.7 Schematic representations of close-range responses of *G. m. morsitans* to host odours in a wind-tunnel: (a) to a screen without any kairomones, (b) to a screen impregnated with close-range kairomones.

These studies indicate that the host-seeking behaviour of tsetse flies is quite complex and it is important to distinguish between initial, distant orientation behaviour and localised, close-range orientation which eventually leads to alighting, probing, and feeding. A combination of these behaviours may be responsible for the host selectivity exhibited by tsetse. An understanding of such behavioural patterns and their semiochemical basis is the key to efficient manipulation of tsetse, which will result in effective management.

7.7 SUCCESSFUL ARTIFICIAL FEEDING OF THE IXODID TICK *R. APPENDICULATUS*

S. M. Waladde, E. I. P. Kamanga-Sollo and S. A. Ochieng'

Argasid ticks have been fed to repletion through different artificial membranes by a number of workers. Similar attempts using the one-host ixodid tick *Boophilus microplus* have met with only limited success in persuading newly moulted adults to attach and feed through a modified baudruche membrane. Although the ticks attached and were able to feed for at least 24 hours this was far short of the period required to attain full engorgement. Similar results were obtained in experiments of this type using flat adults of the three-host ixodid tick *Rhipicephalus appendiculatus* (*ICIPE 1987 Annual Report*). This work has now been taken further by creating optimal conditions for attachment and feeding of *R. appendiculatus*. As a result, we have succeeded in making the flat adults (not preconditioned) attach, feed, mate and attain full engorgement on an artificial membrane. Ticks so fed have gone on to lay eggs with very good hatchability. Membrane-fed ticks had a lower engorgement weight (Table 7.1) but this shortcoming will be met by providing them with a continuous supply of fresh, warm blood.

Table 7.1 Mean weights and egg production of 49 membrane-fed *R. appendiculatus* females compared with 61 fed on rabbits

Feeding system	Unfed wt.(mg)	Fed wt.(mg)	Egg/batch wt.(mg)	Conversion factor†
Rabbit ear	3.4	474.8	212.0	0.567
Membrane	3.4	245.0	115.0	0.472

†Egg weight/engorged weight.

INSTITUTIONAL BUILDING AND INTERACTIVE RESEARCH UNIT

8

Institutional Building and Interactive Research Unit

The mandate of IBIRU is to strengthen the scientific leadership and technological capability in insect science of tropical developing countries through collaborative research and training programmes. During the year there was restructuring of the Unit and an intensification of activities. There was also a change in leadership, and redesigning the headship of the components of IBIRU led to more cohesive functionality within the Unit.

Training activities were consolidated within the Training Department which acquired a substantive coordinator during the year. The continued popularity with institutions all over Africa of the African Regional Postgraduate Programme in Insect Science (ARPPIS) led to an increased number of applications for the yearly enrolment. The collaborative graduate studies for an M.Phil. in biological control, within the ARPPIS programme, came to a satisfactory conclusion in December with the successful completion of their studies by the four students who were registered in the programme.

With regard to the consolidation of the graduate programme at the ICIPE, the task force that was established in the previous year to review the structure and future focus of graduate studies presented its report. A working group was established to continue the work in order to ensure the successful establishment of the proposed Graduate School in the near future.

The Financial and Administrative Management of Research Projects in Eastern and Southern Africa (FAMESA) intensified activities that covered all the major aspects of its mandate. It conducted research resource surveys of national institutions and assessed information management services in eastern and southern Africa. Several regional and national workshops were also conducted during the year, as well as the production of a "Manual on Project Planning, Monitoring and Evaluation". While strengthening existing linkages, FAMESA also made contacts with national and international organisations to explore the possibilities of new collaboration.

The African Regional Pest Management Research and Development Network (PESTNET) assumed the new title of Pest Management R&D Network (PESTNET) to reflect a wider, pan-tropical approach to its mission. It consolidated its interactive collaboration with national programmes and the international scientific community, especially in Africa. Exploratory visits were made to West Africa, South-East Asia and Latin America to identify areas of possible collaboration with PESTNET. Areas of collaborative research in integrated strategies for the control of crop pests were firmly established in the PESTNET countries of Kenya, Somalia and Zambia, whilst tsetse traps were validated for use in fly suppression in Rwanda, especially in the Kagera Basin (see Section 4.17, Tsetse Research Programme). Long-term and short-term training for officers from countries participating in PESTNET was effected. In the area of information exchange, a methodology workshop was organised for Somali nationals in Mogadishu in February, and a Regional Planning Workshop on Information Documentation Services was held in Zambia in November.

Restructuring of short-term courses is being actively pursued; three were conducted in the year:

- *Tick Management*
- *Use of Computers in Pest Management*
- *Use of Radioisotopes in Insect Science.*

The foregoing has shown clearly in general terms the need for development of capacity building and interactions between organisations and institutions. Details of the individual sub-sections are presented by the coordinators.

8.1 THE AFRICAN REGIONAL POSTGRADUATE PROGRAMME IN INSECT SCIENCE (ARPPIS)

Z. T. Dabrowski

The seventh ARPPIS Ph.D. class began its studies in March 1989 with ten scholars from five countries (Kenya, Nigeria, Somalia, Sudan and Tanzania). The cumulative number of ARPPIS scholars that have been registered now totals 59 from 13 countries.

The courses in the teaching semester were taught by ICIPE scientists and visiting lecturers from the ARPPIS participating universities. Dr. K. J. Mbata (University of Zambia, Lusaka) taught Insect Functional Morphology; Professor R. Kumar (Rivers State University of Science and Technology, Port Harcourt, Nigeria) and Dr. R. K. Bagine (National Museums of Kenya, Nairobi) taught Insect Taxonomy; Dr. J. Allotey (RSUST) and Drs. C. Mutero and S. K. Firempong (ICIPE) taught Insect Ecology; Drs. G. P. Kaaya, M. O. Odindo and M. Brownbridge (ICIPE) taught Insect Pathology, and Drs. M. F. B. Chaudhury, E. O. Osir and R. K. Saini (ICIPE) taught Insect Physiology and Biochemistry. Each course was examined by a three-hour written paper; the papers and scripts were externally moderated by Dr. R. W. Mwangi (University of Nairobi, Kenya).

Five ARPPIS scholars received their degrees in 1989 (Table 8.1). Miss D. A. Adabie (1984) and Mr. B. Torto (1985) passed the final examination at the University of Ghana, while Mr. C. B. Maranga (1984) and Mr. B. Wishitemi (1985) at Kenyatta University, and Mrs. U.M. Elneima at the University of Khartoum, successfully defended their theses. Three members of the 1986 ARPPIS M.Phil. class, Mr. K. Kambona, Mr. B. Odongo and Mr. G. Ochiel, and Miss A. Ngi-Song of the 1987 Class, were successful in defending their theses at RSUST.

Two students of the 1989 ARPPIS Ph.D. Class, Miss R. Bob-Manuel and Mr. F. Nwilene, who are involved in the ICIPE/Copenhagen University research project on cassava mite population modelling (sponsored mainly by DANIDA), attended a course in Denmark on applied population dynamics at the Institute of Population Biology, Copenhagen University. They are to develop mathematical models for biological control agents and cassava green spider mite populations on cassava at Mbita Point Field Station.

In a collaborative activity between the ICIPE and the University of Bonn, West Germany, a research and training project is in progress on the development of integrated pest management strategies for the control of the banana weevil and nematode problems in Tanzania. Within the project, two Tanzanian scientists with experience in banana pest management are being trained at the Ph.D. level. They will reinforce the national research system and work on the banana pest complex. The scientists who were identified and offered places in the 1989 ARPPIS Class are Mr. B. E. Uronu from the Tropical Pests Research Institute, Arusha, and Mr. A. A. S. Mbwana from Maruku Agricultural Research Station, Bukoba. After completing their coursework and examinations at the ICIPE Headquarters they have returned to Tanzania to undertake their Ph.D. research projects at Bukoba.

Nine ARPPIS students made presentations during the 19th ICIPE Annual Research Conference. They were: Mr. J. Davies-Cole, Mr. C. Kyorku and Mr. M. Mwangelwa (Tsetse); Mrs. E. Mwangi, Mrs. M. Ndonga, Mr. B. Odongo and Mr. J. Ogwang (Biological Control); Mr. Hassane Mahamat and Mr. B. Torto (Chemistry and Biochemistry).

Table 8.1 ARPPIS scholars awarded degrees in 1989

Name	Shortened thesis title	Registering university
Dr. D. A. Adabie	Pupal ecology and role of predators and parasitoids in natural population regulation of *G. pallidipes*	University of Ghana, Legon, Ghana
Dr. U. M. Elneima	Characterisation of different strains of *T. congolense*	University of Khartoum, Sudan
Dr. C. B. Maranga	Studies of *R. appendiculatus* immunity in goats	Kenyatta University, Nairobi, Kenya
Dr. B. Torto	Sorghum allelochemicals stimulating feeding by *C. partellus* larvae	University of Ghana, Legon, Ghana
Dr. B. E. Wishitemi	Induction of immunity in sheep to *R. appendiculatus* antigens	Kenyatta University, Nairobi, Kenya

The ARPPIS Academic Board met twice during the year, in July and December. The December board meeting was preceded by a one-day scientific meeting at which all second and third year Ph.D. students presented a paper on an aspect of their work. The December meeting also included the Fourth ARPPIS Distinguished Lecture which was given by Professor A. J. Ahianzu, Vice-Chancellor of Rivers State University of Science and Technology.

Seven scholars of the 1986 Class were also awarded their certificates at a ceremony during the December board meeting: Mr. M. Gethi (Kenya), Mr. E. B. Karamura (Uganda), Miss E. M. Minja (Tanzania), Mr. P. K. Muange (Kenya), Mr. Munene wa Macharia (Kenya), Mrs. M. F. Ndongo (Kenya) and Mr. M. A. Njau (Tanzania).

8.2 FINANCIAL AND ADMINISTRATIVE MANAGEMENT OF RESEARCH PROJECTS IN EASTERN AND SOUTHERN AFRICA (FAMESA)

Z. M. Nyiira

In 1989 FAMESA completed its fifth year. FAMESA is devoted to assisting national science and technology institutions in the region to improve their ability to plan, organise, manage and apply scientific research more effectively.

Activity increased substantially during the year in all four parts of the structure, namely, survey of institutional management development changes, curriculum development, delivery of national training courses and R&D management information services. Special emphasis was placed on national training activities to ensure the utilisation of the already developed curricula.

On behalf of the International Development Research Centre (IDRC) Office of Planning and Evaluation, FAMESA coordinated a research resource survey of national institutions in eastern and southern Africa. Before the survey, FAMESA organised a workshop in May 1989 in Nairobi to discuss approaches and standardise the collection of data. The guidelines developed at the workshop were adopted for collation of information from different sector institutions. The actual survey was conducted in Kenya, Malawi, Mozambique, Tanzania, Uganda and Zimbabwe. It covered growth trends in human and financial resources since 1974, local and international collaboration, demand for the use of research outputs and factors influencing the productivity of research institutes.

An up-to-date assessment of information management services in eastern and southern Africa began during the second part of the year. This formed part of the project sponsored by IDRC on the development of a FAMESA training manual on Information Systems Management for Managers of R&D Institutes. Ethiopia and Zambia were reviewed and a similar exercise was started in Kenya.

The development of curricula received an impetus by the allocation of funds to FAMESA by IDRC for the development of a curriculum on information systems management. Fieldwork was undertaken in Ethiopia, and a workshop was conducted in Zambia to collate information that would facilitate the development of a manual. Meanwhile, the *Manual on Project Planning, Monitoring and Evaluation* was finalised and plans were made to start delivering its contents at national training workshops.

During the year, FAMESA hosted a joint Regional Training Workshop on Project Analysis with the United Nations Economic Commission for Africa (UNECA). The workshop was the result of the collaborative linkage established between the two institutions in 1988 in order to improve the capacity of national institutions and individuals to identify and develop fundable projects.

Activity in national training workshops was also intensified during the year, and one was organised to define FAMESA's strategy for management development for the Ugandan agricultural research sector. It was attended by top decision-makers in the Ministry of Agriculture and experts serving under the United States Agency for International Development (USAID) programme in Uganda. The recommendations from the workshop will serve as a guide to areas of emphasis in research management for Ugandan agricultural research managers and scientists.

Zambia organised a National FAMESA Workshop on Information Systems Management and National Information Services. The objective was to examine information management issues and the elements of a pertinent training curriculum for managers and administrators in R&D institutes.

Later in the year, FAMESA organised a national workshop for Kenyan directors of research on the Institute-Constituency Relationship. This was intended to sensitise managers of R&D institutions to the importance of relations with research institutes, the consequences of neglecting institutional clients and the social accountability of research institutions.

Meetings were held with Malawi (Institute of Management), Uganda (National Research Council), Zambia (National Council for Scientific Research and the Office of National Exchange of Scientific Technology) and Zimbabwe (Institute of Management and Institute of Development Studies) to plan national R&D management training in 1990.

Information sharing and activities of the R&D Information and Documentation Service were once again limited to the publication of the *Research Management Review*. A full complement of four issues was published.

FAMESA's linkages were strengthened by adding the Association of Management Training Institutions of Eastern and Southern Africa (AMTIESA) and the Zimbabwe Institute of Management to its list of collaborators. The USAID Manpower for Development Programme expressed interest in implementing joint training for research workers in the FAMESA region on project formulation, implementation and report writing. FAMESA also explored the possibility of collaboration with the University of Arkansas/Winrock International in mounting joint research station management training in the FAMESA region.

The possibilities were discussed with the United Nations Development Programme of initiating a management

development programme for scientific professional staff in Kenya and of linking up with the Kenya Institute of Management and Kenya's Ministry of Research, Science and Technology to offer consolidated management training for scientific research personnel.

8.3 PESTNET COLLABORATIVE SCIENTIFIC RESEARCH

E. O. Omolo

The Pest Management Research and Development Network (PESTNET) has placed ICIPE Resident Scientists in Kenya, Somalia and Zambia, and will soon do so in Rwanda. They collaborated with national scientists in conducting surveys to determine the major economic pests and diseases of maize. On the basis of their results, work began in 1989 to define those components of integrated pest management (IPM) that could be developed as long-term pest management strategies. In addition, studies on banana pests were started in Rwanda.

8.3.1 Kenya

The efficacy and economics of recommended pesticides against stem-borers were compared with alternative control measures in two field studies conducted in Endebess (Trans Nzoia District), a major maize-growing area. The treatments in the first study were: (a) Dipterex pesticide granules applied in the leaf funnel at the knee height growth stage (recommended routine treatment for borer control); (b) Maize/bean intercrop (maize with beans interplanted between the maize rows, as verified for maize/cowpea intercrop at the ICIPE); and (c) Untreated maize monocrop as control.

There was no significant difference in the incidence of borer damage between intercropping and Dipterex treatment (Figure 8.1), but both were significantly reduced in comparison to the control. Grain yield data are being analysed and the economics of these measures for borer management are reported elsewhere.

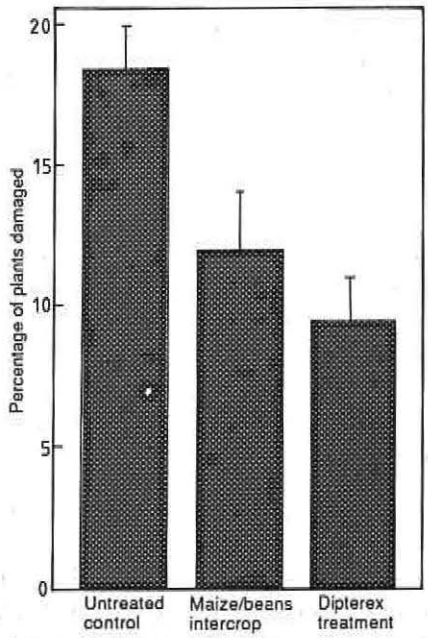


Figure 8.1 Mean percentages of plants damaged by *B. fusca* in a field trial at Endebess, Trans Nzoia District, under three treatment regimes; the bars represent standard errors.

The objective of the second study was to develop and test pheromone trapping technology for monitoring populations of *Busseola fusca* in the field, in order to establish threshold levels for borer control intervention. Vials of pheromone were received from the British Tropical Pest Research Institute.

The results indicated distinct seasonality in moth catches, with peaks occurring at early leaf whorl and tassel stages. This study will continue for some years to allow the development of a model which can be used to predict borer infestation levels and to develop control strategies.

8.3.2 Somalia

Survey of maize stem-borers. During a survey in 1989, the farmers cited drought and stem-borers (especially *Chilo partellus*) as the major factors limiting maize production during *deyr* (the long rains). Wide variation was found in the number of stem-borers on each of the 19 farms surveyed (mean 54.0 ± 8.4, range 6–127 total borers/stem). *Chilo partellus* contributed 96.8% (range 83–100%) of the total borer population on maize in the area. The causes and incidence of natural mortality in the stem-borers are shown in Table 8.2. The farmers did not use chemical insecticides to control pests. The results

Table 8.2 Occurrence of natural mortality factors on the larvae and pupa of *C. partellus* at Afgoye, Somalia, long rains 1988–1989

Life stage	Cause of mortality			
	Patho-gens	Para-sitoids	Nema-todes	Total
Larva I + II	1	0	0	1
Larva III	37	0	0	37
Larva IV	80	6	1	87
Larva V	85	26	0	111
Pupa	45	29	0	74
Total	248	61	1	310

from these surveys show that:

- *C. partellus* is the most important pest of maize, hence a detailed study is required with a view to developing sound IPM practices.
- There exists a rich fauna of natural enemies of stem-borers in Somalia which require identification and detailed investigation as potential components of IPM based on biological control.

Population dynamics of stem-borers on maize. Studies, especially on *C. partellus*, which started at the Central Agricultural Research Station, Afgoye, in 1988 during *deyr*, continued until February 1989. A ridged field was prepared and planted with Somtux maize composite in a 4 x 4 Latin square design. An earthen bund surrounded each plot (measuring 12.5 m x 12.5 m) to ensure water retention during irrigation. Treatments were applied as follows: (a) Basudin 10G at 10 kg/ha by pinch/plant leaf whorl; (b) Nitrogenous fertiliser (urea) at 100 g/plot at planting; (c) Basudin 10G + fertiliser (treatments 1 and 2 combined); and (d) No treatment.

Table 8.3 Mean maize yields under four different treatments in Afgoye, Somalia, long rains 1988–1989

Treatment	kg/100 plants	Ratio†
Basudin 10G	2.9[a]	0.8
N-fertiliser	3.4[ab]	0.9
Basudin 10G + N-fertiliser	4.4[b]	1.2
Untreated control	3.7[ab]	–

Yields followed by a different letter are significantly different ($P < 0.05$).
†Ratio of treatment to control.

All the treatments gave similar stem-borer mortality trends with the highest mortality occurring during the early stages (larva I–larva III) and between larva V and pupa, presumably due to pathogenic micro-organisms.

Grain yields (Table 8.3) of untreated controls were higher than for treatment with either Basudin 10G or fertiliser alone, but were lower than for combined treatment of Basudin 10G and fertiliser.

Several parasitoids were observed during this study. *Pediobius furvus* was successfully maintained on *C. partellus* pupae in the laboratory. Others included a chalcid pupal endoparasitoid and an *Apanteles* species. All require further collection and identification. In conclusion:

- The present recommendations for growing the maize variety Somtux require thorough evaluation to determine its cost efficacy, especially the effectiveness of Basudin 10G for the control of stem-borers and the reduction of yield losses.
- In view of the high populations of stem-borers in the *deyr* season it is vital to develop a suitable control method.

8.3.3 Tanzania

Dr. S. W. Waudo, postdoctoral research fellow and a trained nematologist/plant pathologist, has begun studies on the distribution of nematodes and their interaction with banana varieties. In collaboration with the ICIPE Crop Pests Research Programme, the distribution and incidence of the banana weevil complex is being monitored with Mr. A. A. S. Mbwana, Director of Maruku Agricultural Research Station, and Mr. B. E. Uronu. Both scientists are registered in the ARPPIS Ph.D. programme, and are doing their field research work at Maruku A.R.S.

8.3.4 Zambia

The following studies were conducted at Mt. Makulu Central Agricultural Research Station, Golden Valley and Mansa, which represent the three major agricultural ecosystems in the country.

Composition of Cicadulina *populations and incidence of maize streak virus and stem-borers.* Information is scanty on the incidence of MSV and its leafhopper (*Cicadulina*) vectors in Zambia. A detailed leafhopper survey was carried out in March–April 1989 with the assistance of a consultant, Dr. V. A. O. Okoth, seconded to the programme by the ICIPE for three weeks at the request of the Zambian Government.

The species composition of *Cicadulina* populations as identified from field-collected males was as follows: *C. mbila* and *C. triangula* were the most widely distributed species covering the whole country from north to south, whereas both *C. storeyi* and *C. similis* appeared to be confined to particular climatic regions, and *C. parazea* was found only in areas around Lusaka. Most of the insects were collected from grasses (*Elusine indica, Brachiaria* species and *Digitaria* species).

A laboratory colony of *C. storeyi* was successfully established at Mt. Makulu Research Station and was used to evaluate selected maize lines and hybrids for resistance to MSV.

