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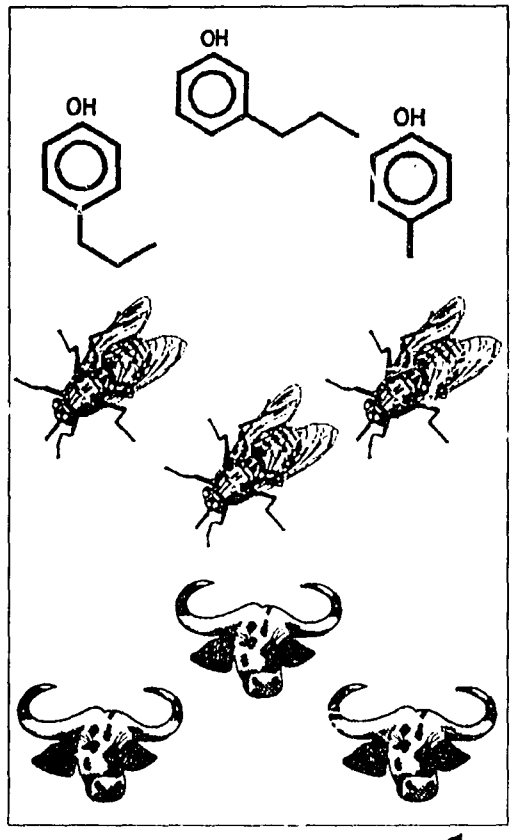

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Preface

The year 1991 was characterised by the great ferment that pervaded the entire community of the International Centre of Insect Physiology and Ecology (ICIPE) in reviewing its developmental successes and programme achievements over the first 20 years of ICIPE's establishment, and in assessing its mission-oriented future prospects in the next 10 years and beyond. One of the key concerns in this regard was the completion in December 1991 of a two-year intensive planning process — all the way from the grassroot, hands-on support staff and the scientific elite of the ICIPE staff and their associates and cooperators, to the policy and governance levels of the Centre. The resultant planning document — *Vision and Strategic Framework for the 1990s* — paints a broad picture of the ICIPE's future-oriented mandate and goals, programmes and development, outreach and capacity building, with the accent being placed on the ICIPE maintaining its reputation as a centre of excellence for serving its various constituencies and as a marketplace for implementable ideas and technologies.

The easy solutions for pest management problems, particularly in the tropics with their floral and faunal richness and diversity, are no longer viable possibilities in the immediate future. There are too many problems with conventional chemical pesticides, especially in terms of environmental sensitivity and ecological sustainability. We have too many gaps in our knowledge of what makes classical biological control sometimes succeed, for us to be able to have designer biological control. And there is no guarantee that insect-active natural products are not just as environmentally deleterious as man-made pesticides, when the impact of each such natural product is monitored in detail.

The scientific business of the ICIPE is to be concerned with this seemingly insoluble conundrum. Consequently, the long-range goal of ICIPE's R&D is to develop a firm foundation for a new-age innovative pest management approach that will make the conventional practices unwanted and obsolete. The kernel of the new ICIPE *Vision and Strategic Framework* is just that.

THOMAS R. ODHIAMBO
Director, ICIPE

Governing Council*

**as at 31 December 1991*

Member	Country	Date of appointment	Nominating body, Term
1992 Retirement Class			
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Professor J. C. Kiptoon** (Vice-Chairman, Programme Committee)	Kenya	1989	HC, I
Dr. William T. Mashler*	USA	1989	SGI, I
Professor Dr. H. Rembold**	Germany	1989	SC, I
Dr. A. R. Sutherst**	Australia	1989	SGI, I
Dr. Moctar Toure*** (Chairman, Nominating Committee)	Senegal	1989	SC, I
1993 Retirement Class			
Dr. Michael Ashburner**	UK	1990	SGI, I
Dr. Victor Rabinowitch*	USA	1990	SC, I
Professor Constantine Safilios-Rothschild*	Greece	1990	SGI, I
Dr. Sitali M. Silangwa**/***	Zambia	1987	SGI, II
1994 Retirement Class			
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Professor Toshitaka Hidaka**	Japan	1988	SC, II
Professor Fotis C. Kafatos**	Greece	1991	SC, I
Dr. John William Meagher*	Australia	1991	SGI, I
Professor Jacob L. Ngu***	Cameroon	1991	SGI, I
Ex-Officio Member			
Professor Thomas R. Odhiambo (Director, ICIPE)*/***			