Preliminary evaluation of selected maize varieties for resistance to MSV. Varieties 1566/1XL12, 1567/1XL12, 1641/3XL12, 1567/1XSC, 1717/1XSC and 1641/3XSC maintained low ratings of 1–2.5 under both natural and artificial inoculation and can be regarded as resistant. Commercial hybrids MM 603, MM 604, MM 612 and MM 752, although high-yielding under favourable climatic conditions (Table 8.4), had MSV ratings of more than 3 and are therefore regarded as susceptible.

Table 8.4 Mean maize streak virus (MSV) reaction scored in twelve maize varieties in Zambia during the 1988–1989 season on a scale of 1–5

MSV rating Variety	Natural infestation	Artificial infestation	MSV reaction†
1566/1XL12	2.0	2.5	R
1567/1XL12	1.8	2.0	R
1717/1XL12	2.3	3.2	MR
1641/3XL12	1.6	2.0	R
1566/1XSC	3.0	3.5	S
1567/1XSC	2.3	2.5	R
1717/1XSC	1.8	2.0	R
1641/3XSC	2.2	2.5	R
MM 603	3.2	4.0	S
MM 604	3.0	5.0	S
MM 612	4.0	4.5	S
MM 752	4.7	5.0	S
Mean	2.8	3.2	

†R = resistant; MR = moderately resistant; S = susceptible.

Effect of time of planting maize on stem-borer incidence and damage. In the three sites, attack on the early planted (December) crop was less than 12%. The incidence of infestation rose to 54% with delay in time of planting and the population of larvae per plant increased similarly. At Mt. Makulu and Golden Valley the proportions of the different stem-borer species were recorded and *C. partellus, Sesamia calamistis,* and *B. fusca* were found to occur. The early crop was predominantly attacked by *C. partellus* while the late crop was attacked mainly by *B. fusca* and *S. calamistis.*

Generally the borer population was very low during the first month after crop emergence and the few larvae recorded at this stage were mostly *C. partellus.* Two peaks of larval population were identified. The first occurred 65 days after crop emergence, and was chiefly *B. fusca* with some *C. partellus;* the population of *S. calamistis* was very low. The second peak occurred towards the end of crop growth (125 days after emergence) and was predominantly *B. fusca* and *S. calamistis;* the incidence of *C. partellus* in this peak was negligible. *Busseola fusca* was not seen until 50 days after germination.

8.4 PESTNET TRAINING PROGRAMME

E. O. Omolo

8.4.1 Long-term training

Miss M. Chumvwa of Zambia (ARPPIS, 1988 Class) is completing the second year of her Ph.D. and Mr. A. N. Duale of Somalia (ARPPIS, 1989 Class) has finished the course work and started his research programme. Both are based at Mbita Point Field Station working with CPRP.

Mr. L. Abreu from Guinea Bissau completed his M.Sc. project at MPFS for presentation at Oklahoma State University, USA.

Mr. J. Kayitare, Director of Plant Protection at the Institut des Sciences Agronomiques du Rwanda, Station de Rubona, was attached to CPRP from September–December and will be joining the ARPPIS 1990 Ph.D. class.

8.4.2 Short-term training

Insect Mass Rearing Technology Course. Two research officers (Mr. M. H. Mohamed and Mr. M. A. Yusuf) and a technician (Miss S. A. Nur) from Somalia's Bonka Dryland Agricultural Research Station and the Central Agricultural Research Station, Afgoye, completed this four-month practical course which included screening maize and sorghum lines for resistance to stem-borer attack. The course was extended to enable the candidates to familiarise themselves with the use of computers in data analysis.

Courses on computer use and application. At the request of national research staff in Somalia, a two-week course on the use of computers for scientific research was organised at Bonka Dryland A.R.S. The course was attended by eight research staff and 27 technicians drawn from this station and the Central A.R.S., Afgoye.

In collaboration with the African Biosciences Network (ABN), ICIPE organised a similar course in Nairobi from December 4–15 for PESTNET countries. The Computer Use in Pest Management Course was attended by National PESTNET Coordinators from Kenya, Rwanda and Ethiopia.

8.5 PESTNET INFORMATION GENERATION AND EXCHANGE

E. O. Omolo

8.5.1 National Workshop, Somalia

The first methodology workshop was held in Mogadishu from February 5–12, attended by 25 Somali nationals plus representatives from the United Nations Development Programme (UNDP), USAID, the German Agency for Technical Cooperation (GTZ), the Kenya Government and the World Bank. Pest management concepts, techniques and methodologies for the long-term integrated control of cereal stem-borers and grain legume-borers were discussed. The ICIPE supplied resource persons.

8.5.2 Eastern and Southern Africa Regional Information and Documentation Services Planning Workshop

This workshop was held in Lusaka, Zambia, from November 27–29 to enable potential partners in the network to draw up a working document for the Pest Management Documentation and Information Systems and Service (PMDISS).

This is a subject-oriented collaborative project that will develop an extensive collection of scientific information on insect pests of agriculture, livestock, forestry, stored products and allied fields. Under this programme, it is planned to develop a regional network of National Coordinating Centres (NCC) with the ICIPE as the focal point.

8.5.3 Newsletter and brochure

Pest management information is disseminated to member countries through *PESTNET Today* and PESTNET brochures. Both of these are undergoing major revision. The PESTNET brochure has been completed and is currently being distributed to participating countries, institutions and insect scientists in the tropics. *PESTNET Today* is waiting to go to press.

8.5.4 PESTNET Steering Committee

The Committee met on November 3 at Mbita Point Field Station and reviewed research and development progress by critically evaluating the programmes presented. It endorsed the establishment of the PMDISS as a major component of PESTNET. The members welcomed the expansion of the PESTNET programme to include the collaborative Pilot Project between the UNECA, ICIPE and the Kagera Basin Authority (KBA) on tsetse in which Burundi, Rwanda, Tanzania and Uganda are participating. The committee was also informed that the Livestock Ticks Research Programme is ready to start testing a series of vaccines against livestock ticks in Kenya in collaboration with PESTNET.

8.5.5 PESTNET Annual Conference

The Third Annual Conference was held on May 7 at ICIPE Headquarters, Nairobi, with the participation of national PESTNET coordinators and delegates representing member countries. Four delegates representing the Eastern, Southern, Western and Northern African regions tabled regional progress reports, whilst Programme Leaders of the four ICIPE Core Research Programmes briefly reviewed the stage of development of their respective long-term IPM strategies.

8.6 STAFF DEVELOPMENT SCHEME

J. F. Omange

The goal of the ICIPE Staff Development Scheme is to increase the capabilities of staff to enable them to perform their functions more effectively.

Members of staff are sponsored by the Centre to undertake training either locally or overseas. Thirteen people benefited from the scheme in 1989 (Table 8.5).

8.7 SHORT COURSES HELD AT THE ICIPE DURING 1989

J. F. Omange

8.7.1 Tick Management Course

The fifth course in the series, jointly sponsored by the European Economic Community and the ICIPE, on the Management of Vectors for the Control of Trypanosomiasis and East Coast fever in Livestock Production was held from January 23–February 17. It was confined to tick management. Nine participants, three each from Kenya, Sudan and Zambia attended the course.

The course consisted of lectures, laboratory practicals and field excursions and one lecture from each trainee. Field visits were made to the Kenya Agricultural Research Institute (KARI), the International Laboratory for Research on Animal Diseases (ILRAD), the Lolgorien study site of the Livestock Ticks Research Programme in the Trans-Mara, and Mbita Point Field Station and Rusinga Island.

The majority of lecturers were from the ICIPE, but there were also three each from ILRAD and KARI, institutions collaborating in the course.

8.7.2 *Regional Training Course on Insect-Related Data Management*

The first course run by the ICIPE and the Kagera River Basin Organisation was held from July 24–August 4 for eight participants (two each from Burundi, Rwanda, Tanzania and Uganda). The aim of the course was to

Table 8.5 ICIPE staff members who trained under the Staff Development Scheme in 1989 and the training they undertook

Name	Course	Place and Date
Scientific Staff		
Dr. J. P. R. Ochieng'-Odero	Ph.D. studies on the biology of *C. jactatana*	University of Auckland, New Zealand; completed in May
Dr. W. G. Z. O. Jura	Distribution of regulatory neuropeptides	Royal Postgraduate Medical School, University of London, UK; Jan. 30–Nov. 1
Dr. P. B. Capstick	Pest management	Imperial College, London, UK; Sep. 8–25
Mrs. R. M. W. Vundla	Arachidonic acid metabolism in *A. aegypti*	University of Nevada, Reno, USA; started Sep. 20
Mrs. M. A. Okech	Arachidonic acid biotechnology	University of Helsinki, Finland; started Nov. 1
Miss N. F. Darji	Gene transfer techniques	Institute of Molecular Biology and Genetics, Buenos Aires, Argentina; Nov. 20–Dec. 2
Administrative Staff		
Miss R. A. Washika	Design and production of audio visual aids	Portsmouth College of Art, Design and Further Education, UK; May 30–Sep. 15
Mr. J. A. Achilla	Hotel management	International Hotel and Tourism Training Institute, Basel, Switzerland; started Sep. 20
Technical Staff		
Mr. J. O. Konyino	Transmission electron microscope maintenance techniques	Philips, Eindhoven, The Netherlands; Oct. 16–Nov. 3
Mr. H. M. Mugalo	Industrial safety and fire fighting	City Council of Nairobi; June 5–30
Mr. J. O. Omogi	Industrial safety and fire fighting	City Council of Nairobi; June 5–30
Mr. J. O. Ohato	Motorcycle mechanics and vehicle maintenance	D.T. Dobie Ltd., Nairobi; Sep. 14–Oct. 28
Mrs. I. A. Wadundwe	Maternal child health/ family planning	Nyeri Provincial Hospital; Oct. 9–Nov. 24

provide the participants with skills that would enable them adequately to handle their data collected under the collaborative ICIPE Project.

A similar course was organised for PESTNET contact scientists. Both courses were organised in collaboration with the Biomathematics Research Unit which provided the instructors.

8.7.3 *Regional Training Course on Radioisotopes*

The second ICIPE/International Atomic Energy Agency Regional Training Course in the Use and Safe Handling of Radioisotopes in Insect Science was held from August 6–26. Nine scientists were trained from universities and research institutes in Chad, Kenya, Sierra Leone, Somalia, Sudan, Tanzania and Uganda. Lecturers were drawn from experts in molecular biology at the ICIPE and the Kenya Ministry of Health, while the IAEA provided two resource persons from the University of Bonn, West Germany.

In implementing ICIPE policy, certificates of participation signed by the Director and the Course Scientific Coordinator were awarded to the participants in each of these courses. Judging by the response received from the participants, there is a need for intensified and extended courses in the use of computers in research. The first data management course and the radioisotope course were organised by Ms. R. Runo, Training Assistant.

BIOMATHEMATICS RESEARCH UNIT

9

Biomathematics Research Unit

Elevation to the status of a research unit has led to rapid expansion of BMRU's broad goals to include the development of improved methods of quantitative analysis, mathematical and statistical modelling of pest population dynamics, and responsibilities for training in computer/statistical applications in pest management. The unit has been involved in the application of geographic information systems (GIS) and remote sensing techniques in the search for better insights into the population dynamics of pests and disease vectors.

Substantive collaborative studies with scientists in the core programmes have resulted in an improvement in the quality of experimental procedures and sample surveys, and of the statistical analysis of the resulting data.

The research activities of the unit have largely centred on the Tsetse and Livestock Ticks Research Programmes. The diffusion process and Euler-Lotka models have been effectively used in the analysis of Nguruman tsetse ecology data, while discrete stochastic functions have been established for parasitic-phase tick data. The research activities of the unit will be extended to the study of sandfly longevity and movement in the Medical Vectors Research Programme, and of predator-prey and host-parasitoid relationships in the Crop Pests Research Programme.

Training of ICIPE and ICIPE-supported staff in various statistical, mathematical and computer applications in pest control/management will continue to be a priority of the unit, performed under staff development training in close collaboration with IBIRU.

9.1 SYNOPSIS OF BMRU'S MAIN ACTIVITIES AND ACCOMPLISHMENTS

K. S. Nokoe

The broad goals of the Unit comprise statistical and computing services, and the mathematical modelling of pest movement patterns and their spatial distribution.

9.1.1 Service activities

During 1989 the Service Section was strengthened with the appointment of three additional staff with basic training in Statistics and Computer Science. This facilitated extensive study and use of the main statistical package, SAS, and the completion of a computerised personnel management system for the Human Resources Department. The ICIPE Personnel Management System has been developed on dBASE IV and is to be networked to three terminals. The system will be instrumental in management decision making as it will provide immediate information and reports on employees, reviews, staff dependants, advances, discipline, leave, staff training and transfers. This information will be secure as the authority to access or update files will be given to appropriate persons only. Staff recruitment should be improved by the immediate availability of accurate information on shortlisted applicants, interviews conducted and appointments made.

In-house training at Duduville and MPFS on the use of statistical and other software packages (Table 9.1) was rigorously pursued during the year; this has led to an increased demand for computers. The Unit's participation in the design of experiments is still minimal, though in the case of CPRP this is due to the general competence of staff in the discipline and the routine nature of most of the trials. However, BMRU has initiated plans to study variability in data arising from mini-plots, and the application of incomplete blocks to overcome the problem of insufficient land area for crop yield trials at the Mbita Point Field Station.

ICIPE's computing power was boosted this year by bringing the total number of computers to about 90. Two 386 system computers were also acquired for evaluation purposes. One of these runs at 20 Mhz with EVA resolution of 1024 by 768. Additionally, it has a 20" Ultra Sync monitor that makes

Table 9.1 Short courses organised by BMRU

Title	Date	Venue	Participants
MS-DOS	May 26–29	Duduville	PESTNET
MS-DOS	July 3	MPFS	ICIPE/ARPPIS
MS-DOS	July 17	Duduville	"
MS-DOS	August 6	Duduville	Kagera[1]
LOTUS 1-2-3	July 4–5	MPFS	ICIPE/ARPPIS
LOTUS 1-2-3	July 18–19	Duduville	ICIPE/ARPPIS
LOTUS 1-2-3	August 7–8	Duduville	Kagera[1]
LOTUS (SYMPHONY)	September 24–October 1	Somalia	PESTNET
MS-WORD	June 13–15	Duduville	ICIPE
MS-WORD	June 23–24	MPFS	ICIPE
DBASE III+	July 5–6	MPFS	ICIPE/ARPPIS
DBASE III+	July 20–21	Duduville	ICIPE/ARPPIS
GRAPHICS	June 27–29	Duduville	ICIPE
HARDWARE	August 9	Duduville	Kagera[1]
SAS	April 24–29	Nairobi	ICRAF
SAS	June 5–9	MPFS	ARPPIS/ICIPE
SAS	June 19–23	Duduville	ICIPE
SAS/STAT	May 17–27	Duduville	ARPPIS
SAS/STAT	July 24–August 5	Duduville	Kagera[1]
STAT/SPSS	September 24–October 8	Somalia	PESTNET
USE OF COMPUTERS	December 4–15	Duduville	PESTNET

[1]Collaborating staff from the joint Kagera Basin Organisation/ICIPE Tsetse Control Project.

possible geographic information system (GIS) observations at very close resolution. It is anticipated that this 386 system will take over the present 286 system for GIS. The other 386 system at 16 Mhz is being evaluated for running the data-base system developed for personnel administration. We are also in the final stages of implementing a local area network called D-LINK. The network has already been designed and will be commissioned in the new offices allocated to BMRU. The networking approach is being pursued to minimise the cost of software licensing and as an alternative to the acquisition of a mini-, or a main-frame, computer.

Computer maintenance and service have continued to be highly satisfactory, but with major problems in the maintenance of our laser printers. This we hope to rectify through further training of the computer engineer. The receipt of a few circuit diagrams for computer monitors has greatly eased the solution of monitor problems at the component level. Environmental monitoring activities during the year have mainly concentrated on the installation and calibration of three weather stations, at Nguruman and in Rwanda. The need to design or develop cheap and easy-to-use data capture devices (loggers) for these weather stations has been identified and will be pursued in coming years.

9.1.2 Research activities

Research continues to rely heavily on the GIS particularly for the tsetse movement and dynamics studies. The application of mathematical modelling and the GIS at Nguruman has been used to interpolate monthly average tsetse fly distributions for the entire project area.

Initial results from a diffusion model, at the one-dimensional level, suggest the sufficiency of 2 traps/km^2 for controlling *Glossina pallidipes*.

On livestock tick modelling, emphasis to date has been on the statistical analysis of the data. However, the ability of the Gompertz function to describe calf-growth data has been demonstrated sufficiently. On other data sets, such as those involving the free-living and parasitic phases of female *Rhipicephalus appendiculatus*, the exponential function as a discrete stochastic distribution function has shown some promise. These results are summarised below as part of the detailed reports.

For the future, BMRU will involve itself in the development of environmental monitoring and computer interface equipment; further expansion of modelling activities through additional incorporation of other functions; participation in the Medical Vectors and Crop Pests Research Programmes; and validation and improvement of models already developed.

9.2 A COMPUTER-SIMULATED MODEL FOR STRATEGIC CONTROL OF *R. APPENDICULATUS*

K. S. Nokoe, H. H. Meena and D. M. Munyinyi

This is a statistically mixed model, with some components of the system being stochastic and others deterministic. Where adequate information is unavailable, a uniform random generator is applied to simulate probability values between 0 and 1.

The simulated model for the African brown ear tick *Rhipicephalus appendiculatus*, written in BASIC, is essentially based on a simple life cycle with inputs of egg development and survival rates of the various instars in the non-parasitic phase. Other inputs include feeding success rates, animal resistance levels and pasture status. It is menu-driven, user-friendly and has facilities for incorporating the frequency, duration and efficiency of intervention or control strategies. This allows for the manipulation of the tick population in any relevant situation, such as increasing population, and the cost of control strategies can thereby be minimised.

Sample simulation outputs for three user-induced interventions are shown in Figures 9.1–9.4, based on the situation under study on Rusinga Island.

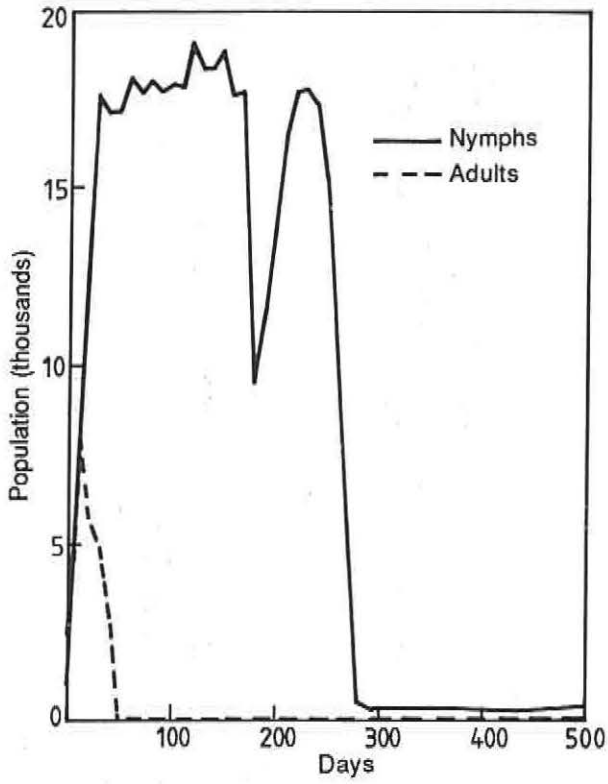


Figure 9.1 Changes in total parasitic-phase populations of *R. appendiculatus* on 15 cattle on Rusinga Island with intervention on day 180 (end of the crop harvesting period) and an intervention efficiency of 50% (larval data omitted).

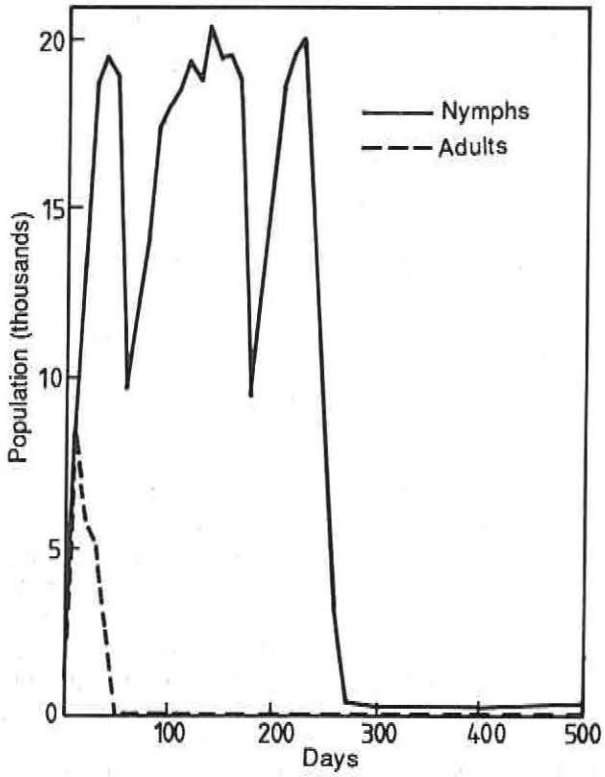


Figure 9.2 As in Figure 9.1, but with an additional intervention on day 60 (before planting of crops); both efficiencies at 50% (larval data omitted).

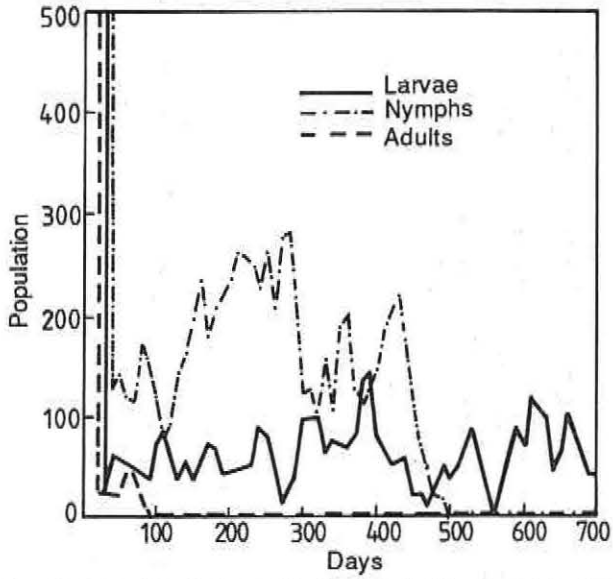


Figure 9.3 Simulations of the total *R. appendiculatus* population (parasitic phase) on 15 highly resistant cattle on a 90 m² area.

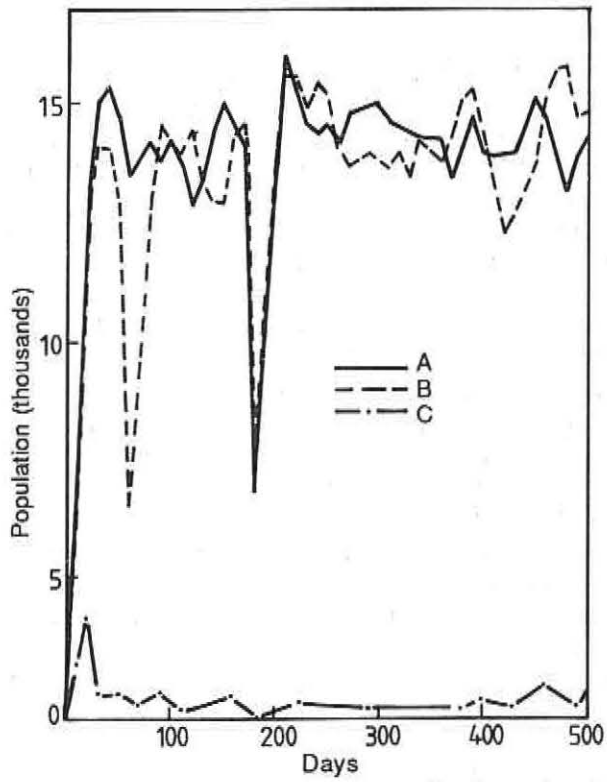


Figure 9.4 Changes in counts of parasitic-phase larval *R. appendiculatus* counts for the scenarios in Figures 9.1 (A), 9.2 (B) and 9.3 (C).

9.3 A CUMULATIVE GROWTH FUNCTION FOR CALVES ON RUSINGA ISLAND

H. Oranga and K. S. Nokoe

Data on calf growth, obtained on a monthly basis from ten farms on Rusinga Island, were studied with a view to fitting a growth function.

A slightly modified form of the Gompertz function, incorporating a parameter for determining the age at which the maximum increment is attained, provided the best fit to the data.

The modified Gompertz function may be expressed as:

$$W_t = K\,[\exp\,\{-\exp\,(-a\,(t-g))\}],$$

where W_t = cumulative growth up to time t, K = maximum growth potential, g = age at maximum growth rate, a = approximate average growth rate.

All the parameters were estimated by the non-linear least squares procedure using the modified Gauss-Newton method of iterative solution in the Statistical Analysis System (SAS).

The growth rate ranged from 0.02–0.20 for individual calves and 0.02–0.12 for farm comparisons. Maximum growth increment was attained at 34–70 weeks suggesting that most of the calves studied on Rusinga Island attained their highest growth rate while still *in utero*.

Studies are being made of the effects of tick infestation level, rate of tick pick-up and other factors, such as nutritional status of the available pasture, on the productivity of these calves. The ultimate aim is to obtain a composite function with the parameters of the Gompertz function expressed as functions of these productivity factors.

9.4 LIVEWEIGHT-DEPENDENT SURVIVORSHIP THRESHOLD MODELS FOR CALVES

H. Oranga and K. S. Nokoe

Observed liveweights of individual animals are a function of the genetic characteristics of the breed and the production system in which they are maintained. Threshold models provide not only an adequate representation of the breed's liveweight potential, but also an early warning system with regard to calves of below-average nutritional status and health, which may be at risk of dying. The upper boundary in practical terms is the maximum liveweight of the breed; more importantly, the lower boundary is the liveweight below which there is a high risk of death from starvation. Survivorship threshold models provide a simple, effective and cheap method of monitoring the productivity of a herd, and are, therefore, crucial tools in herd management. We are studying the application of such models to indigenous zebu (*Bos indicus*) calves in western Kenya.

Suppose we have a sample of size n with weights W_1, $W_2, W_3, \ldots, W_n$, arranged in ascending order of magnitude, then the best threshold model for the lower limit at age t is given by:

$$W_{1,t} = 17.81 \exp(0.0488t)$$

The probability function of $W_{1,t}$ is:

$$g\{W_{1,t}\} = n[1 - F\{W_{1,t}\}]^{n-1} f\{W_{1,t}\},$$

$$0 \leq W_{1,t} \leq \infty;$$

$$= 0, \text{ otherwise,}$$

where $F(W_{1,t})$ and $f(W_{1,t})$ are the cumulative distribution and probability density functions of $W_{1,t}$ respectively. Similarly, the best threshold model for the maximum liveweight at age t is:

$$W_{n,t} = 34.37 \exp(0.1117t - 0.0022t^2).$$

Finally, this model would be useful in evaluating the impact of the individual causal factors (tick and helminth burden and nutrition) on its parameter estimates. The realised deviations between the general model and each of the constrained models provide indications of the nature and extent of liveweight losses attributable to such factors individually or together.

9.5 A STOCHASTIC FUNCTION FOR THE PARASITIC-PHASE DATA OF FEMALE *R. APPENDICULATUS*

D. M. Munyinyi and K. S. Nokoe

Studies of on-host or parasitic phase population data for *Rhipicephalus appendiculatus* on Rusinga Island had shown negligible and insignificant correlations between monthly numbers and climatic factors. Moreover, attempts to identify suitable time lags to describe these on-host tick populations proved unsuccessful. Further study revealed, however, that management practices on the island are likely to play a more significant role than climate. This prompted the search for a discrete stochastic (distribution) function, capable of describing the female tick pick-up data. The function was of the form:

$$P(X=n) = A \exp(-kn) / \{1 + B \exp(-kn)\}$$

where k, A and B are constants to be estimated. The function gives the probability distribution of the female ticks on the host cattle. Very close agreement was obtained when predictions were compared with new data obtained independently.

It was further established that the above function approximates the geometric distribution, with the mass function:

$$P(X=n) = pq^n, \quad n = 0,1,2,3.....,$$

where $p = 0.026477$ and $q = 0.973520$.

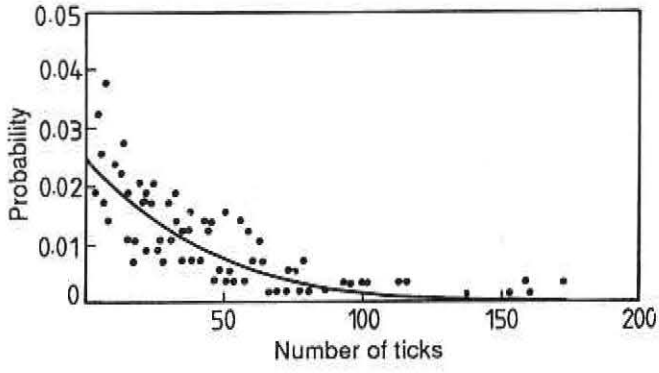


Figure 9.5 Plot of the geometric distribution function superimposed on actual population data for female *R. appendiculatus* from Rusinga Island.

Goodness of fit was confirmed by a chi-square test. Figure 9.5 shows the model compared to actual data. This function has been incorporated in the computer-simulated tick population model.

9.6 THE APPLICATION OF REMOTE SENSING DATA TO THE STUDY OF INSECT DISTRIBUTIONS

B. G. Williams, R. Brightwell, R. D. Dransfield and S. Siziya

About one-third of Africa is infested by tsetse flies. In order to control them we need to be able to determine their patterns of distribution and movement over very large and often inaccessible regions. The key factors that determine tsetse distribution are vegetation, temperature and humidity. Remote sensing provides a powerful means of acquiring information on these key factors and will undoubtedly play an important role in the planning and execution of future control and eradication campaigns. Satellite remote sensing has been used extensively in the distribution study of the vegetation, but relatively little work has been done to investigate its efficacy in obtaining information on the spatio-temporal distribution of insects.

Using a very extensive data set from Nguruman we have been able to model the temporal changes in *Glossina pallidipes* distribution using various climatic parameters as well as the Normalised Difference Vegetation Index (NDVI). The NDVI is obtained from satellite measurements of the reflectivity in the infra-red and red wavebands and gives a measure of the photosynthetically active vegetation on the ground. NDVI data have been recorded over the whole of Africa on a 7.6 km grid, every ten days since 1983.

Tsetse distributional patterns at Nguruman are best predicted when a lag of 20 days is incorporated into the NDVI data. It is known that the NDVI follows changes in water availability with a lag of about 20 days, so the flies and the vegetation are responding to the same changes in water availability. Work is in progress to elucidate further the relationship between tsetse movements and the vegetation as reflected by the NDVI. This will prove invaluable in planning future control and eradication campaigns.

9.7 MODELLING TSETSE FLY MOVEMENT FOR THE DESIGN OF CONTROL PROGRAMMES

B. G. Williams, R. Brightwell, R. D. Dransfield and S. Siziya

Understanding the movement patterns of tsetse flies is crucial for control programmes. Unless we understand how, when and why tsetse flies move we have little chance of effectively controlling their numbers and hence the trypanosome diseases they transmit. Although a considerable amount of work has been done to model the population dynamics of tsetse flies, much less attention has been paid to the modelling of fly movement. Our attempts to model fly movement are still in the early stages. We have begun by investigating the way in which fly movement influences the effectiveness of the traps that are being used both for monitoring and controlling the population. In order to make the problem tractable we have made a number of simplifying assumptions.

To define our traps we imagine that there is a circle of attraction surrounding each, and that within this circle the traps impose an additional mortality on the flies. Clearly, if we increase the radius of attraction or the trapping mortality, we shall increase the rate at which we reduce the population. To define our flies we assume that they move in a diffusive manner with a root-mean-square displacement per day, and that in the absence of traps the population converges to the carrying capacity of the environment at a fixed rate. Provided the habitat is relatively homogeneous we can have some confidence in using such a random walk model. If we increase the rate of diffusion we will reduce the population more rapidly, since the flies will also reach the traps more rapidly. If we increase the rate at which the population converges to the carrying capacity we will reduce the population less rapidly since the flies that are far from the traps will be able to maintain their numbers more easily.

Based on this simplified description of tsetse fly movement and the effect of traps, we have derived a number of analytical results relating the four parameters defined above and the density of traps to the rate of reduction of tsetse fly populations. These results provide the first consistent way of planning trapping and target operations in terms of parameters that can be measured in the field for both flies and traps.

We have also written a simulation model which allows us to predict the rate of reduction of fly populations for various specific field conditions. The agreement between our model predictions and field data has been very good.

We are now extending these models to include non-homogeneous habitats. Eventually, we should be able to use remote sensing data to generate maps of the vegetation, climate and elevation of the area, and then use our geographical information system to compare the predictions of the models with observed changes over both space and time in the field.

9.8 THE APPLICATION OF GIS AND REMOTE SENSING DATA TO THE STUDY OF TSETSE FLY POPULATIONS

R. L. Kruska,[1] B. G. Williams, O. O. Okello, J. A. O. Akiwumi,[2] R. D. Dransfield and R. Brightwell

Data on the distribution of tsetse flies, both in space and time, were collected using biconical and NGU traps covering the Nguruman study area, with the various traps being emptied at intervals ranging from 1–4 days. In order to manipulate this very extensive data set we have used two geographic information systems (GIS), pcARC/INFO and CRIES, a raster-based (or grid cell) system. Having both types of GIS at our disposal has greatly facilitated our work because each has its own strengths and weaknesses.

Many types of information were used to build the Nguruman GIS database. These included seven ordnance survey maps covering 5000 km^2, aerial photographs, satellite imagery and field data. Stereo pairs of aerial photographs were used to map and classify the vegetation patterns for the Nguruman study site.

The locations of all the traps were also plotted and digitized. The number, species, sex and capture date of the flies caught in each monitoring trap were entered into a database management system. A program gives users access to the data on trap locations and fly captures. The program automatically reformats the data and puts out the information selected by the user so that it can be read directly into the GIS for surfacing, and two- and three-dimensional contour maps can be produced. It is possible for a user with little or no GIS experience to access the data, run a surface and display the results.

We put average monthly trap catches for male and female *Glossina pallidipes* and *G. longipennis* from February 1987 to March 1988 into the GIS and the surfaces were calculated. From those for *G. pallidipes* males and females we have mapped out in detail the changes in their distribution at Nguruman and have studied their invasion into the area in November 1987. Producing surface contours in two dimensions from 20 sampling points is very difficult owing to mathematical instabilities, and we had to introduce a number of traps in areas where we believed that there really were no tsetse flies in order to increase the stability of the interpolation. This procedure will of course introduce a bias into the interpolated data and we decided to compare these results with those derived from the biconical trap data.

Biconical traps are strategically placed in different vegetation types to obtain a better idea of fly numbers in different environments. This made it possible for us to explore ways of using the vegetation to improve the calculation of the surfaces. The vegetation type surrounding each trap was used to weight the interpolations. The effect of vegetation was first taken out of the analysis for the resurfacing, and then put back in to reflect real differences in trap catches based on vegetation type.

The two independently produced sets of contour maps for each month of the year agreed well, showing that if one is able to take into account knowledge of the distribution of the vegetation which is available from remote sensing data, the interpolation of the distribution can be greatly improved. In particular, for those areas in which the two interpolation schemes differed significantly we were able to explain the differences. For example, at the foot of the escarpment in areas where we had forced zeros using the first interpolation scheme, the second interpolation scheme based on the vegetation indicated that at certain times of year there should be significant numbers of flies present. The interpolation based on vegetation therefore allows us to make predictions about areas in which trapping has not been done, and we can now set traps in those areas to see if the predictions are confirmed.

More information is needed on the biotic and abiotic factors influencing tsetse fly dynamics at Nguruman. We were to acquire SPOT imagery which, although expensive, will provide improved vegetation maps of the immediate study area at possibly half the cost of infrared aerial photography. Landsat Thematic Mapper imagery can be relied upon to provide even wider area coverage if necessary. Finally, for regional or country-wide studies, the satellite-derived Normalised Difference Vegetation Index (NDVI) can provide clues on changing vegetation patterns. Currently, only the rather coarse 7.6 km resolution data is available (Global Area Coverage); within the next 1–2 years, 1.1 km data should be obtainable (Local Area Coverage) on a real time basis. In addition, cold cloud cover from the satellite Meteosat is now becoming available and may offer useful information on the distribution and amount of rainfall. GIS will be an invaluable tool for integrating and manipulating data from these sources to produce useful results.

[1]GIS Specialist, until July 31 1989.
[2]Research Assistant, until June 23 1989.

9.9 TSETSE FLY POPULATION DYNAMICS AND THE ESTIMATION OF MORTALITY RATES FROM LIFE-TABLE DATA

B. G. Williams, R. Brightwell and R. D. Dransfield

The estimation of tsetse fly mortality rates from life-table data is central to studies of population dynamics and to the development of tsetse fly control programmes. For a population in a steady state with a stable age distribution, the age-specific mortalities may be estimated directly from the number of individuals in each age class. However, a correction must be applied when the population is not in a steady state. Such estimates will also be inaccurate if mortality rates are changing with time, since the population will take time to reach a new stable age distribution.

We have developed a population dynamics model in order to study the loss rate of a tsetse fly population as a function of pupal mortality, adult mortality and mortalities applied to each age class separately. This is based on an extension of the Euler-Lotka equation to continuous time, which relates the age-specific mortality and fecundity to the overall growth rate of the population.

Using the results from this model we are able to relate the age-specific mortality and fecundity to the overall population growth rate, and this provides a convenient starting point for the analysis of life-table data. In particular, we are able to estimate the rate of decline of flies in control programmes as a function of adult mortality, provided the pupal mortality is known or can be estimated. The dependence of the rate of decline on the mortality of flies in age class 1 can be used to estimate the overall rate of decline of a population subject to a sterile male release campaign, in which it appears that the number of sterile males should exceed 10% of the total population. The variation of loss rate with the ovarian age at which all of the flies are killed can be used to estimate the relative efficiency of traps or targets if the age bias of the traps is known or can be estimated.

We have also developed a simulation model in order to quantify, and to set limits on, the precision of mortality estimates when the mortalities are themselves changing. Simulations in which an additional mortality is applied to a fly population in a steady state show that it takes about 100 days before the population reaches a new stable age distribution. For this reason, mortality estimates taken from individual pairs of age categories may be in error by as much as 50% of the true value, but fortunately the maximum likelihood estimates determined from all age classes are

considerably more accurate, generally to within about 20% of the true value in the simulations presented here. It is important to note that after an abrupt change in the mortality, the relative numbers in each age class may vary considerably with time.

The population dynamics model that we have developed will eventually be incorporated into the models relating fly movement to the efficacy of control campaigns, and should provide us with a powerful predictive tool for use in the planning of such work.

9.10 NATURAL DISPERSAL OF FEMALE *G. PALLIDIPES* UNDER WET CONDITIONS IN NGURUMAN

S. Siziya, B. G. Williams and R. D. Dransfield

Glossina pallidipes is the major vector of trypanosomiasis at Nguruman in south-western Kenya. In order to control this pest, and hence the disease, knowledge of its dispersal is vital.

A mark-release-recapture study was carried out in April–May 1989. Up to ten NGU traps were used for three days to catch tsetse flies which were marked individually with artist's oil paint and then immediately released. Sixty-four NGU and biconical traps were used for 30 days to monitor how far the marked flies travelled. The recapture points were plotted on a map of the area, and the straight-line distances travelled by flies were measured.

During the monitoring period it rained on 17 out of 30 days, with maximum precipitation of 40 mm on day 6. Minimum and maximum daily temperatures ranged from 15.5–21.5°C. The analysis was limited to female flies because not enough males were recaptured. A scatter plot of mean square distance (for 34 recaptures out of 436 marked flies) against time suggested that female *G. pallidipes* moved at random, under the conditions prevailing within the monitoring period, with a mean displacement of 1.0 ± 0.1 km/day. There was no evidence from the data of directed movement, limit on the habitat or escape response. A concurrent simulation study on diffusion of tsetse flies has shown that for such active flies the efficiency of the trap is critical in ensuring effective control.

9.11 HOST-PARASITOID MODELS FOR *CHILO PARTELLUS* AND *TRICHOGRAMMA* SP.

A. J. Ngi-Song, K. S. Nokoe and M. Brownbridge

A laboratory experiment provided the data base for host-parasitoid models. Known quantities of *Trichogramma* sp. (near *mwanzai*) were released in three different sequences and the consequent levels of parasitisation of *C. partellus* eggs were determined.

The results indicated positive correlations between the parasitoid population density and the number of eggs and egg batches parasitised, but mutual interference between the parasitoids was observed at the highest density of 48 per cage. Generally, as host density increased, significant variations were noticed in the rate of parasitism.

A modified form of the generalised host-parasitoid model, with additional parameters describing climatic data (temperature and the relative humidity at the time when the parasitoids were released) fitted most of the data adequately. The incorporation of a quadratic term (log *Trichogramma* level) and the deletion of the climatic parameters (as they showed inconsistent effects) did not improve the fit, but allowed computation of the density for which parasitism was maximal.

Initial validation of models with field data has shown promising results, but further refinements are necessary, using a wider range of data sets for numbers of parasitoids and host egg batches.

SOCIAL SCIENCE INTERFACE RESEARCH UNIT

10

Social Science Interface Research Unit

Following its establishment the previous year, the Social Science Interface Research Unit (SSIRU) continued during 1989 to consolidate its work within the framework of the ICIPE's overall mandate. In May, a one-day workshop was held which reviewed and summarised the experience of social sciences/ biological sciences interface research for the support and achievement of the ICIPE mandate. The theme was: developing economically feasible and sustainable, socially acceptable and culturally relevant integrated pest management (IPM) strategies for the resource-poor farmer in Africa and the tropical world. A number of recommendations emerged from the workshop, and are being incorporated into the Unit's work. The workshop proceedings have been published.