Notes

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

HC Kenya government nominee

SGI Sponsoring Group for the ICIPE (SGI) nominee

SC Nomination from the scientific community

* Member of the Executive Board

** Member of the Programme Committee

*** Member of the Nominating Committee

**** To maintain a rotation schedule, any term of a member completed by another member is excluded from that member's tenure.

1991 ICIPE Donors

African Development Bank (ADB)
African American Institute
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Danish International Development Agency (DANIDA)
Directorate for NGO, International Education and Research Programme (DPO) — Netherlands Government
European Economic Community (EEC)
Federal Ministry for Economic Cooperation (BMZ) — West Germany
Finnish International Development Agency (FINNIDA)
France (through the World Bank)
German Academic Exchange Programme (DAAD)
German Agency for Technical Cooperation (GTZ)
Institute of Molecular Biology and Biotechnology — Greece
International Bank for Reconstruction and Development (IBRD) — World Bank
International Council for Scientific Unions (ICSU)
International Development Research Centre (IDRC) — Canada
International Fund for Agricultural Development (IFAD)
Japanese Society for the Promotion of Science (JSPS)
Kenya Government
Netherlands Government
Norwegian Government
OPEC Fund for Economic Development
Pew Trust (through the World Wildlife Foundation)
Rockefeller Foundation
Swedish Agency for Research Cooperation with Developing Countries — SAREC
Swiss Government
Technical Centre for Agriculture Cooperation — Netherlands
United Nations Development Programme (UNDP)
UNDP-Regional Bureau for Africa
United Nations Economic Commission for Africa (ECA)
United Nations Environment Programme (UNEP)
United Nations Children's Fund (UNICEF)
United States Agency for International Development (USAID)

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1 Crop Pests Research Programme

This Programme is aimed at contributing to sustainable increase in the production of staple food crops in developing tropics, particularly Africa, by reducing losses due to insect pests through their appropriate management. The strategies being developed for this purpose need to be friendly to the environment, economically viable and socially acceptable to the small-scale farmers.

The research and development activities of the Programme, based at the Mbita Point Field Station (MPFS) and directed to achieve the above-mentioned objectives, are being undertaken in the following Sections, as reorganised in July 1991: (i) Plant Resistance to Insect Pests (PRIP); (ii) Biological Control (BC); (iii) Cultural Control (CC), and (iv) IPM and Population Biology (IPB). The first three Sections are involved in generating individual IPM components in the respective areas. The IPB Section is engaged in integrating these IPM components into combinations or "menus" that are most effective in reducing the pests' attacks and consequent losses. The Programme also has attached to it an IPM R & D unit at the Oyugis Sub-Station of the MPFS. This unit undertakes trials with selected IPM "menus" on farmers' fields under their own management, involving collaboration between extensionists, social scientists and biologists.

With reference to the target crops and insects, the Programme continued its focus on the stem borers (Chilo partellus, Busseola fusca) *of sorghum and maize; the pod borer* (Maruca testulalis), *the flower thrips* (Megalurothrips *sp.) and the aphid* (Aphis craccivora) *on cowpea. The banana weevil* (Cosmopolites sordidus) *and nematodes* (Pratylenchus *spp.) also continued to be studied under a special project and so was the cassava green spider mite* (Mononychellus *spp.). The research undertaken by the IRRI rice breeder on upland rice also continued during the year.*