During the year the staff of the Unit increased greatly. A fully multi-disciplinary team has now emerged consisting of anthropologists, sociologists, a social psychologist, an agricultural economist, an economist and a computer research assistant.

Several new series of SSIRU publications have also been initiated. These will include occasional papers, research reports, discussion papers and research papers.

10.1 IMPACT STUDY OF IPM: OYUGIS AND KENDU BAY

K. K. Prah

This study examined the attitudes of participating and non-participating farmers in Oyugis and Kendu Bay to the ICIPE IPM strategies. The projects in Oyugis and Kendu Bay represent the ICIPE's first extensive attempt to implement integrated strategies for crop pest management and control. The study aimed to assess the impact of IPM, not only on the project participants but on non-participating farmers from the same communities.

A simple random sample of a hundred non-participating farmers was taken, fifty each from Oyugis and Kendu Bay. The whole group of fifty participating farmers was included. Farmers most commonly cited line planting and intercropping as the most significant features of the ICIPE IPM package (Table 10.1). The most serious deficiency of the package was most often cited as bird feeding preference for the sorghum varieties employed (Table 10.2).

Participating farmers were very positive about the overall impact of the ICIPE IPM package. Especially popular components were those that related closely to agricultural practices and the deepening of indigenous

Table 10.1 Participating farmers' assessment of the most significant features of the ICIPE IPM package

Feature	Percentage
Line planting and intercropping	48
Timely adoption of agricultural operations	36
Use of resistant cultivars	8
Adoption of early maturing varieties	6
No response	2

Table 10.2 Participating farmers' assessment of the most serious deficiencies of the ICIPE IPM package

Deficiency	Percentage
Bird feeding preference for sorghum varieties	50
Seed colours of maize varieties	26
Greater labour requirement for intercropping and line planting	22
No response	2

knowledge. Seeds require further improvements with respect to yields. Non-participating farmers would like to join the scheme and some opportunities may need to be created for this. Interaction between participating and non-participating farmers would greatly enhance the diffusion of the IPM strategy at relatively little cost to the sponsors. The fundamental viability of the IPM strategy was proven by the results of the study.

10.2 PRELIMINARY SOCIAL STUDY, ICIPE BANANA PROJECT

K. K. Prah and O. Zethner

This study in Kisii District and Oyugis Division, South Nyanza District attempted to assess the prevalence and significance of banana pests. The study appraised farmers' views of banana cultivation in general, and their perceptions of the influence of pests (banana weevils and nematodes), in particular. Initial expert views suggested that agro-forestry approaches would be the best way to address the problem at this stage.

The survey focused on the following topics:

(a) Farmers' knowledge base of banana pests and their control.

(b) Perceptions of the value of intercropping and agro-forestry.

(c) Farmers' preferences in terms of tree species for agro-forestry.

(d) Initial insights into the labour implications of agro-forestry.

The study amply demonstrated that farmers have a substantial indigenous knowledge base which could be used as a foundation for the development and incorporation of IPM strategies. Clearly, farmers are well aware of the damage wreaked by weevils and nematodes. They possess skills and cultural practices relating to banana plant crops. Certain intercropping/agro-forestry combinations appear to be particularly favoured by farmers. They also demonstrate a good knowledge of trees for shade and fencing purposes. The marketability of bananas and their significance to the household economy is considerable. For this reason, farmers should have an interest in improving their crop through the adoption of IPM strategies.

10.3 THE ICIPE/KENYA GOVERNMENT/ECA PROJECT, OYUGIS AND KENDU BAY

M. M. Mwangi

The ICIPE Crop Pests Research Programme, in conjunction with the Kenya Government and the United Nations Economic Commission for Africa (ECA) have a project that aims at reducing food losses through a combination of integrated pest management (IPM) and the use of small-scale and low-cost farm equipment. In 1989 SSIRU collaborated with CPRP in monitoring the adoption and diffusion of these technologies among both participating and non-participating farmers.

The SSIRU study showed that farmers had learned and adopted various IPM control practices. For instance, they now remove infested plants, plough early, remove crop residue after harvest and intercrop (Table 10.3). They also plant insect-resistant cultivars. Table 10.3 shows the proportion of project farmers who practised various IPM techniques in 1989.

Table 10.3 Percentages of project farmers practising various IPM measures in 1989

IPM measures	Oyugis (n=25)	Kendu Bay (n=25)
Removal of infested plants	96	63
Ploughing	76	96
Simultaneous planting with neighbours	36	83
Removing/destroying crop residue	84	79
Crop rotation	36	29
Intercropping	96	92
Other methods	48	–

SSIRU also examined the constraints that farmers face. The prime constraint in local farming and the application of IPM appears to be labour input. Every IPM method seems to require more labour input than previously. The average farmer uses about Ksh 800.00 each season to complete his various farming operations.

Among project farmers, increased use of oxen has released labour that can be utilised for other productive activities. In both divisions, over 50% of non-participating farmers, but less than 20% of participating farmers, used a hoe (*jembe*) for land preparation. Those farmers not using hoes tended to plough with oxen in Oyugis and tractors in Kendu Bay.

SSIRU also monitored the use of equipment provided by the project. There has been good utilisation of an improved grain storage structure, jointly constructed by farmers and the project, which is efficient in drying grain and guarding against rats. Many farmers have already constructed similar structures of their own in Oyugis.

The project's maize sheller has been well utilised and is promising in terms of releasing constrained female labour. Not only is the sheller efficient and time saving, it is now used by many men, even though grain processing has traditionally been regarded as a female job in this and most other parts of the continent.

ICIPE's insect-resistant cultivars of sorghum (LRB 5 and LRB 8) and cowpea (ICV 2) continued to produce higher yields than local cultivars of the same crops. However, the resistant maize did not perform as well.

Farmer training continued in 1989. A joint workshop for all participating farmers was organised in Kendu Bay Division and was well attended. Participants included Ministry of Agriculture and administration personnel, as well as farmers and ICIPE staff. On-farm training for project farmers and their neighbours continued, with specific reference to IPM. The project staff also participated in a workshop on farmer training organised by

the US Agency for International Development (USAID) and the Ministry of Agriculture.

10.4 LIVESTOCK TICKS INTERFACE RESEARCH

J. W. Ssennyonga

10.4.1 Mariakani Project

Veterinary research at Mariakani is attempting to determine strategic dipping regimes that will produce good results with minimal application of acaricides. The SSIRU component seeks to establish the optimal socio-economic conditions for developing strategic dipping. Five socio-economic determinants have been identified and are being investigated:

(a) The importance of livestock in the economy and the type of animals reared.

(b) Farmers' knowledge and methods of controlling ticks and tick-borne diseases (TBDs).

(c) Management of dipping programmes.

(d) Cost of dipping programmes.

(e) Land use/pasture management.

Working with 32 extension staff among 433 farmers, we have established that livestock is ranked second in importance behind crops. Producers operate highly diversified economies to maximise subsistence, a strategy that precludes capital or resource intensive technology. Indigenous high-resistance breeds form 95–99% of herds and flocks, and farmers farm-out or farm-in animals in order to exploit ecological diversity and offset production constraints such as labour and land scarcity (Figure 10.1). This creates multiple interests in animal products; for example, some farm-in cattle to obtain milk while others farm-out animals to areas where there are fewer endemic diseases. Tick control measures are expected to reflect these patterns.

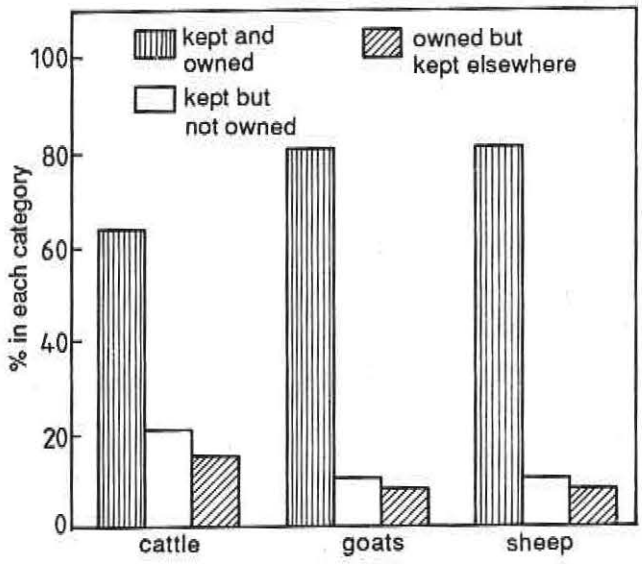


Figure 10.1 Proportions of livestock kept, owned and farmed out in Kilifi District.

Although TBDs are rated of highest importance, only a minority of farmers know that these diseases are transmitted by ticks. For example, 47% and 30%, respectively, know that East Coast fever and anaplasmosis are tick-transmitted; furthermore only 30% cite the transmission of diseases as one kind of damage caused by ticks.

Six different methods of controlling ticks are known but they are not applied regularly or effectively. Dipping levels are not only low, but are declining; for example although 26% of farmers are registered as dip users, only 19% say that they are currently dipping. The numbers of animals dipped show an even sharper decline (Figure 10.2). Low levels of dip use are due mainly to the farmers' ignorance of the role of ticks in disease transmission, the long distances to dips and the constant shut-downs, and the unacceptable cost-sharing measures introduced two years ago. Subsequent phases of the study will address these issues.

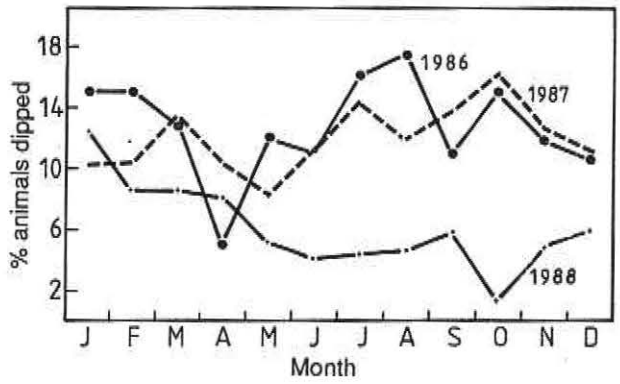


Figure 10.2 The proportion of cattle dipped over the year in Kilifi District, 1986–1988.

10.4.2 Rusinga Project

Current biological research in the project aims to determine the differential impact of malnutrition, external parasites (especially ticks) and worms on cattle productivity under indigenous animal husbandry. Complementary socio-economic work carried out in 112 homesteads reveals contrasts and similarities with the situation in Mariakani. For example, Rusinga farmers rank disease as by far the most important constraint, accounting for 46% of aggregated weighted scores. Management constraints come second (33%) with, surprisingly, malnutrition last (21%). Veterinary identification of diseases named in Dholuo is incomplete, but it is clear that although some farmers rank TBDs highly they do not associate them with ticks (Table 10.4). While 19% of farmers say that ticks transmit diseases, only 2% recognise that particular TBDs are associated with ticks. Most, however, are aware that ticks are harmful to their livestock.

Although ten different ways of controlling ticks and tick-caused damage are known, application is irregular and minimal. There are no dipping facilities nor do farmers

use hand-pump sprays; only 20% seek assistance from veterinary staff and an equal proportion uses preparations made from plants, 30 of which are being identified botanically. Most crucially, 74% do not control ticks or remedy the damage caused by them, because they believe it is futile and animals are best left to heal on their own.

Two important issues emerge from both the Mariakani and Rusinga studies. First, extension work and services have a long way to go to meet the needs of an effective tick control programme. Second, even if it were technically feasible to develop a single method that could eliminate ticks, under current socio-economic conditions it would not work. It may therefore be more effective to develop a tick control "cocktail", made up of several methods that are individually inadequate but, together, exert a vigorous synergy.

Table 10.4 Rusinga farmers' perceptions of the most important damage caused by ticks to domestic animals

Damage	Farmers citing damage	
	Number	Percentage
Loss of blood	63	25.9
Damaged skin	50	20.6
Transmission of diseases	45	18.5
Damaged teats/loss of milk	34	14.0
Farmer does not know	45	18.5
Others	6	2.5
Total	243	100.0

10.5 POPULAR PERCEPTIONS REGARDING TSETSE AND RELATED ISSUES IN LAMBWE VALLEY

A. W. Oendo, K. K. Prah and L. H. Otieno

A survey was carried out among a sample of 184 local farmers covering all the eight locations of Mbita Division. Its aims were two-fold:

(a) To establish the context of knowledge and attitude in which tsetse control activities were soon to be initiated.

(b) To explore the potential, and prepare the ground, for the anticipated community-based ownership, control and management of tsetse traps.

A structured questionnaire was administered with the assistance of a field technician and enumerators. The work will be completed in due course by follow-up informal interviews and participant observation. Supplementary information will also be sought through interviews with government officials and extension workers in the area.

The initial findings indicate that cattle ownership in the area is still high (Table 10.5).

Table 10.5 Ownership of cattle in the locations of Mbita Division

Location	No. of respondents	Percent owning cattle
Mfangano	37	94.6
Gembe	28	92.9
Gwasi North	21	95.2
Gwasi East	18	50.0
Gwasi Central	21	81.0
Rusinga	15	80.0
Lambwe	21	100.0
Kaksingri	21	71.4

In all the locations there was unanimity that tsetse are a major problem. However, with regard to cattle diseases, more farmers mentioned bloat than trypanosomiasis (Table 10.6).

Table 10.6 The number of farmers in Mbita Division mentioning various cattle diseases

Diseases	No. farmers
Bloat (*aremo/agobadi*)	130
Trypanosomiasis (*maugo*)	111
East Coast fever (*okuodo*)	47
Foot and mouth disease (*dachani*)	30

It has been suggested that cattle losses through trypanosomiasis lead to poor health and inadequate nutrition among the local population. The people seem to be equally aware, however, of sleeping sickness and its direct effects on their own health and that of their households. Of the 58% of the respondents who said they had suffered personally from the presence of tsetse, 15% had suffered cattle losses, 22% the sickness or death of a family member, 19% general economic hardship and loss, and 2% other effects.

Despite an initial general lack of understanding of ICIPE's strategies and intentions regarding tsetse control, the farmers now appear to be enthusiastic about the initiatives that are being taken. Of the farmers interviewed, 83% expressed willingness to take an active part in any control activities initiated by ICIPE. This is despite the fact that only 48% were aware of the presence and activities of ICIPE in the area and only 11% said they had benefited from them. In locations where the work of ICIPE scientists drastically reduced tsetse populations, the demonstrated effectiveness of the trap seems to have done more than anything else to promote its use among the local farmers.

10.6 LIVESTOCK REARING IN THE ECONOMY OF RURAL MUHAKA

A. W. Oendo

This is an ongoing study among farmers in Muhaka close to the coast in Kwale District. It is proceeding in three phases:

(a) Formal interviews with 120 farmers in the study area who own cattle

(b) Formal interviews with a sample of 80 farmers, who are not cattle owners

(c) Informal interviewing and participant observation of a selected number of farmers in both categories.

The main purpose of this study is to examine livestock rearing practices and gather general background information as a basis for future research. It is also intended to acquire baseline information on which strategic decisions regarding research and extension can be based. Data are being collected on the following areas of interest:

(a) Household economy

(b) Land use

(c) Cattle ownership and general care of livestock

(d) The social and economic uses of cattle

(e) Awareness of the tsetse situation and of insect pests in general

(f) General behaviour and strategies for coping with insect pest harassment.

The first phase of the study has been completed, and the results analysed. The second and third phases are planned for the month of March 1990. All the results will then be presented together.

10.7 MUHAKA TSETSE PROJECT

A. W. Oendo

In 1989 the tsetse research programme at Muhaka was still in its early stages. The social science component of this project is intended to complement and facilitate the research into tsetse ecology and trypanosomiasis epidemiology taking place in the area. Studies have been designed that also anticipate the extension phase of the project and attempt to collect and systematise information that will facilitate it.

The social science work currently under way revolves around the following:

(a) Studying the role of cattle rearing in the local economy, in the light of the traditional Digo aversion to cattle herding and their apparently symbiotic relations with the Duruma, who were designated with the herding role.

(b) Investigating the social and economic effects that the emergence of livestock rearing among the Digo has had on their relations with the Duruma.

(c) Understanding the relative importance of internal and external economic pressures, and contacts with the traditionally cattle-herding neighbouring peoples and immigrant communities, to the future of livestock rearing among the Digo.

(d) Evaluating the contribution of relevant agencies and government departments to the development of livestock rearing in the area.

(e) Exploring the internal factors which might have prompted or fostered livestock rearing, and the socio-structural and gender implications of its emergence.

(f) Establishing the social and economic costs of adopting the trapping technology, and the implications of meeting the minimal scientific requirements for effective tsetse control.

(g) Studying the socio-structural and organisational prerequisites and anticipated constraints to the implementation of the proposed extension phase of the project.

ADMINISTRATION AND INFORMATION DIVISION

11

Administration and Information Division

All the four departments making up the Administration and Information Division had another busy and rewarding year. The Human Resources Department had to clear a large backlog of vacancies for various categories of staff, while at the same time undertaking a special exercise to reduce the number of ancillary and temporary staff, and convert approved temporary positions into regular establishment with corresponding terms and conditions of service. These tasks were accomplished on schedule in addition to the normal workload, and the Department is to be congratulated on an outstanding all-round performance during the year.

There is a comprehensive report of the activities of the Communication Services Department which included organising and hosting several international study workshops in Nairobi and an open day at Mbita Point Field Station. The relocation of the ICIPE headquarters and the main research and development laboratories to Duduville has led to a marked increase in the number of visitors to the Centre, and has presented new challenges to this department.

The Publishing and Documentation Department continued with their efforts to strengthen the ICIPE Science Press as the Centre's main vehicle for information dissemination. Good news for the Department — and for the Centre as a whole — came in the form of a funding agreement signed with the Swiss Government for a purpose-designed library and documentation building. By the close of the year the tender for the construction of this new facility had been awarded to China Sichuan Corporation for International Techno-Economic Cooperation (SIETCO), which had just completed the Administration Block. It is expected that by mid-1991 the new Library will be fully operational.

The Administrative Services Department was involved in the reorganisation of both transport and security services, which have now become extra-departmental units within the Divison. The reorganisation will be completed during the first half of 1990, and will greatly enhance the efficiency and effectiveness of these two vital support services. Another major challenge for this Department was the change from an externally administered medical insurance scheme to an in-house scheme centred on St. Luke's Clinic in Nairobi and St. Jude's Clinic at Mbita Point Field Station, but with staff having access to a number of designated hospitals when necessary. The experiment has so far gone well and is likely to be preferred to an insurance scheme in the long term.

11.1 CAPITAL DEVELOPMENT

L. Okola

The completion of the Administration Block during the year brought Phase II of the Duduville Capital Development Programme to a successful conclusion, and it now moves into Phase III with the Library and Documentation Building.

The Executive Board at its annual October meeting in Washington DC approved some limited additional capital development work at Mbita Point Field Station, comprising a training hostel and 12 two-bedroomed apartments for staff. These will be completed by October 1990 and will go a long way towards easing the acute problem of staff accommodation at the Field Station.

The year also saw the official opening of Marigat Field Research Site by the ICIPE Director. This now gives the Medical Vectors Research Programme some basic, but well-designed, laboratory space and limited guest accommodation in Baringo, which is the Programme's main field research area. Similar developments are planned for Ungoye near Mbita Point Field Station, Kuja River (also in South Nyanza District), and at Muhaka in Coast Province, where the ICIPE has adequate land for a more ambitious capital development programme than is possible at any of the other field research sites.

11.2 COMMUNICATION SERVICES

R. A. Washika

11.2.1 19th Annual Research Conference

The 1989 Research Conference marked a significant departure from the traditional pattern for a number of reasons.

This year's conference, which saw a much wider representation than usual of both scientific and policy groups, was preceded by several important meetings designed to address specific issues in major areas crucial to the success of R & D work at the ICIPE. The first of these was the meeting on May 4, to present their final report, of the Task Force appointed to make recommendations on the future development of graduate training at the ICIPE. The second was the Workshop on the Interface between Social and Biological Sciences in Agricultural Research which took place on May 6 and was attended by more than 55 social scientists and natural scientists. The aim was to review progress by ICIPE in establishing the interface between research and the persons intended to benefit from it, and to use this experience to draw up an agenda for future work†.

On the evening of May 6 the ICIPE Alumni Association was inaugurated at a memorable ceremony attended by a host of ICIPE associates and friends. The Guest of Honour, the Hon. L. K. H. Goma, Minister for Higher Education in Zambia, and himself a distinguished ICIPE Alumnus, gave a most enlightening address which was followed by the presentation of certificates to Founder Members.

The 19th Annual Conference was officially opened on May 7 by the Hon. Elijah W. Mwangale, in one of his first assignments after installation as Kenya's Minister for Agriculture. The conference focused on the research of the Tsetse Programme, the Biological Control Subprogramme and the Chemistry and Biochemistry Research Unit. Other components of ICIPE research were displayed on posters during the period of the conference. The winning poster, presented by an ARPPIS Scholar with the Crop Pests Research Programme, Miss E. M. Minja, was entitled "Effect of Intercropping Sorghum and Cowpea on the Population Development of the Stem-borer Complex."