The emphasis during the year was on interaction among Sections of CPRP and with other Research units, particularly Chemistry and Biochemistry Research Unit, Social Science Interface Research Unit and Biomathematics Research Unit. Also, collaboration continued with the following institutions: (i) The International Agricultural Research Centres (IARCs) — ICRISAT, CIMMYT, and IITA for exchange of plant germplasm and information; (ii) National Agricultural Research Systems (NARS) for trials on performance of sorghum, maize and cowpea genotypes as well as performance of insect pathogens (Nosema marucae, Bacillus thuringiensis) *for biological control of stem borers; (iii) Universities of Lund and University of Agricultural Sciences at Uppsala in Sweden on a special project on pheromonal and population biology of* C. partellus *under a grant from SAREC; (iv) University of Bonn in Germany on banana weevil* (Cosmopolites sordidus) *and nematodes* (Pratylenchus *spp.) under a special project grant from BMZ; (v) University of Copenhagen on cassava green spider mite under a special project grant from DANIDA; (vi) IRRI on upland rice in Kenya and on leaf-folders in the Philippines.*

The work carried out during the year is reported under different Sections.

PLANT RESISTANCE TO INSECT PESTS (PRIP)

Research and development of strategies for utilising plant resistance to insect pests for their integrated pest management continued to involve four major activities during the year: (a) Evaluation of sorghum, maize and cowpea genotypes from different sources for resistance to crop borers and other major insect pests; (b) Elucidation of mechanisms of resistance in these crops to the target insects; (c) Genetics of pest resistance; and (d) Improvement of selected genotypes for resistance and other agronomic characters.

The plant materials evaluated were obtained from different sources: (a) National Agricultural Research Systems (NARS) in Kenya and Zambia (b) International Agricultural Research Centres like ICRISAT (India), CIMMYT (Mexico) and IITA (Nigeria); and (c) materials developed at the ICIPE during previous seasons.

The stem borers of sorghum and maize against which resistance was studied under natural infestation continued to be Chilo partellus, Busseola fusca, Eldana saccharina, *and* Sesamia calamistis. *Studies under artificial infestation included this year* C. partellus *as well as* B. fusca *which could be produced in sufficient numbers by the Insect and Animal Breeding Unit (IABU) at the ICIPE.*

1.1 SORGHUM RESISTANCE TO STEM BORERS

K. N. Saxena, F. Odawa, F. Oloo and S. Otieno

1.1.1 Evaluation of sorghum genotypes for resistance to stem borers

This activity involved (a) improvement of methodology for evaluation of sorghum genotypes for resistance to stem borers; (b) development of profiles of components of resistance in diverse genotypes; (c) performance of selected genotypes at different locations; (d) mechanisms of borer resistance in selected genotypes.

Improvement in methodology for evaluation of sorghum genotypes for resistance to stem borers. As described in previous reports, the methodologies developed by these authors earlier for evaluating sorghum and maize for resistance to stem borers involved assessment of levels of: (i) infestation with (a) eggs and (b) larvae + pupae; and (ii) damage in respect of (a) foliar lesions, (b) dead-heart and (c) stem-tunnelling. These parameters were assessed in the 1st stage evaluations, on genotypes grown in single-row plots and infested artificially with stem borer larvae as well as ovipositing females. In the 2nd stage evaluations, the test genotypes were grown in multi-row plots under artificial infestation with ovipositing adults. It may be noted that artificial infestation was to ensure the desired minimum level of insect attack and it could be supplemented by natural infestation. Because the absolute values of the above parameters would vary for any given genotype from one season to another at any site, the ratios of the parameters for a test genotype to those of a reference check were calculated to give relative indices (RI) which were more consistent than the absolute values in different experiments. The sorghum genotype used as the check is IS 18520 (Serena) because it is officially recommended and commercially produced in Kenya, and is tolerant to *C. partellus*.

However, difficulties have been experienced in the past in expressing the foliar damage appropriately so as to discriminate between resistant and susceptible genotypes. The foliar lesions caused by the feeding of stem borer larvae were scored on 1–9 scale for each individual leaf of a plant and the average of all leaves (excluding those that were outside the whorl at infestation time) represented the foliar damage score for a particular plant. The average of the foliar damage scores (AVFD) of all the sampled plants of a genotype represented the foliar damage of the population tested. But these average values did not discriminate between different genotypes which visually showed marked differences in the extent of leaf lesions. There was, therefore, a need for developing a system of expressing foliar damage that would distinguish different genotypes. Two additional methods have been found to be satisfactory. In both, the leaves of each plant in an experiment are scored individually on 1–9 scale as before. Thereafter, in one system, the average leaf score for each plant is calculated and the percentage of plants in a test showing foliar damage score equal to or above a certain level, e.g. 3.0 or 4.0, is calculated. This percentage is quite discriminatory between tested populations of different genotypes. In the second system, the percentage of leaves showing a foliar damage score equal to or above a

Table 1.1 Comparison of foliar damage by *C. partellus* larval feeding on three sorghum cultivars 3–4 weeks after infestation with 30 neonate first instar larvae per plant

Cultivar	Average FD score[1] per plant (1–9 scale)[2] (Mean ± S.E.)	% Plants with FD score ≥ 3.0 (Mean ± S.E.)[3]	% Leaves with FD score ≥ 4.0 (Mean ± S.E.)
IS 18363	4.2 ± 0.5	75.0 ± 12.6	47.5 ± 10.3
IS 18520	3.1 ± 0.2	60.0 ± 7.1	34.7 ± 4.9
IS 1044	2.6 ± 0.2	22.5 ± 10.3	17.1 ± 4.9

[1]FD, Foliar damage.
[2]Mean of 40 plants arranged in four replicates of 10 plants each, every plant scored separately.
[3]Mean of four replicates of 10 plants each, every plant scored separately.

predetermined level, e.g. 3.0 or 4.0, for each plant is calculated. The predetermined level depends on the level of infestation and the objectives. Generally, under artificial infestation with neonate larvae, the level of 4.0 and under natural infestation, 3.0 are found useful. The lower the percentage, the greater the resistance of that plant to foliar damage. This parameter is particularly useful in selection by breeders of individual plants for resistance to foliar damage.

The above three systems of evaluating foliar damage may be illustrated with reference to three sorghum cultivars: Susceptible IS 18363, tolerant IS 18520 and resistant IS 1044 (Table 1.1). It can be observed that the Average Foliar Damage (AVFD) score per plant did not differ significantly among the three cultivars. But, the percentage of plants with FD score > 4.0 was significantly higher for IS 18363 than for IS 1044 indicating the latter's resistance relative to the former. Similarly, the percentage of leaves on a plant showing FD score ≥ 4.0 was also greater for the susceptible IS 18363 than for the resistant IS 1044. In this case, since the percentage leaves with FD score ≥ 4.0 was assessed for each plant, it was possible to identify individuals that would have the highest (say, above 80) percentage leaves with FD score less than 4.0 or even 3.0 and select them for resistance to foliar damage.

Profiles of components of resistance to stem borers. Previously reported work of the authors has shown that various sorghum genotypes may differ from one another in their relative resistance or susceptibility to stem borers in respect of one or more of the following major components:

(A) Infestation levels:
- (i) egg-population density, and
- (ii) larval + pupal population density

(B) Damage levels:
- (iii) foliar damage
- (iv) deadheart
- (v) stem-tunnelling

Some lines may have a greater resistance in one or more of these components and greater susceptibility in other components than other lines. It will therefore be most useful for the plant breeders to have profiles of relative levels of different resistance components in as many sorghum genotypes as possible. Such profiles will enable the breeders to select the lines with the desired types and levels of resistance components for developing varieties that will combine overall resistance with other desirable characters including yield.

Reference to the existing literature on sorghum resistance to stem borers shows that a large number of genotypes have been screened for resistance to the insects over the past few decades in different parts of the world. An exhaustive review of such screenings has recently been given by Singh B. U. and Rana B. S. (*Insect Sci. Applic.* 10: 3–27, 1989). These authors have listed various sorghum genotypes under different categories according to their resistance to one or more different parameters. But these listings are not adequate to serve as profiles of resistance components mainly because of two reasons: First, the levels of absolute or relative resistance of the listed genotypes in respect of different parameters have not been given and therefore cannot be compared quantitatively. Secondly, the parameters as well as methods for screening different genotypes and their resistance to stem borers differ markedly from one report, author, institution or place to another and from time to time even for the same author. It, then is not reliable to compare the levels of overall or components of resistance in a batch of genotypes evaluated on the basis of one set of parameters and methods with another batch of genotypes evaluated on the basis of another set of parameters and methods.