The highlight of each conference is the presentation of the Annual Awards for Innovative Research. This year was of particular interest because an award was made to a team of ICIPE scientists, technicians and field assistants from several programmes and units, as well as the Maasai community in Nguruman, Kajiado District, who all participated in the development of a simple but cost-effective trapping system for tsetse. In their acceptance speech the Maasai community, represented by a team of five, praised the ICIPE for choosing Nguruman for its work and pointed out that dramatic results had been achieved because of the team spirit and cooperation that existed among all those involved. Dr. W. Lwande was the other recipient of the 1989 Medal for Innovative Research for his studies on airborne volatile compounds of sorghum and cowpea.

The African Regional Pest Management Research and Development Network for Integrated Control of Crop and Livestock Pests (PESTNET) held its Steering Committee meeting on May 5 and later its Annual Conference. Presentations included progress reports on scientific work in Kenya, Somalia, Uganda, Zambia and Zimbabwe.

The now traditional Guest Lecture was delivered by Dr. Paolo Piccardi of Agrimont Gruppo Montedison, Milan, Italy, who spoke on "The Challenge of Plant Protection by the Year 2000".

†*Report published by ICIPE Science Press.*

11.2.2 Open Day at Mbita Point Field Station

ICIPE recognizes that information exchange between research scientists and the user communities is fundamental to providing a basis for continued and effective agricultural research in the tropics. Therefore, at regular intervals, ICIPE opens its doors to local farming communities, national research and extension workers, donors, and the general public, to ensure that its clientele is conversant with its activities, performance and achievements and to increase mutual awareness, exchange of ideas, and encouragement of collaboration.

At the Open Day on June 9, the ICIPE's major field station at Mbita Point was again the meeting point for farmers, research workers, donors and the media. The Hon. George K. Muhoho, Minister for Research, Science and Technology, was the Guest of Honour, with an

entourage of senior officers from his Ministry. Over 2000 visitors saw the laboratories, demonstrations and experimental plots at the Field Station. In his speech the Minister stressed the need for coordination of the national agricultural research effort to enable the small scale farmer, in particular, to achieve his production aims.

11.2.3 First International Symposium on the Cereal Stem-Borer, Chilo, *July 26–29, 1989*

ICIPE hosted this symposium at its headquarters at Duduville, Nairobi. The theme of the meeting was set by Prof. K. N. Saxena, Leader of the ICIPE Crop Pests Research Programme, who stated: "Species of *Chilo* are notorious pests of rice, maize, sorghum and sugarcane in the developing, as well as the developed world. Although research on *Chilo* has been going on for several years, the resultant knowledge is not readily available. Therefore, there is a pressing need for researchers to get together in order to integrate their findings and generate a uniform and concerted approach to solving the problems".

The symposium was attended by 59 participants representing over 25 countries; 56 papers were presented under the following themes:

- Status and control of *Chilo* spp. in different regions of the world
- Taxonomy, distribution, population ecology, dynamics and crop losses
- Physiology, behaviour and biochemistry
- Rearing and quality control
- Host plant resistance
- Breeding and resistance genetics
- Cultural, genetic and chemical control
- Biological control
- Pheromonal control
- Integrated pest management
- International cooperation.

The symposium was officially opened by Prof. Thomas R. Odhiambo, Director of the ICIPE, while Dr. K. M. Harris, of the Commonwealth Institute of Entomology, gave the keynote address. The proceedings of this symposium are being published as a special issue of *Insect Science and its Application.*

11.2.4 Second International Conference on Tropical Entomology, July 31–August 4, 1989

Following the very successful First International Conference on Tropical Entomology (ICTE), held in Nairobi in September 1986, the Second ICTE took place at Duduville, Nairobi, on the theme "Biological Control in the Tropics".

Over 130 scientists participated, representing scientific institutions from many countries in the developed and developing regions of the world. A total of 88 papers was presented in five symposia:

- Biological control of insect pests and vectors
- Microbial control of insect pests and vectors
- Recent advances in acridid physiology and their application
- Tick biology and control
- Post harvest insect pests and their management.

In the opening lecture Dr. David Greathead, of the Commonwealth Institute of Biological Control, reviewed the past history and future prospects for biological control of pests in the tropics, and emphasised the increasing momentum of integrated pest management (IPM) implementation in farming, especially in the rice-growing systems of Asia.

Dr. K. M. Harris, of the Commonwealth Institute of Entomology, spoke during the closing ceremony on the retrieval, validation and dissemination of information. He praised the ICIPE for establishing PESTNET to promote interactive research and development in tropical pest management. The proceedings of the conference are being published by the ICIPE Science Press as a special issue of *Insect Science and its Application.*

11.2.5 Workshop on Recent Advances in Research on Tsetse Population Dynamics and Behaviour in Relation to Control, August 6–11, 1989

At the close of the 2nd ICTE a good number of scientists stayed on to participate in another important international study workshop organised by the ICIPE.

The workshop brought together a diverse and distinguished group of over 30 active tsetse experts who reviewed recent advances in this field and in aspects of related application, determined priorities for future research, and explored possible types of collaborative projects between institutions.

The Hon. Maina Wanjigi, Kenya's Minister for Agriculture, officially opened the workshop: In his address, the Minister said that previous control methods (like bush clearance and spraying insecticides on tsetse habitats) had produced only short-term effects, were expensive and contributed to environmental pollution. He noted that ICIPE had made commendable strides in the development of simple but effective trapping technology which will be welcomed by all.

On the third day, participants visited the Nguruman site in Kajiado District, where ICIPE is conducting extensive trials of its odour-baited trap for suppression of tsetse fly populations.

The proceedings of this workshop are also being published as a special issue of *Insect Science and its Application.*

11.2.6 First ICIPE Mobile Seminar

ICIPE chose the Nordic countries for its first Mobile Seminar, held in Stockholm, Sweden, on September 21 1989. Mobile seminars are a new venture to enhance the exchange of information with collaborators, well-wishers and the scientific community at large. Through them, ICIPE aims to expand and strengthen its international recognition and support, and develop new partnerships in different parts of the world. Plans to hold a second seminar are already under way.

It was fitting that the first seminar should be for the Nordic countries, and that it should be hosted by the Swedish Agency for Research Cooperation with Developing Countries (SAREC) in Stockholm. Norway,

Sweden and Denmark were among the first countries in the developed North to recognise ICIPE's potential as a vehicle for science-driven development in Africa and the developing world in general. In its formative years, ICIPE became known to the international community largely through its association with the Nordic academies of science. In particular, the Royal Swedish Academy of Science served for many years as the secretariat for the ICIPE Foundation, and was thus a rallying point for international recognition and support.

The one-day seminar was well attended and focused on the theme "Overcoming Hunger Through Sustainable Community-Based Pest Management". Forty key representatives from national and international research institutes, universities and government agencies participated in the meeting which received presentations, posters and publications, displays and a demonstration of the ICIPE odour-baited trap for tsetse, which is presently on pilot trials in a number of countries in Africa. This successful seminar was well covered by the local media; new collaborative linkages were forged and strong donor support was developed. Advice, suggestions and recommendations emanating from these discussions with ICIPE's Nordic partners have been incorporated into the Centre's operational plans.

11.2.7 Visitors to the ICIPE

A selection is given below from the very wide range of visitors to whom ICIPE was host in 1989, representing the national and international scientific community, donors, diplomatic corps and government officials, as well as members of the Kenya farming community and a large number of university and high school students.

- Mr. Fakudin Ahmed, Chief of Agricultural Programme, World Bank Resident Mission, Kenya
- Dr. Alva App, Senior Research Adviser with Global Responsibilities, UNDP
- Mr. Adama Bar, Senior Economic Consultant, UNESCO, Paris
- Dr. G. Coleman, Alabama A & M University, USA
- Dr. R. W. Cummings, Chairman of the International Livestock Centre for Africa (ILCA) Board
- Dr. Tahir Diop, OAU/CSTR (Council for Scientific and Technological Research) Consultant
- Dr. John D. Edman, Chairman, Department of Entomology, University of Massachusetts, USA
- Prof. R. D. Eikenbary, Oklahoma State University, USA
- Prof. H. G. Gyllenberg, Institute of Biotechnology, University of Helsinki, Finland
- Prof. T. Habtemariam, Director, International Center for Tropical Animal Health and Biomedical Information Management Systems, Tuskegee University, Alabama, USA
- Dr. I. H. Haines and Mr. S. Turner, ODA, UK
- Dr. J. H. Hulse, Chairman of the Board, Commonwealth Institute of Biological Control
- Mr. Obaidull Khan and Mr. Harry Palmier, CGIAR Special Programme for African Agricultural Research (SPAAR)
- Ms. Tami Hultman, Africa News Service, Durham, North Carolina, USA
- Prof. Basil Ikede, Professor of Veterinary Pathology, National Coordinator, Trypanosomiasis Research, Nigeria
- Dr. A. M. Jordan, Director, Tsetse Research Laboratory, University of Bristol, UK
- Mr. Christopher Kahangi, Regional Representative, African Development Bank
- H.E. Mr. A. Kamer, Swiss Ambassador to Kenya
- Dr. Hyung-ki Kim, Adviser, Economic Development Institute, World Bank, Washington DC
- Prof. George B. Kirya, Vice-Chancellor, Makerere University, Uganda
- H.E. Mr. Christopher Laidlaw, New Zealand High Commissioner to Zimbabwe
- Dr. Liz Levey and Dr. J. Thomas Ratchford, American Association for the Advancement of Science
- Miss Veronica Li, World Bank, Washington DC
- Dr. David Luschinger, Animal Health Adviser, USAID
- Dr. M. Mahadevappa, Professor of Agricultural Botany, University of Agricultural Sciences, Bangalore, India
- Dr. A. L. Mbiele, Scientific Secretary Inter-African Phytosanitary Council, OAU
- H.E. Mr. Romeo Mendoza, Philippine Ambassador to Kenya
- Dr. R. B. Mitra, Director, Central Leather Research Institute, Madras, India
- Mr. Jan Mulder, EEC, Brussels
- Mr. Yasushi Murao, Director, Research Cooperation, Japanese Society for the Promotion of Science
- Mr. Daniel Nanjira, Kenya's Ambassador to Italy and to the Food and Agriculture Organisation (FAO), Rome
- Dr. Adriel Njogu, Director, Kenya Trypanosomiasis Research Institute (KETRI)
- Dr. Cyrus Nderitu, Director, Kenya Agricultural Research Institute (KARI)
- Mr. Babacar N'Diaye, President, African Development Bank
- Prof. Thomas Ogada, Kenya's Permanent Representative to the United Nations in Geneva
- Dr. S. R. Shree Rangaswamy, Director, School of Genetics, Tamil Nadu Agricultural University, India
- Dr. Wendell G. Rayburn, President, Lincoln University, Nebraska, USA
- Dr. Robert Rowe, Senior Programme Officer, IDRC, Nairobi
- Hon. Mrs. Marianne Samuelsson, Member of Swedish Parliament
- Mr. Kabonyi Sebasigari, International Network for the Improvement of Bananas and Plantains (INIBAP)
- Dr. Eugene Terry, Director, West African Rice Development Authority (WARDA)
- Dr. Moctar Toure, Executive Secretary of SPAAR, and Member of the ICIPE Governing Council.
- Ms. Marit Vedeld, NORAD
- Dr. John Walsh, Director General of ILCA.

11.3 ICIPE SCIENCE PRESS (ISP)

R. M. Newson, S. W. Mwanycky and W. A. Oyuko

11.3.1 Scientific Editorial Unit: 10th Anniversary, 1980–1989

Insect Science and its Application celebrated its 10th anniversary this year. The journal began publication in 1980 as a quarterly of barely 400 pages; since 1984 it has appeared bimonthly, and now contains over 800 pages per volume.

Since ISP took over publication in 1988, there have been changes in the methods of production and in the design. The Scientific Editor, after training in Israel in late 1988, took charge of the typesetting and preparation of "camera-ready" artwork for the journal. This year the journal has been set on a Macintosh computer in Nairobi, with camera-ready artwork prepared in-house by staff of the Graphics Unit, then printed in UK.

The ten years of *Insect Science and its Application* culminated in the production of Volume 10 Number 6 with 10th Anniversary review articles and a section on the proceedings of the ICIPE/World Bank Conference on Integrated Pest Management and the African Farmer, held in May 1989.

The Unit has continued to promote the journal by direct mailing of brochures.

11.3.2 Graphics Unit, and other editing

Once again, the other major production for the year was the ICIPE Annual Report. This, for the first time, was taken to the camera-ready stage with our own staff and equipment. We also edited and prepared a number of other reports and proceedings which appeared during the year, or will come out in 1990. In addition, the proceedings of two important workshops held at ICIPE were edited and typeset outside ISP itself, although published by us. There was also the usual stream of programmes of meetings, leaflets and brochures for use by ICIPE. We were able, for the first time, to print most of these in-house once our offset printing machine started work in February when the newly appointed Book Production Technician took up his duties.

The Graphic Arts Unit was strengthened by the appointment of two graphic artists, one to work at our main base at Chiromo and one attached to the Crop Pests Research Programme at Mbita Point Field Station. Apart from work on the design and production of publications, the Unit continued to create material for posters, slides and illustrations, as required, and in particular for the Annual Research Conference and for the ICIPE Mobile Seminar that visited Scandinavia in September.

The printing machine was fully occupied for the rest of the time printing most of ICIPE's own stationery requirements. Outside work was also undertaken. The Graphic Arts Unit was able to generate revenue by accepting some outside commissions.

The ISP continued to edit all manuscripts of ICIPE scientists destined for publication in the scientific literature, in whatever journal the author chose. Staff constraints again meant that this process was often delayed, and some assistance was obtained from two outside editors. This editing process was entirely separate from the work of the Scientific Editorial Unit which is responsible for the production of the journal and for books in the "Current Themes" series.

11.4 ICIPE LIBRARY AND DOCUMENTATION SERVICE

N. S. M. Nsubuga

The efforts so far made by the ICIPE to provide an effective library and documentation service to enhance its research and training activities were rewarded. The Swiss Government approved a grant not only for the construction of a 10-year capacity building with fittings and furniture, but also to cover the cost of reading materials and staff training for three years. Construction of the new library is scheduled to start in 1990.

Meanwhile, in September, the Library was again moved in order to give more laboratory space to the Centre's expanding research activity. It was relocated within the new administration complex where it will remain until the new building is ready.

11.4.1 Pest Management Documentation and Information System and Service (PMDISS)

Work continued towards the development of a regional documentation facility on insect pests and disease vector management. The most significant event in this regard was the PESTNET Eastern and Southern Africa Regional Information and Documentation Services Planning Workshop held in Lusaka, Zambia, November 27–29. This meeting not only approved the ICIPE initiatives but also furnished useful input. It is planned that PMDISS will develop into a regional network with ICIPE forming the focal point.

11.4.2 Acquisition of reading materials

In addition to the regular research and training needs, further demand for reading materials came from the new Locust Research Programme and PMDISS. Price inflation in the book trade, and currency exchange rate adjustments, continued to reduce the purchasing power of the Library's already limited book budget. However, books arrived to boost acquisition that had been purchased from a 1988 grant from the Direct Aid to Educational Establishments in Developing Countries (DSO) of the Netherlands.

Acquisitions amounted to 412 books and approximately 400 reprints. The figure for periodical subscriptions did not change from 120 but acquisition through donation and exchange increased to about 50, thanks to increased collaborative and cooperative activity as reported below.

11.4.3 Services

Current awareness continued to be the main output of the library and documentation services. The *Library and Documentation Bulletin* was issued quarterly

throughout the year, while the subscriptions to relevant published indexes and abstracts were maintained. Selective dissemination of information (SDI) continued against in-house scientific personnel profiles and the institutional profile was maintained with Commonwealth Agricultural Bureaux International. In addition, 25 retrospective computer searches were done against specific requests, and 1874 documents were supplied on request.

11.4.4 Cooperation and collaboration

With the instalment of PMDISS closer and more formal relationships were established, not only with the information systems of national programmes in the target region, but also with those of the African regional systems such as the Pan-African Development Information System (PADIS) and the Preferential Trade Area (PTA).

Further afield, in January, the Senior Librarian once again joined other information personnel in the Second Documentation and Information Services Meeting of the CGIAR held in Hyderabad at the ICRISAT Centre. The meeting opened new avenues of further collaboration at international level and also between international agricultural research centres and national agricultural research systems.

Through this kind of cooperation ICIPE's information and documentation resources have reached further and, in turn, the ICIPE has been able to complement the scope of its own resources. About 35% of the documents delivered to ICIPE readers came from interlibrary partners.

Other notable cooperative events included:

- The Library's hosting of two meetings of the Nairobi Information Group which comprises information specialists from Nairobi-based international organisations.
- The offering of two apprenticeships, each lasting about two months. One was to a student from the Faculty of Information Science at Moi University, and the other to a trainee from the Kenya Government.

1989 Seminars Hosted by ICIPE

SPEAKER	TITLE
Mr. P. G. N. Njagi, Sensory Physiology Research Unit, ICIPE	The Attractions of the Male Queensland Fruit Fly *Dacus tryoni*: Sensory Labellar Gustatory Neurones
Prof. K. K. Prah, Social Science Interface Research Unit, ICIPE	Science for Technological Development in Africa: Natural Scientists and the Notion of a Sociological Vacuum
Dr. Alan J. Teale, ILRAD, Nairobi	Trypanotolerance and Lymphocyte Antigen Polymorphism
Dr. Andrew Agnew, University College of Wales, Aberystwyth, UK	Mosaics and Ecotones in Plant Communities
Dr. Chris Curtis, London School of Hygiene and Tropical Medicine, UK	Appropriate Technology for Mosquito Control
Dr. Meier Broza and Dr. M. Brownbridge, Biological Control Sub-Programme, ICIPE	Recent Experiments in the Use of *Bacillus thuringiensis* for the Control of the African Armyworm, *Spodoptera exempta*, in Small Farms of South Nyanza, Kenya
Prof. Z. T. Dabrowski, Warsaw University of Agriculture, Poland	Training Components in the Research on *Cicadulina* Leafhoppers as the Vectors of Maize Streak Virus in Africa
Dr. Lucy M. Mutharia, Department of Biochemistry, University of Nairobi	Studies on Surface Glycoproteins of Culture Procyclic Forms of Trypanosomes
Dr. Pritam Singh, Entomology Division, DSIR, New Zealand	Insect Rearing Management: What Is It and Why Practice It?
Dr. Richard A. Jafferson, FAO Consultant, Joint Division, FAO/IAEA, Vienna	New Approaches in Molecular Biology Using Gene Fusion

1989 Conferences Attended by ICIPE Staff

10th Annual Medical Scientific Conference of the Kenya Medical Research Institute (KEMRI) and the Kenya Trypanosomiasis Institute (KETRI). Nairobi, Kenya, February 6–10.
J. B. Kaddu

International Deutsche Landwirtschafts-Gesellschaft (DLG) Symposium on Integrated Pest Management in Tropical and Sub-Tropical Cropping Systems. Bad Duerkheim, West Germany, February 8–15.
K. N. Saxena

8th Annual Joint Scientific Conference. Arusha, Tanzania, February 22–24.
G. P. Kaaya

Research for Desert Locust Forecasting and Population Dynamics. FAO, Rome, Italy, March 14–16.
B. G. Williams

International Crop Protection Information Workshop (ICPIW). Wallingford, UK, April 9–14.
K. V. Seshu Reddy

20th Meeting of the International Scientific Council for Trypanosomiasis Research and Control (ISCTRC). Mombasa, Kenya, April 10–14.
M. F. B. Chaudhury, R. D. Dransfield, S. Mihok, L. H. Otieno, R. K. Saini

International Symposium: Towards Greater International Collaboration in Pest Management, with Special Reference to Biological Control. Imperial College, Ascot, UK, April 15.
K. V. Seshu Reddy

Pest Management and the African Farmer. ICIPE/World Bank Conference on Integrated Pest Management in Africa. ICIPE, Nairobi, Kenya, May 22–26.
A. M. Alghali, T. R. Odhiambo, G. W. Oloo, E. O. Omolo, K. K. Prah, W. W. Wapakala, O. Zethner

7th International Symposium on Insect-Plant Relationships. Budapest, Hungary, July 3–8.
S. M. Waladde

German-Israeli Agricultural Research Agreement (GIARA): The Role of Allelochemics of Maize Plants. Max-Planck Institute for Biochemistry, Munich, West Germany, July 10–11.
A. Hassanali

1st International Workshop on Chemosensory Function and Coding in Phytophagous Insects. Einsiedeln, Switzerland, July 10–13.
S. M. Waladde

8th International Congress of Protozoology. Tsukuba, Japan, July 10–17.
O. O. Dipeolu, J. B. Kaddu, A. A. Latif, M. J. Mutinga, L. H. Otieno

1st International Symposium on the Cereal Stem-Borer, *Chilo*. ICIPE, Nairobi, Kenya, July 25–29.
Meeting convened by K. V. Seshu Reddy with contributions from the ICIPE Director and 22 staff members

7th International Congress of Immunology. Berlin, West Germany, July 30–August 5.
A. O. Mongi

2nd International Conference on Tropical Entomology. ICIPE, Nairobi, Kenya, July 31–August 5.
Conference Secretary: M. F. B. Chaudhury. Contributions from the ICIPE Director and some 30 staff members

32nd International Union of Pure and Applied Chemistry (IUPAC) Congress. Stockholm, Sweden, August 1–7.
A. Hassanali

International Study Workshop on Tsetse Populations and Behaviour. ICIPE, Nairobi, Kenya, August 7–11.
Meeting convened by R. K. Saini with contributions from the ICIPE Director and 18 staff members

6th Annual International Society for Chemical Ecology (ISCE) Meeting. Gothenberg, Sweden, August 7–11.
A. Hassanali

4th Epidemiological Association African Regional Conference. Harare, Zimbabwe, August 7–12.
F. A. Amimo, C. M. Mutero

2nd Workshop on Networking for Tropical Diseases. Kadoma, Zimbabwe, August 13–21.
M. J. Mutinga

6th International Conference of the Society for the Advancement of Breeding Researches in Asia and Oceania (SABRAO). Tsukuba, Japan, August 21–25.
R. S. Pathak

5th International Theriological Congress. Rome, Italy, August 22–29.
S. Mihok

International Conference: Editing into the Nineties. Ottawa, Canada, September 10–14.
R. M. Newson

African Mathematical Union. Arusha, Tanzania, September 10–15.
K. S. Nokoe

Annual Conference of Brazilian Veterinary Association. Bage, Brazil, September 25–October 1.
A. O. J. Amoo

Semiochemicals and Pest Control: Prospects for New Applications. Wageningen, Netherlands, October 15–20.
G. P. Kaaya, W. Lwande

International Symposium on Molecular Insect Science. Tuscon, Arizona, USA, October 22–27.
G. P. Kaaya, E. O. Osir, M. Vundla

Conference on the Future of Technical Cooperation, Deutsche Stiftung für Entwicklung. Berlin, West Germany, October 24–28.
K. K. Prah

1st Scientific Meeting, African Statistical Association. Abuja, Nigeria, October 29–November 3.
K. S. Nokoe

Information Storage and Retrieval in Vector Biology and Control. WHO, Geneva, Switzerland, November 15–18.
B. G. Williams

Information Programme Seminar. University of Lagos, Nigeria, November 21–25.
H. H. Meena, W. N. K. Ssebunya

10th Anniversary Symposium, African Association of Insect Scientists: Insect Pests and Sustainable Food Production in Africa. Lusaka, Zambia, December 4–8.
Seventeen members of staff attended, of whom three were also office bearers

7th Tanzania Veterinary Association Scientific Conference. Arusha, Tanzania, December 5–7.
G. P. Kaaya

Centennial Meeting, Entomological Society of America. San Antonio, Texas, USA, December 10–14.
D. K. Punyua, R. K. Saini

International Workshop on Design Issues in Farmer-Managed Irrigation Systems. Chiang Mai, Thailand, December 12–15.
J. W. Ssenyonga

1989 Publications by ICIPE staff

Ampofo J. K. O. The expression of maize resistance to the spotted stem-borer *Chilo partellus* (Lepidoptera: Pyralidae) in relation to plant age and infestation. *Acta phytopathologica et entomologia Hungarica* 24, 17–24.