In view of the above, the authors have been employing a standardised approach and methodology to evaluate selected sorghum genotypes from diverse sources, including those that have already been screened by others as well as those not evaluated before, for the overall and the components of resistance to the stem borers, *Chilo partellus* and *Busseola fusca*. As explained before, these evaluations have thus far been for the components of resistance listed above.

During the present reporting year, single-row evaluations were carried out on 22 sorghum genotypes listed in Table 1.2. The first one (IS 18520) served as the main check, the second (IS 18363) as the susceptible check and the third (IS 1044) as the resistant check. The nos. 4–7 were the cultivars developed at the ICIPE, nos. 8, 9 were the ones officially recommended in Kenya, 10–12 from Kenya, 13–19 from ICRISAT and 20–22 from Sudan. Of these, the first 20 were taken from the previous evaluations to examine the consistency in their performance, and the last two (A-672; CR: 35:5) were the additional genotypes. The multi-row evaluations were carried out on 14 genotypes of which three were additional ones and the remaining were from previous evaluations. These 14 genotypes were also tested for their performance at different locations: Ogongo/Lambwe (farmers' fields); Busia/Alupe (KARI station), Embu (KARI station).

The profiles of the stem borer resistance components in the genotypes evaluated in single-row plots under artificial infestation with adults and larvae are given in Table 1.2 and those in multi-row plots under artificial infestation with adults in Table 1.3.

Under artificial infestation of the plants with *C. partellus* adults + larvae in single-row tests, the genotype IS 1044 continued to show the lowest relative indices and, hence, highest resistance to all five parameters. Another genotype, IS 3962 also showed almost as high resistance in all five components as IS 1044. The deadheart, which greatly reduces the grain yield in the affected plants, was almost nil in these two cultivars in contrast to the high level of 73% in the main check IS 18520 and still higher in the susceptible check IS 18363. The grain yields of these two resistant lines were only slightly higher (IS 1044) or lower (IS 3962) than those of the commercial Serena. The only other cultivars that showed a high resistance to deadheart was IS 5469 and moderate resistance was observed in IS 2146, IS 2269, IS 4405 and IS 4660. The ICIPE's cultivar ICS 4 (=LRB 8) had a higher infestation as well as damage levels, yet its grain yield (108.5 g/plant) was higher not only than the check Serena but also fairly close to that in the uninfested plants (118

Table 1.2 Relative indices of the major components of resistance to stem borers in different sorghum genotypes in single-row plots under artificial infestation with ovipositing adults and first instar larvae of *Chilo partellus* (long rains 1991, MPFS)

	Relative infestation index		Relative damage index			
Sorghum genotype	Eggs	Larvae + pupae	Foliar damage	Deadheart	Stem-tunnelling	Grain (g/plant) (Mean ± S.E.)
IS 18520	1.0	1.0	1.0	1.0	1.0	83.0 ± 19.8
(Serena)	(21.3)[1]	(54.3)	(60.0)	(73.0)	(38.9)	
IS 18363	0.8	1.5	1.3	1.2	1.8	16.8 ± 4.8
IS 1044	0.7	0.5	0.4	0.1	0.8	93.4 ± 5.9
ICS-3(=LRB 5)	1.2	1.7	1.0	1.2	1.4	72.8 ± 9.9
ICS-4(=LRB 8)	1.2	1.4	0.8	0.9	1.1	108.5 ± 27.1
LRB 6	0.9	1.5	1.0	0.9	1.2	75.7 ± 19.4
LRB 7	1.0	1.3	1.1	1.0	1.6	61.2 ± 7.9
Seredo	0.8	1.2	1.0	1.1	1.0	79.3 ± 22.9
2Kx17	0.7	0.9	1.2	1.0	2.3	37.8 ± 21.9
KAT 18333	0.5	1.1	1.3	1.0	1.0	63.2 ± 11.4
KAT 83369	0.6	1.1	1.0	0.8	1.1	51.4 ± 6.3
KAT 83487	0.9	1.5	0.5	0.7	1.1	80.0 ± 19.6
IS 2146	1.4	1.3	0.5	0.5	0.8	61.5 ± 9.9
IS 2269	1.0	1.3	0.3	0.5	0.8	72.9 ± 14.2
IS 3962	0.7	0.8	0.2	0.1	0.5	75.7 ± 22.8
IS 4405	0.9	0.6	1.2	0.5	1.1	84.9 ± 56.3
IS 4660	0.8	1.2	0.2	0.5	0.7	70.9 ± 10.9
IS 5469	1.1	1.3	0.3	0.2	0.9	66.1 ± 13.6
IS 18463	0.8	0.6	0.8	0.9	1.0	67.7 ± 18.6
Gadam El Hamam	0.7	0.5	1.0	1.0	2.1	77.2 ± 29.3
A-672	1.2	0.8	0.7	0.6	1.0	80.4 ± 19.7
Cr: 35:5	1.1	0.7	1.2	0.8	1.4	89.8 ± 19.8

[1]The values within the parentheses are actual data means for the check genotypes expressing (i) egg-infestation level as no. egg batches/10 plants during 3–15 weeks after plant emergence; (ii) larval/pupal infestation level as nos./10 plants at harvest; (iii) foliar damage as % plants showing a score of 3.0 or above; (iv) deadheart as % plants showing the damage, and (v) stem-tunnelling as % of plant height tunnelled.

Table 1.3 Relative indices (RI) for the major components of resistance in selected sorghum lines evaluated in multi-row plots under artificial infestation with ovipositing females of *C. partellus* at MPFS (long rainy season 1991)

	Relative infestation index		Relative damage index			
Sorghum line	Eggs	Larvae + pupae	Foliar damage	Dead-heart	Stem-tunnelling	Grain yield (g/plant) (Mean ± S.E.)
IS 18520	1.0	1.0	1.0	1.0	1.0	138.0 ± 11.1
(Serena)	(34.0)	(50.3)	(23.3)	(3.4)	(29.1)	
IS 18363	1.3	2.1	1.4	1.1	1.5	31.2 ± 6.4
IS 1044	0.9	0.3	0.7	0.?	0.4	109.7 ± 7.7
ICS 3 (=LRB 5)	1.6	1.3	1.3	1.2	1.2	104.6 ± 17.1
ICS 4 (=LRB 8)	1.7	2.2	1.1	0.5	1.0	107.5 ± 4.1
LRB 6	1.1	2.0	1.7	1.1	1.3	110.1 ± 14.8
LRB 7	1.1	1.8	1.0	0.9	1.3	143.3 ± 14.5
Seredo	1.1	1.2	0.6	0.5	1.0	123.1 ± 3.2
2Kx17	1.2	0.9	1.2	1.8	0.8	106.1 ± 15.4
IS 4405	1.4	1.0	1.2	0.6	0.5	100.8 ± 17.0
ICSV 219	1.1	1.5	1.2	0.8	1.8	94.1 ± 5.7
ICSV 335	1.1	1.9	1.2	0.8	1.8	130.5 ± 15.3
Gadam El Hamam	1.1	0.7	0.4	0.8	0.8	102.1 ± 15.6
A-672	1.2	1.2	0.6	0.6	1.1	144.8 ± 29.9

Note: Legends as in Table 1.2.

g/plant), suggesting and confirming its high tolerance level. Same was more or less the case with ICS 3 (=LRB 5) except that the grain yield of 72.8 g/plant was about 40% less than that in uninfested plants compared to corresponding reduction of 30% in the Sudan's genotype Gadam El Hamam and 20% in the check Serena.