Ampofo J. K. O. and Saxena K. N. Screening methodologies for maize resistance to *Chilo partellus* (Lepidoptera : Pyralidae). In *Toward Insect Resistant Maize for the Third World: Proceedings of the International Symposium on Methodologies for Developing Host Plant Resistance to Maize Insects, CIMMYT, Mexico, 9–14 March 1987*, pp. 170–177. Centro Internacional de Mejoramiento de Maiz y Trigo, Mexico, DF.

Aniedu I., Mutinga M. J. and Mutero C. M. Age composition and survival rate of *Anopheles gambiae* Giles complex (Dipt., Culicidae) in Baringo District, Kenya. *Journal of Applied Entomology* 107, 387–394.

Ayele T. and Mutinga M. J. A new record of *Phlebotomus celiae* (Diptera: Phycodidae) in Ethiopia. *Insect Science and its Application* 10, 569–571.

Bada S. O., Nokoe S. and Okojie J. A. Population dynamics of selected tree species in a strict natural reserve in the moist tropical forest. *Discovery and Innovation* 1,(3) 71–76.

Basimike M., Mutinga M. J. and Mutero C. M. Vertical distribution of phlebotomine sandflies in two habitats in Marigat leishmaniases endemic focus, Baringo District, Kenya. *Insect Science and its Application* 10, 645–650.

Chiera J. W., Newson R. M. and Karuhize G. R. Adaptation of field strains of *Rhipicephalus appendiculatus* Neumann (Acarina: Ixodidae) to host resistance. *Parasitology* 99, 149–155.

de Castro J. J. and Newson R. M. Resistance in cattle against *Rhipicephalus appendiculatus* with an assessment of cross-resistance to *Rhipicephalus pulchellus* (Acari: Ixodidae). *Experimental and Applied Acarology* 6, 237–244.

Dipeolu O. O. Evidence of heredity in oviposition capability of ticks. *Insect Science and its Application* 10, 591–599.

Dipeolu O. O. Research on ticks of livestock in Africa: Review of the trends, advances and milestones in tick biology and ecology in the decade 1980–1989. *Insect Science and its Application* 10, 723–740.

Dipeolu O. O. and Mutinga M. J. Recent advances in malaria research in lizards in Africa. *Discovery and Innovation* 1(1), 34–43.

Dipeolu O. O. and Mutinga M. J. Saurian malaria in Kenya: Description of ten new species from West Pokot District. *Insect Science and its Application* 10, 413–436.

Dipeolu O. O. and Mutinga M. J. Saurian malaria in Kenya: Redescription of some *Plasmodium* species of lizards in Africa and a key for the identification of all reported species. *Insect Science and its Application* 10, 531–544.

Dransfield R. D. and Brightwell R. Problems of field testing theoretical models: a case study. *Annals de la Société Belge de Médecine Tropicale* 69, (suppl.1), 147–154.

Dransfield R. D., Brightwell R., Kiilu J., Chaudhury M. F. B. and Adabie D. A. Size and mortality rates of *Glossina pallidipes* in the semi-arid zone of southwestern Kenya. *Medical and Veterinary Entomology* 3, 83–95.

Gooding R. H., Rolseth B. M. and Tarimo Nesbitt S. A. Mapping four loci in *Glossina morsitans submorsitans* Newstead (Diptera:Glossinidae). *Canadian Entomologist* 121, 823–824.

Hassanali A. and Lwande W. Antipest secondary metabolites from African plants. In *Insecticides of Plant Origin: Symposium on Insecticides of Plant Origin, 3rd Chemical Congress of North America, Toronto, Canada, 5–11 June 1988, American Chemical Society Symposium Series* No. 387, pp. 78–94. American Chemical Society, Washington DC.

Hassanali A., Nyandat E., Obenchain F. D., Otieno D. A. and Galun R. Humidity effects on response of *Argas persicus* (Oken) to guanine, an assembly pheromone of ticks. *Journal of Chemical Ecology* 15, 791–797.

Jura W. G. Z. O. and Kaaya G. P. Subcellular degeneration of mycetomal endocytobionts in tsetse, *Glossina morsitans morsitans*, inoculated twice with *Escherichia coli*. *Current Microbiology* 19, 347–352.

Kaaya G. P. *Glossina morsitans morsitans:* mortalities caused in adults by experimental infection with entomopathogenic fungi. *Acta Tropica* 46, 107–114.

Kaaya G. P. Assessment of antibiotic potentials of insect antibacterial factors. *Insect Science and its Application* 10, 341–346.

Kaaya G. P. A review of the progress made in recent years on research and understanding of immunity in insect vectors of human and animal diseases. *Insect Science and its Application* 10, 751–769.

Kaaya G. P. and Darji N. Mortality in adult tsetse, *Glossina morsitans morsitans*, caused by entomopathogenic bacteria. *Journal of Invertebrate Pathology* 54, 32–38.

Kaddu J. B. and Nyamori M. P. Nutrient broth for the cultivation of *Leishmania*. *Journal of Parasitology* 76, 265–266.

Kantiki L. M. and Ampofo J. K. O. Larval establishment and feeding behaviour of *Eldana saccharina* Walker (Lepidoptera: Pyralidae) on maize and sorghum plants. *Insect Science and its Application* 10, 577–582.

Khan Z. R., Rueda B. P. and Caballero P. Behavioral and physiological responses of rice leaffolder *Cnaphalocrocis medinalis* to selected wild rices. *Entomologia experimentalis et applicata* 52, 7–13.

Lwande W., McDowell P. G., Amiani H. and Amoke P. Analysis of airborne volatiles of cowpea (*Vigna unguiculata*). *Phytochemistry* 28, 421–424.

Maina J. N., Maloiy G. M. O., Warui C. N., Njogu E. K. and Kokwaro E. D. Scanning electron microscope study of the morphology of the reptilian lung: the savanna monitor lizard *Varanus exanthematicus* and the pancake tortoise *Malacochersus tornieri*. *Anatomical Record* 224, 514–522.

Mongi A. O., Capstick P. B., Otieno L. H., Odhiambo T. R., Newson R. M. and de Castro J. J. The presence of antibodies in naive cattle and rabbits to homogenate of fully-fed *Rhipicephalus appendiculatus* ticks. *Discovery and Innovation* 1(1), 80–84.

Murega T. N. Cross-breeding studies on the cassava green spider mite *Mononychellus* sp. (Acari: Tetranychidae) in East Africa. *Experimental and Applied Acarology* 6, 85–90.

Mutayoba B. M., Gombe S., Waindi E. N. and Kaaya G. P. Comparative trypanotolerance of the small East African breed of goats from different localities to *Trypanosoma congolense* infection. *Veterinary Parasitology* 31, 95–105.

Mutero C. M. and Birley M. H. The effect of pre-gravid development on the estimation of mosquito survival rates. *Journal of Applied Entomology* 107, 96–101.

Mutero C. M., Mutinga M. J. and Musyoki R. Isolation of leishmanial parasites from a wild caught *Anopheles gambiae* in Kenya. *International Journal for Parasitology* 19, 931–934.

Mutinga M. J. Social science interface and the Medical Vectors Research Programme. A challenge. In *The Social and Biological Sciences Interface Research Experience at ICIPE* (Edited by Prah K. K.), pp. 45–48. ICIPE Science Press, Nairobi.

Mutinga M. J. and Dipeolu O. O. Saurian malaria in Kenya: Description of new species of haemoproteid and haemogregarine parasites, anaplasma-like and pirhemocyton-like organisms in the blood of lizards in West Pokot District. *Insect Science and its Application* 10, 401–412.

Mutinga M. J., Kamau C. C., Kaddu J. B., Kyai F. M., Omogo D. M., Mwandandu J. and Ndambuki J. The biology and colonization of some Kenyan phlebotomine sandfly species (Diptera: Psychodidae). *Insect Science and its Application* 10, 677–683.

Mutinga M. J., Kamau C. C., Kyai F. M. and Omogo D. M. Epidemiology of leishmaniasis in Kenya. V. Wider search for breeding habitats of phlebotomine sandflies in three kala-azar endemic foci. *East African Medical Journal* 66, 173–182.

Mutinga M. J., Kihara S. M., Lohding A., Mutero C. M., Ngatia J. A. and Karanu F. Leishmaniasis of a domestic goat from Transmara, Narok District, Kenya. *Tropical Medicine and Parasitology* 40, 91–96.

Mwangi J. W., Muriuki G., Addae-Mensah I., Munavu R. M., Lwande W., Craveiro A. A. and Alencar J. W. Essential oil of *Lippia wilmsii* H. H. W. Pears. *Revista Latinoamericana de Quimica* 20, 143–144.

Mwangi R. W. and Awiti L. R. S. Hypertrehalosaemic activity in corpus cardiacum-corpus allatum-aorta complex and adipokinetic response of *Glossina morsitans*. *Physiological Entomology* 14, 61–66.

Newson R. M. and Chiera J. W. Development of resistance in calves to nymphs of *Rhipicephalus appendiculatus*

(Acarina: Ixodidae) during test feeds. *Experimental and Applied Acarology* 6, 19–27.

Newson R. M. and de Castro J. J. The use of irradiated *Rhipicephalus appendiculatus* ticks (Ixodoidea: Ixodidae) to induce resistance to infestation. In *Progress in Acarology: Proceedings of the 8th International Congress of Acarology, Bangalore, India, 3–6 August 1986* (Edited by ChannaBasavanna G. P. and Viraktamath C. A.), 2, 387–391. Oxford & IBH Publishing Co., New Delhi.

Njagi P. G. N. and Rice M. J. Responses of male Queensland fruitfly, *Dacus tryoni* (Froggat) to cue-lure: A structure activity electrophysiological study on a cue-lure sensitive gustatory neurone in the labellar sensilla. In *Application of Pheromones to Pest Control: Proceedings of a Joint CSIRO-DSIR Workshop, Canberra, Australia, 11–14 July 1988* (Edited by Bellas T.), pp. 32–36. Commonwealth Scientific and Industrial Research Organisation, Canberra.

Njau B. C. Resistance to *Rhipicephalus evertsi evertsi* in immunosuppressed rabbits. *Veterinary Research Communications* 13, 93–102.

Nokoe S. and Munyinyi D. Interface with Social Science Research Unit: Experience with analysis of Kendu Bay and Oyugis data. In *The Social and Biological Sciences Interface Research Experience at ICIPE* (Edited by Prah K. K.), pp. 63–68. ICIPE Science Press, Nairobi.

Nyeko J. H. P., Golder T. K. and Otieno L. H. *Trypanosoma congolense*. Drug resistance during cyclical transmission in tsetse flies and syringe passages in mice. *Experimental Parasitology* 69, 357–362.

Nyiira Z. M. Management of financial resources for scientific research. In *Science for Development in Africa* (Edited by Odhiambo T. R. and Isoun T. T.), pp. 143–152. ICIPE Science Press and Academy Science Publishers, Nairobi.

Nyindo M., Essuman S. and Dhadialla T. S. Immunization against ticks: use of salivary gland antigens and infestations with *Rhipicephalus appendiculatus* (Acari:Ixodidae) in rabbits. *Journal of Medical Entomology* 26, 430–434.

Odhiambo T. R. Perspectives on African agriculture and food policy. In *Completing the Food Chain: Strategies for Combating Hunger and Malnutrition: Papers and Proceedings of a Colloquium Organised by the Smithsonian Institution* (Edited by Hirschoff P. M. and Kotlev N. G.), pp. 54–62. Smithsonian Institution, Washington DC.

Odhiambo T. R. Visions for IPM in Africa. In *Pest Management and the African Farmer* (Edited by Zethner O.), pp. 137–141. ICIPE Science Press, Nairobi.

Odhiambo T. R. and Isoun T. T. (Editors) *Science for Development in Africa*. ICIPE Science Press and Academy Science Publishers, Nairobi.

Odindo M. O., Otieno W. A., Oloo G. W., Kilori J. and Odhiambo R. C. Prevalence of microorganisms in field-sampled borers on sorghum, maize, and cowpea in Western Kenya. *Insect Science and its Application* 10, 225–228.

Oendo A. and Otieno L. H. Some observations on social science interface in the Tsetse Programme. In *The Social and Biological Sciences Interface Research Experience at ICIPE* (Edited by Prah K. K.), pp. 50–54. ICIPE Science Press, Nairobi.

Okot-Kotber B. M., Mutinga M. J. and Kaddu J. B. Biochemical characterisation of *Leishmania* spp. isolated from man and wild animals in Kenya. *International Journal for Parasitology* 19, 657–663.

Okuda T. Aggressive characteristics of diapausing larvae of a stem borer *Busseola fusca* Fuller (Lepidoptera: Noctuidae) in artificially crowded conditions. *Applied Entomology and Zoology* 24, 238–239.

Oloo G. W. The role of local natural enemies in population dynamics of *Chilo partellus* (Swinh.) (Pyralidae) under subsistence farming systems in Kenya. *Insect Science and its Application* 10, 243–251.

Oloo G. W. ICIPE's philosophy and approach to developing appropriate IPM technology for the resource-poor farmer in Africa. In *Pest Management and the African Farmer* (Edited by Zethner O.), pp. 70–76. ICIPE Science Press, Nairobi.

Omolo E. O. Implications of biological and social science interface research in PESTNET (African Regional Pest Management Research and Development Network for the Integrated Control of Livestock Pests). In *The Social and Biological Sciences Interface Research Experience at ICIPE* (Edited by Prah K. K.), pp. 33–39. ICIPE Science Press, Nairobi.

Omoogun G. A., Dipeolu O. O. and Akinboade O. A. Distribution and seasonal variation of tsetse population in the Egbe area of Kwara State, Nigeria. *Insect Science and its Application* 10, 713–718.

Osir E. O., Labongo L. V. and Unnithan G. C. A high molecular weight diapause-associated protein from the stem-borer *Busseola fusca*: purification and properties. *Archives of Insect Biochemistry and Physiology* 11, 173–187.

Osir E. O. and Law J. H. Purification and characterization of vitellin from the palo verde beetle, *Derobracus geminatus*. *Insect Science and its Application* 10, 259–267.

Otieno L. H., Odindo M., Kaaya G. P. and Banda H. Virus particle infections in laboratory-reared *Glossina pallidipes* Austen (Diptera: Glossinidae). In *Nuclear Techniques in the Study and Control of Parasitic Diseases of Livestock*. Technical Report Series No. 293. IAEA, Vienna.

Owaga M. L. A. Efficiency of the biconical trap and biases in catches of females and tenerals of *Glossina pallidipes* Austen. *Insect Science and its Application* 10, 651–659.

Prah K. K. *Science for Technological Development in Africa: The Natural Scientist, and the Notion of a Sociological Vacuum*. Occasional Paper No. 1. Social Science Interface Research Unit, ICIPE, Nairobi, 11 p.

Prah K. K. (Editor) *The Social and Biological Sciences Interface Research Experience at ICIPE: Problems and Prospects*. ICIPE Science Press, Nairobi.

Prah K. K. Some conceptual issues related to the problems of social/natural science interface for technological development and transfer in ICIPE. In *The Social and Biological Sciences Interface Research Experience at ICIPE* (Edited by Prah K. K.), pp. 4–12. ICIPE Science Press, Nairobi.

Prah K. K. and Okeyo A. P. The role of social science in generating technologies for the farming community in Africa. *Insect Science and its Application* 10, 777–782.

Randolph S. E., Dransfield R. D. and Rogers D. J. Effect of host odours on trap catch composition of *Glossina pallidipes* in Kenya. *Medical and Veterinary Entomology* 3, 297–306.

Saini R. K., Hassanali A. and Dransfield R. D. Antennal responses of tsetse to analogues of the attractant 1-octen-3-ol. *Physiological Entomology* 14, 85–90.

Saxena K. N. Interaction between the Crop Pests Research Programme and the Social Science Interface Research Unit. In *The Social and Biological Sciences Interface Research Experience at ICIPE* (Edited by Prah K. K.), pp. 13–18. ICIPE Science Press, Nairobi.

Saxena K. N., Okeyo A. P., Seshu Reddy K. V., Omolo E. O. and Ngode L. Insect pest management and socio-economic circumstances of small-scale farmers for food crop production in Western Kenya: A case study. *Insect Science and its Application* 10, 443–462.

Saxena R. C. and Khan Z. R. Factors affecting resistance of rice varieties to planthopper and leafhopper pests. *Agricultural Zoology Reviews* 3, 97–132.

Seshu Reddy K. V. Sorghum stem borers in Eastern Africa. In *Proceedings of an International Workshop on Sorghum Stem Borers, 17–20 November 1987, ICRISAT Centre, India*, pp. 33–40. International Crops Research Institute for the Semi-Arid Tropics, Hyderabad.

Seshu Reddy K. V., Sum K. O. S. and Lubega M. C. Empirical models for predicting yield loss in sorghum caused by *Chilo partellus* (Swinhoe). *Discovery and Innovation* 1(1), 90–94.

Smalley M. E. Educational and training programmes for the interface of social science and insect science. In *The Social and Biological Sciences Interface Research Experience at ICIPE* (Edited by Prah K. K.), pp. 57–62. ICIPE Science Press, Nairobi.

Ssenyonga J. W. How to identify the diversification of rural production systems. *Rural Development in Practice* 1, 7–12.

Ssenyonga J. W. and Punyua D. K. Interface research in the Livestock Ticks Research Programme. In *The Social and Biological Sciences Interface Research Experience at ICIPE* (Edited by Prah K. K.), pp. 22–31. ICIPE Science Press, Nairobi.

Unnithan G. C. and Seshu Reddy K. V. Incidence, diapause and carry over of the cereal stem borers on Rusinga Island, Kenya. *Tropical Pest Management* 35, 414–419.

Waladde S. M., Hassanali A. and Ochieng' S. A. Taste sensilla responses to limonoids, natural insect antifeedants. *Insect Science and its Application* 10, 301–308.

Wapakala W. W. Extension systems and technology transfer: the case of IPM. In *Pest Management and the African Farmer* (Edited by Zethner O.), pp. 46–55. ICIPE Science Press, Nairobi.

Zethner O. (Editor) *Pest Management and the African Farmer. Proceedings of an ICIPE/World Bank Conference on Integrated Pest Management in Africa*. ICIPE Science Press, Nairobi.