In multi-row plots, 14 genotypes (Table 1.3) were evaluated at the Mbita Point Field Station under natural infestation supplemented with release of ovipositing females once a week during 3–7 weeks after plant emergence. IS 1044 continued to show highest resistance in almost all five components, as in previously reported evaluations. ICS 3 and ICS 4 continued to show tolerance, giving grain yields fairly close to that of the official variety Serena, in spite of much higher levels of egg- and larval/pupal-infestations. Same was more or less true for LRB 6 and LRB 7. These four sorghum lines of the ICIPE have since been purified and breeders seed has been prepared for further trials on a wider scale.

Resistance in sorghum to B. fusca *in relation to its oviposition, feeding and development.* The study of sorghum resistance to the stem borer *B. fusca* was initiated in 1990 and levels of components of resistance in the following three genotypes under artificial infestation with the larvae were presented in the previous Annual Report: IS 18363, IS 18520 and IS 1044. Previous work on their resistance/susceptibility to the other stem borer species, *C. partellus* has shown that IS 18363 is highly susceptible, IS 18520 is tolerant and IS 1044 highly resistant to this insect. Tests with *B. fusca* showed that IS 1044 was most resistant to larval establishment, foliar damage, and stem-tunnelling. IS IP363 was more susceptible in larval establishment, less susceptible to foliar damage and stem-tunnelling than IS 18520. Further studies on the resistance in these three genotypes to *Busseola* during the current year involved comparison of three of its colonising responses to the same genotypes: oviposition, larval feeding and development.

1.1.2 *Mechanisms of resistance in sorghum to stem borers*

Role of leaf tissue constituents in antibiosis. Previously reported studies have shown that behavioural nonpreference of *Chilo partellus* for oviposition, larval orientation and feeding responses to certain sorghum lines, e.g. IS 1044, contributes to their resistance or susceptibility. Some of the factors that determine the behavioural responses of the insect to different sorghum lines have been reported before. Another major mechanism or resistance in plants to insects is antibiosis. There was some indication that antibiosis may also be partly involved in the resistance of the line IS 1044. It was also reported before that the utilisation of food from IS 1044 by *C. partellus* larvae was poorer than that from the susceptible line IS 18363, reflecting antibiosis in IS 1044. Such an effect of the food from IS 1044 could be due to lack of adequate nutrients and/or presence of toxic chemicals that interfere with the metabolic processes in the insect. The first step in understanding the factors governing antibiosis was to examine whether or not the leaf tissues of different sorghum lines, when incorporated in an artificial diet would affect larval survival and development.

Table 1.4 Development of *Chilo partellus* larvae from the first instar to the fourth and the pupal stage on an artificial diet containing leaf tissues of different sorghum lines

Diet[1]	Development index[2] to 4th instar	Development index[2] to pupa
BM	1.3 ± 0.3[f]	0.8 ± 0.2[e]
BM + CP	1.7 ± 0.4[f]	0.8 ± 0.2[e]
BM + IS 18520 LP	6.4 ± 0.3[ab]	1.7 ± 0.1[cd]
BM + IS 18520 BL	6.6 ± 9.2[ab]	2.0 ± 0.2[cd]
BM + IS 18363 LP	4.8 ± 0.2[cd]	2.2 ± 0.1[bc]
BM + IS 18363 BL	7.1 ± 0.7[a]	2.5 ± 0.2[ab]
BM + IS 2146 LP	3.9 ± 0.4[de]	2.0 ± 0.2[cd]
BM + IS 2146 BL	5.9 ± 0.4[bc]	3.0 ± 0.4[a]
BM + IS 4660 LP	4.7 ± 0.5[cd]	1.4 ± 0.2[d]
BM + IS 4660 BL	6.2 ± 0.5[bc]	1.7 ± 0.1[cd]
BM + IS 2205 LP	5.7 ± 0.2[bc]	1.5 ± 0.2[d]
BM + IS 2205 BL	3.8 ± 0.8[e]	0.9 ± 0.1[e]
BM + IS 1044 LP	5.3 ± 0.4[cd]	1.5 ± 0.1[d]
BM + IS 1044 BL	1.4 ± 0.3[f]	0.5 ± 0.1[e]

[1]BM, basic medium; CP, cellulose powder; BL, blended fresh leaves; LP : dry leaf powder; IS nos. refer to the sorghum lines tested.
[2]Ratio between % insects developing and development period.
Differences between means followed by the same letters are not significant ($P > 0.05$; DMRT on arcsine-square root - transformed data for % development and on untransformed data for the other two parameters).