ADDITIONAL 1988 PUBLICATIONS BY ICIPE STAFF

Dawson G. W., Griffiths D. C., Hassanali A., Pickett J. A., Plumb R. T., Pye B. J., Lesley E., Smart L. E. and Woodcock C. M. Antifeedants: a new concept for control of barley yellow dwarf virus in winter cereals. In *British Crop Protection Conference: Pests and Diseases. Proceedings of a Conference held in Brighton, UK, November 17–20, 1986*, pp. 1001–1008. BCPC Publications, Thornton Heath.

Firempong S. K., Ampofo J. K. O. and Saxena K. N. *Chilo partellus* oviposition, larval feeding and development on different maize cultivars in relation to their resistance levels. In *Towards Self Sufficiency: Proceedings of the 2nd Eastern, Central and Southern Africa Regional Maize Workshop, Harare, Zimbabwe,*

15–21 March 1987, pp. 213–222. CIMMYT, Mexico, DF.

Morzaria S. P., Musoke A. J. and Latif A. A. Recognition of *Theileria parva* antigens by field sera from Rusinga Island, Kenya. *Kenya Veterinarian* 12, 8.

Nokoe S. Modelling approaches to vectors. *Kenya Veterinarian* 12, 22–23.

Ssenyonga J. W. The application of socioeconomics to vector-borne disease research. *Kenya Veterinarian* 12, 28–31.

1989 Personnel*

**as at December 31 1989*

OFFICE OF THE DIRECTOR
Professor T. R. Odhiambo, *director*
Dr. P. B. Capstick, *deputy director*
Mr. V. S. Mutisya, *principal internal auditor*
Miss D. W. Mwangi, *internal auditor*
Mrs. G. M. A. Ochola, *personal assistant to the director*
Mrs. R. J. C. Kemei, *senior administrative secretary*
Mrs. M. A. Warrakah, *secretary*
Mrs. L. A. Were, *secretary*
Mr. D. A. Odhiambo, *clerical assistant*
Mr. J. K. Kibor, *senior technician/driver*
Mr. O. Ogallo, *driver*
Mr. S. O. Okiri, *driver*
Mr. J. O. Aroko, *driver*
Mr. S. N. Thairu, *driver*
Mr. J. L. Mwangai, *messenger/clerk*
Mr. H. O. Agonyo, *messenger/clerk*

Planning and Development Unit (PDU)
Mrs. R. A. Odingo, *chief planning officer*
Dr. W. A. Otieno, *senior research and development officer*
Miss M. H. Bugembe, *senior planning officer*
Ms. A. Midiwo-Odembo, *planning assistant*
Mr. J. R. Kapkirwok, *planning assistant*
Mrs. J. A. Sabaya, *senior secretary*
Mrs. K. C. Yaa, *secretary*
Miss B. A. Muganda, *secretary*
Mr. F. O. Ujiji, *driver*

CROP PESTS RESEARCH PROGRAMME
(based at Mbita Point Field Station)
Professor K. N. Saxena, *senior principal research scientist/ programme leader*

Bionomics and Applied Ecology (BAE)
Dr. K. V. Seshu Reddy, *senior research scientist/section head*
Dr. G. C. Unnithan, *senior research scientist*
Dr. A. M. Alghali, *senior research scientist*
Dr. L. M. Smith, *postdoctoral research fellow*
Mrs. N. E. M. Smit, *graduate research scholar*
Miss R. A. Nyang'or, *senior research assistant*
Mr. K. O. S. Sum, *senior research assistant*
Mr. C. J. Simbi, *principal technician*
Mr. M. C. Lubega, *senior technician*
Mr. P. O. Ollimo, *senior technician*
Mr. S. O. Paye, *technician*
Mr. R. C. Odhiambo, *technician*
Mr. E. L. Kidiavai, *technician*
Mr. G. O. Amala, *junior technician*
Mr. D. O. Nyagol, *technical assistant*
Mr. J. A. Onyango, *field assistant*
Mr. D. A. Atieno, *field assistant*
Mr. P. A. Oreng, *field assistant*
Mr. G. S. Odhiambo, *field assistant*
Mr. W. O. Owuor, *field assistant*
Mr. J. O. Ondijo, *field assistant*
Mr. I. O. Odhul, *field assistant*

Special ICIPE-BMZ† Project on Banana Weevils and Nematodes
Nairobi-based
Dr. O. Zethner, *scientist-in-residence/IPM specialist*

MPFS-based
Mr. P. R. Speijer, *graduate research scholar*
Mr. A. M. Koppenhofer, *graduate research scholar*
Mr. A. J. Odhiambo, *field assistant*
Mr. I. O. Mayoga, *field assistant*

Tanzania-based (Bukoba)
Dr. S. W. Waudo, *postdoctoral research fellow*

†*Bundesministerium für Wirtshaftliche Zusammenarbeit.*

ICIPE-ECA Project (Oyugis/Kendu Bay)
Dr. Brigitte T. Nyambo, *senior scientific officer*
Mr. L. Ngode, *national project officer*
Mr. C. Odhiambo, *technician*
Mr. P. K'odondi, *technician*
Mr. D. Ombuoro, *technician*
Mr. T. O. Oyoyo, *technician*
Mrs. M. Owitti, *technician*
Mr. R. M. Okech, *technician*
Mr. S. O. Ng'iela, *field assistant*
Mr. M. O. Owino, *field assistant*
Mr. J. M. Mwangangi, *driver*

Plant Resistance to Insect Pests (PRIP)
Professor K. N. Saxena, *senior principal research scientist/ section head*
Dr. R. S. Pathak, *senior research scientist*
Dr. H. Kumar, *research scientist*
Dr. A. E. M. Nour, *research associate*
Dr. P. G. Tokro, *research associate*
Mr. J. D. Onyango, *research assistant*

Mr. J. N. Ngoya, *research assistant*
Mr. J. C. Olela, *chief technician*
Mr. S. M. Othieno, *principal technician*
Mr. E. O. Nyangiri, *principal technician*
Mr. F. D. O. Odawa, *senior technician*
Mr. C. O. Oloo, *technician*
Mr. M. O. Arwa, *technical assistant*
Mr. J. O. Ngare, *field assistant*
Mr. J. A. Adero, *field assistant*
Mr. P. O. Okello, *field assistant*
Mr. P. A. Odongo, *field assistant*
Mr. P. O. Omolo, *field assistant*
Mr. J. O. Adero, *field assistant*
Mr. J. O. Ogoro, *field assistant*
Mr. S. O. Malachi, *field assistant*
Mr. G. A. Asino, *field assistant*
Mrs. H. A. Abade, *secretary*
Miss D. A. Apondi, *assistant secretary*
Mr. J. O. Otunge, *driver*
Mr. S. G. Ogechi, *driver*
Mr. W. Jayatileka, *driver*
Mr. M. O. Aguko, *driver*
Mr. R. Musa, *driver*

ICIPE-IRRI Research Project
Based in the Philippines
Dr. Z. R. Khan, *research scientist*
Dr. R. Ramachandran, *postdoctoral research fellow*
Ms. M. L. P. Abenes, *research assistant*
Mr. F. F. D. Villanueva, *research aide*
Mr. E. Panisales, *laboratory aide*
Mr. V. Langit, *field assistant*
Ms. C. M. Barba, *secretary*

Biological Control Sub-Programme (BCSP)
Nairobi-based
Dr. G. P. Kaaya, *senior research scientist/research leader*
Mrs. M. A. Oketch, *senior scientific officer (on training from November 1)*
Dr. Lucy M. Rogo, *senior scientific officer (on leave of absence)*
Mr. M. T. Lusele, *junior technician*
Miss E. A. Ouna, *junior technician*
Mr. J. A. Nyawach, *field assistant*
Mrs. P. N. Kaweru, *secretary*
Mr. A. Mwangi, *driver*

MPFS-based
Dr. M. O. Odindo, *senior research scientist*
Dr. N. K. Maniania, *research scientist*
Dr. J. M. Chacko, *scientist-in-residence*
Dr. M. Brownbridge, *postdoctoral research fellow*
Dr. E. F. Dwumfour, *postdoctoral research fellow*
Mr. C. Omondi, *scientific officer*
Mr. K. Ogedah, *senior research assistant*
Mr. Z. N. Otieno, *research assistant (on leave of absence)*
Mr. J. T. Kilori, *principal technician*
Mr. E. K. Ngugi, *senior technician*
Mr. R. O. Okello, *technician*
Mr. P. A. Amutalla, *technician*
Mr. P. O. Agwaro, *technician*
Mr. L. O. Were, *junior technician*
Mr. J. O. Ochieng', *technical assistant*
Mr. R. O. Oluoch, *field assistant*
Mr. P. B. O. Ogola, *field assistant*
Mr. M. O. Odoyo, *field assistant*
Mr. J. O. Awendo, *field assistant*
Mrs. T. A. Odero, *field assistant*
Mrs. J. A. Okelo, *field assistant*
Mr. M. Y. Oriwo, *field assistant*
Mr. T. M. Okello, *field assistant*
Mr. C. Oyugi, *field assistant*
Mr. J. A. Otieno, *field assistant*
Mr. F. O. Odondo, *field assistant*
Mrs. D. T. Ongondo, *field assistant/copy typist*
Mr. J. Mokaya, *driver*

ICIPE-DANIDA-University of Copenhagen Cassava Project (MPFS)
Mr. H. S. Pedersen, *research scholar*
Miss J. Tomkiewiz, *research scholar*
Mr. J. Wanga, *field assistant*
Miss J. A. Ongoma, *field assistant*
Mr. J. O. Obilo, *field assistant*
Miss M. A. Andere, *field assistant*
Mr. H. O. Abong'o, *field assistant*
Mr. K. O. Onyango, *driver*

Insect Mass Rearing Technology Unit (IMRT)
Nairobi-based
Dr. J. P.O. Odero, *scientific officer/acting unit head*
Mr. J. Wanyonje, *chief technician*
Mr. J. M. Kagoiya, *principal technician*
Mr. A. K. Ikhunyalo, *senior technician*
Mr. P. E. W. Njoroge, *senior technician*
Mr. G. M. Birir, *senior technician*
Mr. J. M. Ongudha, *technician*
Mr. E. O. Awuoche, *technician*
Mrs. R. G. G. Kariuki, *technician*
Miss M. G. Wanjiru, *junior technician*
Mr. S. M. Mbugua, *junior technician*
Mr. G. M. Ng'ang'a, *junior technician*
Mr. N. Mwikya, *field assistant*
Mr. A. Majanje, *field assistant*

MPFS-based
Mr. F. O. Onyango, *associate scientific officer*
Mr. H. K. Banda, *principal technician*
Mr. M. D. O. Bungu, *senior technician*
Mr. E. O. Amboga, *technician*
Mr. J. K. Gitegi, *junior technician*
Mr. P. A. Nyakwamba, *field assistant*
Mr. W. I. O. Odhiambo, *field assistant*
Mr. J. O. Maoro, *field assistant*
Mr. J. O. Opere, *field assistant*
Mr. S. O. Okoth, *field assistant*
Miss J. N. Kunyu, *field assistant*
Mr. J. O. Osuri, *field assistant*
Mr. W. O. Oganda, *field assistant*
Mr. P. O. Wagara, *field assistant*
Mr. A. Gadi, *field assistant*

LIVESTOCK TICKS RESEARCH PROGRAMME (LTRP)
Professor O. O. Dipeolu, *principal research scientist/programme leader*
Dr. M. A. Nyindo, *senior research scientist*
Dr. O. A. Mongi, *research scientist*
Dr. A. A. Latif, *research scientist*
Dr. S. Essuman, *research scientist*
Dr. E. I. P. Kamanga-Sollo, *postdoctoral research fellow*
Dr. Tania Yonow, *research associate*

Mr. D. K. Punyua, *senior scientific officer*
Mr. J. W. Chiera, *senior research assistant*
Mr. A. Chapya, *chief technician*
Mr. J. G. Kabii, *principal technician*
Mr. M. M. Malonza, *senior technician*
Miss R. Chesang, *senior technician*
Mr. S. S. ole Sipala, *senior technician*
Mr. J. G. Mugane, *technician*
Mr. J. N. Ndungu, *technician*
Mr. P. P. Muteria, *junior technician*
Mr. F. M. Thuo, *junior technician*
Mr. G. M. Hindi, *technical assistant*
Mr. M. G. Kimondo, *technical assistant*
Mr. N. J. Opere, *field assistant*
Mr. M. G. Kinyua, *field assistant*
Mr. C. O. Ashira, *field assistant*
Mr. G. K. O. Ochung, *field assistant*
Mr. M. J. Khadiakala, *field assistant*
Mr. P. S. Muchisu, *field assistant*
Mr. J. K. Njuguna, *field assistant*
Mr. R. Kairu, *field assistant*
Mr. J. N. Njuguna, *field assistant*
Mr. G. K. Kanyi, *field assistant*
Mr. B. P. Kavi, *field assistant*
Mrs. M. A. Kichamu, *secretary*
Mr. A. A. Enana, *driver*
Mr. G. M. Kinyanjui, *driver*

MPFS-based
Dr. D. K. G. Manyasi, *postdoctoral research fellow*
Dr. S. M. Hassan, *research associate*
Mr. P. O. Ngoko, *technician*
Mr. J. N. Odhiambo, *field assistant*
Mr. J. A. Arus, *field assistant*
Mr. J. O. Odida, *field assistant*
Mr. N. O. Dibogho, *field assistant*
Mr. J. O. Otila, *field assistant*
Mr. D. O. Odipo, *field assistant*
Mr. G. B. Were, *field assistant*

Mariakani-based
Dr. A. O. J. Amoo, *research scientist*
Miss L. N. Gichuru, *research associate*
Mr. R. Ojowa, *senior technician*

MEDICAL VECTORS RESEARCH PROGRAMME (MVRP)
Dr. M. J. Mutinga, *principal research scientist/programme leader*
Dr. J. B. Kaddu, *research scientist*
Dr. C. M. Mutero, *research scientist*
Dr. M. Basimike, *postdoctoral research fellow*
Dr. E. J. Asimeng, *postdoctoral research fellow*
Mr. C. C. Kamau, *associate scientific officer*
Mr. F. A. Amimo, *senior research assistant*
Mr. B. N. Odero, *chief technician*
Mr. M. P. Nyamori, *principal technician*
Mr. F. M. Kyai, *technician*
Mr. D. M. Omogo, *technician*
Miss E. M. Mwangi, *junior technician*
Mr. R. M. Musyoki, *technical assistant*
Mr. D. M. Mativo, *technical assistant*
Miss R. M. O. Omeno, *laboratory assistant*
Mr. J. M. Ndambuki, *laboratory assistant*
Miss S. M. Kagondu, *senior secretary*
Mr. R. M. Mogaka, *driver/mechanic*

Baringo/Marigat/West Pokot-based
Mr. S. M. Mutua, *technical assistant*
Mr. P. K. Munguti, *technical assistant*
Mr. B. M. Muia, *field assistant*
Mr. W. K. Kilonzo, *field assistant*
Mr. S. M. Singi, *field assistant*
Mr. P. B. Chepkoimet, *field assistant*
Mr. P. M. Munyuoki, *field assistant*
Mr. J. K. Kwiswili, *field assistant*
Mr. P. O. Manyuanda, *field assistant*
Mr. M. M. Miti, *field assistant*
Mr. D. K. Mbavu, *field assistant/driver*

Kitui/Machakos-based
Mr. P. K. Wandei, *field assistant*
Mr. R. K. Muoki, *field assistant*

TSETSE RESEARCH PROGRAMME (TRP)
Dr. L. H. Otieno, *principal research scientist/programme leader*
Dr. R. D. Dransfield, *senior research scientist*
Dr. S. Mihok, *senior research scientist*
Dr. Kazuyo Ichimori, *research associate*
Dr. M. M. M. Ahmed, *postdoctoral research fellow*
Mrs. M. L. A. Owaga, *senior scientific officer*
Miss N. F. Darji, *principal research assistant*
Mr. R. Brightwell, *senior research assistant*
Mr. P. A. Onyango, *chief technician*
Mr. E. N. Munyoki, *senior technician*
Mr. E. Mpanga, *senior technician*
Mr. D. P. Uvyu, *senior technician*
Mr. J. M. Wambugu, *senior technician*
Mr. C. O. Machika, *technician*
Mr. M. O. Kotengo, *technician*
Mr. P. M. Mwamisi, *technician*
Mr. J. K. Kiilu, *technician*
Mr. J. Likhanga, *technician/driver*
Mr. D. K. Mungai, *junior technician/driver*
Mr. Z. M. Muriuki, *junior technician/driver*
Mr. S. O. Maramba, *technical assistant*
Miss E. Afandi, *senior secretary*

MPFS-based
Mr. J. M. Muchiri, *junior technician*
Mr. S. E. Mokaya, *driver*

Nguruman-based
Mr. F. O. Oloo, *research associate*

Muhaka-based
Mr. C. A. Kyorku, *research associate*
Mr. J. Cheruiyot, *research associate*
Mr. J. Mwandandu, *technician/driver*

Ethiopia-based (Addis Ababa)
Mr. G. Tikubet, *scientific officer*

ICIPE-Kagera Basin Organisation Tsetse Control Project
Rwanda-based (Kigali)
Mr. C. S. Tarimo, *project coordinator*
Mr. S. S. Wakapc, *technician*
Mr. A. M. Macharia, *technician*

LOCUST RESEARCH PROGRAMME (LRP)
Dr. G. W. Oloo, *senior research scientist*
Mrs. J. K. Eyobo, *senior secretary*

INSTITUTIONAL BUILDING AND INTERACTIVE RESEARCH UNIT (IBIRU)
Dr. Y. A. O. Olaniran, *head, IBIRU*
Mr. J. F. Omange, *administrator, IBIRU*
Miss R. Runo, *training assistant*
Mrs. A. A. Okumali, *senior secretary*
Mrs. M. Antao, *senior secretary*

ARPPIS: African Regional Postgraduate Programme in Insect Science
Professor Z. T. Dabrowski, *training coordinator*
Mr. J. O. Davis-Cole, *Ph.D. scholar, 1987 class*
Mr. H. Mahamat, *Ph.D scholar, 1987 class*
Dr. S. K. Mbogo, *Ph.D. scholar, 1987 class*
Mr. T. N. Murega, *Ph.D. scholar, 1987 class*
Mr. M. I. Mwangelwa, *Ph.D. scholar, 1987 class*
Mrs. E. N. Mwangi, *Ph.D. scholar, 1987 class*
Mrs. V. C. Nyambati, *Ph.D. scholar, 1987 class*
Mr. J. Ogwang, *Ph.D. scholar, 1987 class*
Mr. H. Oranga, *Ph.D. scholar, 1987 class*
Miss M. Chumvwa, *Ph.D. scholar, 1988 class*
Mr. A. M. A. Malik, *Ph.D. scholar, 1988 class*
Mr. C. F. Mugoya, *Ph.D. scholar, 1988 class*
Mr. K. Mugwe, *Ph.D. scholar, 1988 class*
Mr. A. E. Onyido, *Ph.D. scholar, 1988 class*
Mrs. B. A. Rapuoda, *Ph.D. scholar, 1988 class*
Mr. M. K. Salah, *Ph.D. scholar, 1988 class*
Mr. S. Siziya, *Ph.D. scholar, 1988 class*
Mr. I. M. I. Abu Zinid, *Ph.D. scholar, 1988 class*
Mr. A. E. B. Ali, *Ph.D. scholar, 1989 class*
Mrs. D. D. S. Bawo, *Ph.D. scholar, 1989 class*
Miss R. B. Bob-Manuel, *Ph.D. scholar, 1989 class*
Mr. A.-N. H. Duale, *Ph.D. scholar, 1989 class*
Mr. H. K. Kiara, *Ph.D. scholar, 1989 class*
Mr. A. A. S. Mbwana, *Ph.D. scholar, 1989 class*
Mr. E. A. R. Ndhine, *Ph.D. scholar, 1989 class*
Mr. F. E. Nwilene, *Ph.D. scholar, 1989 class*
Miss E. O. A. Oladimeji, *Ph.D. scholar, 1989 class*
Mr. B. E. M. A. Uronu, *Ph.D. scholar, 1989 class*
Mr. S. I. Kamara, *M.Sc. scholar, 1987 class*
Mr. A. B. Kanu, *M.Sc. scholar, 1987 class*
Mr. J. C. Mbapila, *M.Sc. scholar, 1987 class*
Miss A. J. Ngi-Song, *M.Sc. scholar, 1987 class*
Mrs. M. Myendo, *secretary*
Mr. D. Isoso, *driver*
Mr. S. Rukungu, *driver*

FAMESA: Financial and Administrative Management of Research Projects in Eastern and Southern Africa
Dr. Z. M. Nyiira, *FAMESA coordinator*
Mrs. M. U. Arara, *senior secretary*

PESTNET: African Regional Pest Management Research and Development Network
Dr. E. O. Omolo, *senior research scientist/PESTNET coordinator*
Mr. J. A. Lago, *senior technician (data-input)*
Mrs. M. A. Odera, *secretary*
Mr. D. O. Muok, *driver*

MPFS-based
Dr. S. K. Firempong, *scientific officer*
Mr. S. A. Ondiek, *field assistant*
Mr. J. O. Obara, *field assistant*

Somalia-based (Mogadishu)
Dr. J. B. O. Owuor, *senior scientific officer*
Mr. K. K. Oyugi, *research assistant*

Zambia-based (Lusaka)
Dr. S. H. O. Okech, *senior scientific officer*

CHEMISTRY AND BIOCHEMISTRY RESEARCH UNIT (CBRU)
Professor A. Hassanali, *principal research scientist/unit head*
Dr. W. Lwande, *senior research scientist*
Dr. T. S. Dhadialla, *research scientist (on leave of absence)*
Dr. E. O. Osir, *research scientist*
Dr. I. O. Ndiege, *postdoctoral research fellow*
Mrs. R. M. W. Vundla, *senior scientific officer (on study leave)*
Mr. F. O. Oduol, *postgraduate research scholar*
Mr. I. O. Ogwayo, *associate scientific officer*
Mr. D. O. Nyarango, *associate scientific officer*
Mr. W. P. Ouma, *research assistant*
Mr. E. N. ole Sitayo, *principal technician*
Mr. E. Nyandat, *senior technician*
Mr. L. V. Labongo, *senior technician*
Mr. L. M. Moreka, *technician*
Mr. G. V. Achieng', *technician*
Mr. H. A. Chanzu, *technical assistant*
Miss M. W. Wafula, *senior administrative secretary*

CELL BIOLOGY RESEARCH UNIT (CRU)
Dr. N. N. Massamba, *senior research scientist/unit head*
Dr. Elizabeth D. Kokwaro, *research scientist*
Dr. W. G. Z. O. Jura, *research scientist*
Mr. M. M. B. Chimtawi, *chief technician*
Mr. P. Lisamulla, *chief technician*
Mrs. J. K. Murithi, *principal technician*
Mr. A. M. Ngei, *technician*
Mr. R. K. Rotich, *technical assistant*

SENSORY PHYSIOLOGY RESEARCH UNIT (SPRU)
Dr. M. F. B. Chaudhury, *senior research scientist/unit head*
Dr. S. M. Waladde, *research scientist*
Dr. R. K. Saini, *research scientist*
Mr. P. G. N. Njagi, *scientific officer*
Mr. H. M. Kahoro, *principal technician*
Mr. S. A. Ochieng', *senior technician*
Mr. J. A. Andoke, *senior technician*
Mr. P. O. Ahuya, *technician*
Mrs. S. M. A. Otieno, *secretary*

BIOMATHEMATICS RESEARCH UNIT (BMRU)
Dr. K. S. Nokoe, *senior research scientist/unit head*
Dr. B. G. Williams, *senior research scientist*
Mrs. W. N. K. Ssebunnya, *senior systems analyst*
Mr. S. O. E. Lota, *senior computer engineer*
Mr. D. M. Munyinyi, *senior computer applications specialist*
Mr. J. M. Otedo, *computer programmer*
Mr. H. H. Meena, *research assistant*
Mr. O. O. Okello, *principal technician*
Mr. M. N. Akello, *junior technician*
Miss B. A. Nanga, *senior secretary*

MPFS-based
Mr. J. O. Omwa, *technician*

SOCIAL SCIENCE INTERFACE RESEARCH UNIT (SSIRU)
Professor K. K. Prah, *principal research scientist/unit head*
Dr. A. W. Oendo, *postdoctoral research fellow*
Mr. K. C. Chitala, *research assistant*
Mrs. S. N. Govedi, *secretary*
Mr. A. Kathoka, *driver*

MPFS-based
Dr. J. W. Ssennyonga, *senior research scientist*
Mr. S. O. Ambogo, *field assistant*
Mr. R. O. Yogo, *field assistant*

Oyugis-based
Miss M. M. Mwangi, *scientific officer*
Mr. B. A. Omollo, *senior technician*

Mariakani-based
Mr. E. O. Kongere, *technical assistant/driver*

ADMINISTRATION AND INFORMATION DIVISION
Mr. L. Okola, *manager for administration and information*
Mrs. M. R. Opande, *office management supervisor*
Mrs. J. A. Ojuka, *secretary*
Mrs. G. N. Gathura, *secretary*

Human Resources Department
Dr. V. O. Musewe, *head, human resources*
Mr. S. M. Kimaita, *principal administrative officer*
Mrs. A. M. Mulei, *administrative assistant*
Mrs. G. A. Kwanya, *senior secretary*
Mrs. P. N. Owitti, *senior secretary*
Mr. J. M. Mwendar, *clerical assistant*
Mr. E. E. O. Opondo, *clerical assistant*

Administrative Services Department
Mr. M. M. Moinde, *principal administrative officer*
Miss G. M. Wachuru, *senior secretary*
Mrs. G. M. Weya, *telephonist/receptionist supervisor*
Mrs. M. Assetto, *receptionist/telephonist*
Mrs. M. B. Mohochi, *receptionist/telephonist*
Miss S. O. Onani, *receptionist/telephonist*
Mr. J. Elegwa, *assistant mail clerk*
Mr. L. Kisutia, *machine operator*

Transport Section
Mr. E. M. Kusimba, *transport controller*
Mr. S. G. Mwangi, *automobile foreman*
Mr. V. O. Odhiambo, *transport assistant*
Mrs. H. Githinji, *assistant secretary*
Mr. J. O. Madero, *data input clerk*
Mr. J. O. Oduol, *senior mechanic*
Mr. A. J. Ombija, *senior mechanic*
Mr. F. O. Hamala, *senior mechanic*
Mr. R. M. Kiboi, *driver/mechanic*
Mr. M. O. Ombech, *senior driver*
Mr. P. N. Mahogo, *senior driver*
Mr. P. O. Owuor, *driver*
Mr. P. Otiende, *driver*
Mr. E. N. Kiio, *driver*
Mr. P. T. Litaba, *driver*
Mr. J. M. Mutunga, *driver*
Mr. S. M. Mureithi, *driver*
Mr. S. O. Mdimba, *driver*
Mr. H. N. Njachi, *driver*

Security Section
Mr. M. P. Arrumm, *chief of security and protocol*
Mr. M. A. Ndede, *security officer*
Mr. J. O. Odero, *security guard supervisor*
Mr. T. S. Ekisa, *security guard*
Mr. A. M. Muhindi, *security guard*
Mr. F. M. Muindi, *security guard*
Mr. C. K. Mulela, *security guard*
Mr. J. D. Nyawalo, *security guard*
Mr. E. H. Otieno, *security guard*
Mr. A. M. Ouma, *security guard*
Mr. A. A. Ogaja, *security guard*
Mr. D. M. Mwilu, *security guard*
Mr. W. Mayienga, *security guard*
Mr. S. O. Odheru, *security guard*
Mr. J. A. Vudavira, *security guard*
Mr. N. O. Dimba, *security guard*
Mr. P. O. Apodo, *security guard*
Mr. J. O. Omogi, *security guard*
Mr. J. M. Musundi, *security guard*
Mr. M. A. Kamuga, *security guard*
Mr. D. O. Otiu, *security guard*
Mr. T. Munyalo, *security guard*
Mr. C. M. M'Reche, *security guard*
Mr. S. Abdala, *senior security guard (Muhaka)*
Mr. J. ole Kobaai, *security guard (Nguruman)*

Janitorial Section
Mr. S. A. Akhaya, *janitor*
Mr. L. L. Ayekha, *messenger*
Mr. E. Asami, *cleaner/messenger*
Mr. D. Chege, *cleaner/messenger*
Mr. E. N. Okulo, *cleaner/messenger*
Mr. N. O. Okumbe, *cleaner/messenger*
Mr. C. A. Ondago, *cleaner/messenger*
Mr. J. Isedia, *cleaner/messenger*
Mr. E. O. Ogol, *cleaner/messenger*
Mr. A. A. Muguna, *cleaner/messenger*
Mr. W. O. Adhiambo, *cleaner/messenger*
Mr. P. N. Muasa, *cleaner/messenger*
Miss E. J. Tirop, *cleaner/messenger*
Mr. T. O. Adongo, *cleaner/messenger*
Miss L. W. Mwaura, *cleaner/messenger*
Mr. B. M. Oketch, *cleaner/messenger*
Mr. W. Ambaka, *cleaner/messenger*
Mr. I. Asalu, *cleaner/messenger*
Mr. D. Munyao, *cleaner/messenger*
Mr. J. D. Okoth, *cleaner/messenger*
Miss C. R. Adero, *cleaner/messenger*
Mr. D. M. Muthama, *cleaner/messenger*
Mr. E. Ondeyo, *incinerator attendant*
Mr. G. S. K. Kariuki, *incinerator attendant*

Publishing and Documentation Department
Mr. L. Okola, *publisher/head of department*

ICIPE Science Press (ISP)
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Mrs. W. A. Oyuko, *production officer (graphics)*
Mr. N. M. Komeri, *senior scientific illustrator*
Miss I. A. Ogendo, *graphic artist*
Mr. E. W. Mwangi, *paste-up artist*
Mrs. D. O. Odhiambo, *proof reader*
Mr. G. K. N. Suka, *book production technician*

Mrs. J. J. Gombe, *senior secretary*
Miss D. Munene, *typesetter/secretary*
Mrs. Y. Obiero, *secretary*

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Miss D. W. Barasa, *documentalist*
Miss A. W. Muhato, *senior secretary*
Miss E. N. Kahuhu, *library assistant*
Mr. A. Shisoka, *clerical assistant*

Communication Department
Miss R. A. Washika, *principal communication officer*
Mrs. R. P. Ortega, *communication officer*
Mr. F. J. Utanje, *travel officer*
Miss C. A. Otieno, *secretary*

FINANCE DIVISION
Mr. E. J. English, *financial manager*
Mr. R. M. P. Okura, *chief accountant*
Mr. G. W. Kanza, *principal accountant*
Mr. R. Otieno, *senior accountant*
Mr. A. A. M. Oguda, *accountant*
Mr. M. Kawaka, *accountant*
Mrs. L. W. Kimani, *assistant accountant*
Mr. V. M. Kamanyi, *assistant accountant*
Mrs. R. A. Nyamunga, *assistant accountant*
Mrs. L. W. Muchene, *assistant accountant*
Mr. P. O. Ngugi, *assistant accountant*
Mr. L. J. Ondieki, *accounts assistant*
Mr. C. M. Oloo, *senior supplies officer*
Mr. D. O. Olalo, *storekeeper*
Miss F. Ojode, *senior administrative secretary*
Mrs. M. M. Butali, *secretary*
Mr. J. O. Madiwia, *clerical assistant*
Mr. J. B. Oyondi, *senior driver*
Mr. A. O. Kirimba, *driver*
Mr. A. Bubusi, *senior cleaner/messenger*

WORKSHOPS AND LABORATORY SERVICE UNIT—NAIROBI
Mr. J. A. Mando, *principal controller for technical services/unit head*
Mr. R. C. Joshi, *maintenance engineer*
Mr. J. O. Konyino, *electronics and instrumentation engineer*
Mr. D. Murali, *electronics and instrumentation engineer*
Mr. B. S. Masyanga, *farm controller*
Mr. H. N. Rai, *refrigeration technologist*
Mr. G. S. Kidunda, *electronics and instrument technologist*
Mr. P. O. Nyachieo, *principal technician*
Mr. J. M. Maina, *principal technician*
Mr. J. O. Onyango, *principal technician*
Mr. P. O. Auma, *maintenance foreman*
Mr. J. B. Omullo, *senior technician*
Mr. T. O. Ocholloh, *senior technician*
Mr. J. O. Ogalo, *senior technician*
Mr. P. A. Oluya, *technician*
Mr. K. Kibe, *technician*
Mr. J. O. Omondi, *junior technician*
Mr. T. O. Ochieng', *technical assistant*
Mr. M. O. Odada, *workshop assistant*
Mrs. P. W. Njama, *secretary*
Mr. C. N. Kageche, *driver/technical assistant*

MBITA POINT FIELD STATION (MPFS)
Office of the Station Manager
Mr. W. W. Wapakala, *station manager*
Mr. J. E. Okiri, *principal administrative officer*
Mrs. R. A. Okoth, *senior secretary*
Miss F. B. Esalako, *secretary*
Mr. R. R. Nyaridi, *clerical assistant*
Mr. G. K. Khisa, *telephonist/receptionist*
Miss M. A. Okoth, *telephonist/receptionist*

Accounts and Supplies Section
Mr. F. K. Ongola, *accountant*
Mr. M. N. E. Asudi, *assistant accountant*
Mr. B. T. Kanyara, *accounts assistant*
Mr. J. O. Gombe, *assistant supplies officer*
Mr. E. O. Jasor, *stores clerk*

Library
Miss M. W. Mathai, *librarian*
Mr. E. A. Sonye, *clerical assistant*

Transport Section
Mr. C. O. Ojoo, *transport assistant*
Mr. J. N. Asanyo, *assistant automobile foreman*
Mr. J. H. Ohato, *senior driver/mechanic*
Mr. J. A. Kisero, *assistant boat master*
Mr. P. O. Mbuya, *senior driver*
Mr. L. O. Odongo, *driver*
Mr. G. arap Too, *driver*
Mr. J. O. Otunge, *driver*
Mr. T. O. Kokello, *cleaner/messenger*
Mr. E. O. Ndiao, *automobile assistant*
Mr. S. O. Haira, *automobile assistant*

Janitorial/Estate Maintenance Section
Mr. S. S. Pertet, *senior janitorial assistant*
Mr. Z. O. Nyandere, *cleaner/messenger*
Mr. R. Y. Owawa, *cleaner*
Mrs. Z. P. Mmbone, *cleaner*
Mr. B. O. Yana, *cleaner*
Mr. S. M. Mkamba, *cleaner*
Mrs. J. A. Ogutu, *cleaner*
Mrs. M. O. Walter, *groundsman*
Mr. G. O. Ogero, *groundsman*
Mr. T. A. Owiti, *groundsman*
Mr. V. O. Nyangute, *groundsman*
Mr. T. K. Adwar, *groundsman*
Mr. M. O. Omollo, *groundsman*
Mr. J. D. Orimbo, *refuse collector*

Security Section
Mrs. P. A. Oriwa, *senior security officer*
Mr. J. K. N. Birir, *security supervisor*
Mr. B. W. Okello, *security guard*
Mr. D. O. Oyoto, *security guard*
Mr. J. N. Kavemba, *security guard*
Mr. A. O. Omondi, *security guard*
Mr. H. M. Mugalo, *security guard*
Mr. D. A. Aloo, *security guard*
Mr. J. M. Chacha, *security guard*
Mr. D. E. Odhiambo, *security guard*
Mr. E. A. Onyango, *security guard*
Mr. A. O. Agugo, *security guard*

Mr. J. O. Musingo, *security guard*
Mr. O. Obwanda, *security guard*

Ungoye-based
Mr. P. O. Opinde, *security guard*
Mr. W. K. Makori, *security guard*
Mr. P. O. Okech, *security guard*
Mr. E. A. Augo, *security guard*

Oyugis-based
Mr. A. I. Okapesi, *security assistant*
Mr. I. N. Danga, *security guard*
Mr. J. N. Omoke, *security guard*

Farm Services
Mr. P. Nyongesa, *farm supervisor*
Mr. E. G. Kabiru, *farm foreman*
Mr. P. O. Ouma, *senior farm assistant*
Mr. P. L. Rakwach, *tractor driver/mechanic*
Mr. J. W. Achola, *farm assistant*
Mr. F. O. Arum, *farm assistant*
Mr. P. O. Auta, *farm assistant*
Mrs. P. Ogito, *farm assistant*
Mr. J. Sagini, *farm assistant*
Mr. S. O. Odero, *farm assistant*
Mr. J. O. Osumba, *farm assistant*
Mr. F. O. Bwire, *farm assistant*

Workshops and Laboratory Services Unit
Mr. J. A. Mtei, *controller for technical services*
Mr. P. M. Alianda, *senior technician (water works)*
Mr. P. M. Okwanyo, *senior technician (carpentry)*
Mr. T. L. Ngutu, *senior technician (metal work and machines)*
Mr. E. E. Okello, *technician (electronics)*
Mr. J. O. A. Wasinda, *technician (electrical)*
Mr. R. M. Nzioka, *technician (plumbing)*
Mr. S. M. Karanja, *junior technician (general maintenance)*
Mr. J. O. Okech, *junior technician (masonry)*
Mr. D. O. Wanjara, *junior technician (carpentry)*
Mr. W. O. Omonge, *junior technician (welding)*
Mr. P. B. Gati, *technical assistant (oxidation ponds)*
Mr. C. A. Otuta, *workshop assistant*
Mr. Z. B. Ooko, *workshop assistant*
Mr. N. O. Otengo, *water pump assistant*

AMENITIES AND SOCIAL SERVICES UNITS

Duduville International Guest Centre System
DIGC Nairobi
Mr. J. A. Achilla, *senior business and catering controller (on training from September 20)*
Mr. J. A. Kooro, *assistant business and catering controller*
Mr. S. M. Aritho, *assistant accountant*
Mr. C. B. Oyieyo, *food and beverage supervisor*
Mrs. J. A. O. Musiga, *housekeeper*
Mrs. P. A. Ochola, *assistant housekeeper*
Mr. J. E. Mwangi, *head chef*
Mr. A. Lweya, *senior cook*
Mr. G. Gichuru, *cook*
Mr. J. M. Mwakisha, *cook*
Mr. D. K. Yaem, *stores assistant*
Mr. P. A. Omollo, *senior barman/waiter*
Mr. H. M. Kibisu, *senior launderer*
Mrs. R. M. Wekesa, *senior telephonist/receptionist/cashier*
Miss J. A. Misaki, *receptionist/cashier*
Mr. D. O. Resa, *receptionist assistant*
Mr. L. M. Mulae, *room steward*
Mrs. T. A. Ogongo, *room stewardess*
Mr. H. Wara, *room steward*
Mr. W. M. Ngatia, *kitchen assistant*
Mr. J. W. Mburu, *kitchen assistant*
Mr. J. O. Mukhobi, *janitorial assistant*
Mr. A. O. Were, *messenger/waiter/cleaner*
Mr. P. Mungithya, *messenger/cleaner*
Mrs. J. A. Awich, *messenger/cleaner*
Mr. S. Obondo, *gardening assistant*
Mr. K. K. Omari, *gardening assistant*
Mr. G. S. O. Omondi, *gardening assistant*
Mr. J. N. Chege, *assistant waiter*
Miss R. R. Mbui, *assistant waitress*
Miss M. W. Gichoya, *assistant waitress*
Mr. G. O. Oketch, *assistant waiter*
Mr. C. M. Omondi, *room attendant*
Miss L. A. Olack, *room attendant*
Mr. G. O. Odero, *laundry attendant*
Mr. J. N. Kipserem, *laundry attendant*
Mr. W. E. Esirenyi, *dining room attendant*
Mr. W. O. Odera, *dining room attendant*
Mr. D. M. Kaberi, *senior driver*
Mr. S. O. Araka, *driver*

MPFS International Guest Centre
Mr. W. O. Matundura, *catering officer*
Mr. E. O. D. Odhiambo, *accounts assistant*
Mr. P. O. Odote, *head cook*
Mr. J. O. Koyaa, *assistant cook*
Mr. H. O. Onyango, *barman/waiter*
Mrs. H. A. Ouma, *telephonist/receptionist*
Miss J. W. Weru, *telephonist/receptionist*
Mr. C. O. Nyagaya, *room steward*
Mrs. R. Osuna, *room stewardess*
Mr. A. O. Nyarimah, *kitchen assistant*
Mr. F. O. Orwa, *kitchen assistant*
Mr. E. J. Odero, *assistant waiter*
Mr. H. O. Omala, *assistant waiter*
Miss M. A. Nalo, *assistant launderer*
Mr. F. N. Omutsembi, *assistant launderer*

Medical and Clinical Services Unit
St. Lukes' Clinic, Duduville
Dr. J. B. Odhiambo, *institutional doctor*
Mrs. F. P. Mbogo, *clinical officer*
Mrs. I. A. Wadundwe, *nurse*
Mrs. C. E. Okoth, *nurse*
Mr. S. Kirera, *laboratory technologist*
Mr. J. K. Awino, *pharmaceutical technologist*
Miss J. W. Mwaniki, *medical secretary*
Miss P. Siva, *janitorial assistant*

St. Jude's Clinic, MPFS
Mr. J. H. Odoyo, *senior clinical officer*
Mrs. S. A. L. Chybire, *public health nurse*
Mr. P. M. Kaliech, *laboratory technologist*
Mr. C. O. Nyanjom, *pharmaceutical technologist*
Miss D. N. Oreta, *enrolled community nurse*
Mrs. F. K. W. Mukoko, *clerical assistant/typist*
Mr. A. O. Olwoko, *senior driver*
Mrs. L. A. Abuya, *janitorial assistant*

Mbita Point International School
Mrs. P. A. Ogada, *principal*
Mr. N. H. Ebrahim, *teacher*

Mr. Y. M. Koko, *teacher*
Mrs. C. O. M. Ndiege, *teacher*
Mr. F. O. Owino, *teacher*
Mr. D. B. E. Okongo, *teacher*
Mr. P. W. Mburu, *teacher*
Mr. J. P. Niyonagize, *teacher*
Mrs. M. N. Okach, *assistant secretary*
Miss S. A. Omune, *school attendant*
Mrs. O. A. Ojwang', *school attendant.*

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