For this study, newly emerged first instar larvae of *C. partellus*, taken from its laboratory culture, were given various artificial diets. These diets were agar-based basic medium with or without cellulose powder, dry leaf powder or fresh leaf paste of six different sorghum lines, as given in Table 1.4. The percentage of larvae that developed to the fourth instar and to the pupal instar, together with the period of their development were recorded. The ratio of the percentage development to the developmental period gave the development index (DI) which was compared among the tested diets. The lower the DI, the greater the unsuitability of the diet. The basic medium alone or with cellulose powder showed the poorest dietary quality in-as-much as it did not support more than 26–32% larval development (Table 1.4). The tolerant sorghum IS 18520 leaf tissues, incorporated in the artificial diet as dry powder or fresh leaf-paste, were more efficient in supporting as high larval development as natural host plants. The diets with the leaf-pastes of the susceptible IS 18363 and IS 2146 as well as the moderately resistant IS 4660 also supported equally high larval development but the dry leaf powder of these lines was somewhat inferior in its dietary quality. In contrast, the leaf-paste of the highly resistant IS 1044 and of moderately resistant IS 2205 rendered the quality of the artificial diet as poor as the basic medium, reflecting deleterious effect on larval development due to antibiosis (Table 1.4). Such an effect was eliminated by drying the leaves and incorporating their powder in the diet.

1.2 MAIZE RESISTANCE TO STEM BORERS

H. Kumar

1.2.1 Components of resistance to Chilo partellus *in maize genotypes from CIMMYT*

196 maize families were screened from the International Wheat and Maize Improvement Centre, (CIMMYT), Mexico during July 1990 under its Multiple Insect Resistant Tropical (MIRT) pool. These maize families were planted in MPFS during the long rainy season, 1991. The two maize genotypes previously identified as highly susceptible (Inbred A) and highly resistant (MP 704) were also included in the trial along with the following maize hybrids from Kenya: H-511, H-622 and Pwani Hybrid. For the comparison of different components of resistance across the maize entries, H-511 was treated as the check in view of it being the cultivar that is officially recommended and commercially available for growing in test area and its environs in western Kenya.

The crop was infested at 20 days after the plant emergence with almost 50–60 eggs of *C. partellus* at black head stage. The egg mass was put directly into the central whorl of each plant.

A comparison of the overall resistance/susceptibility index (ORSI) as well as its components among the 196 entries and the previously identified resistant MP 704 ranged from 0.4 to 0.6. These entries (Table 1.5) were thus 40–60% more resistant than the check Hybrid 511. The other commercial Hybrids 622 and Pwani as well as susceptible check Inbred A were 1.3–1.5 times more susceptible than H-511.

The most striking feature was the resistance/susceptibility to deadheart (Table 1.5). The percentage of Inbred A plants having deadheart was the highest whereas the resistant MP 704 showed 11.1% deadheart. In contrast,

Table 1.5 Evaluation of maize genotypes (1990 MIRT 004) from CIMMYT for components of resistance to the stem borer *Chilo partellus* under artificial infestation at Mbita Point Field Station, ICIPE (long rainy season 1991)[1]

Entry No.	Relative infestation level (larvae + pupae)	Relative foliar damage	Relative deadheart	Relative stem-tunnelling	ORSI	Grain yield/ plant in g
MP 704	0.8	0.5	0.6	0.2	0.53	22.11 ± 13.89
MIRT 1	0.9	0.5	0.6	0.4	0.50	121.6 ± 12.1
2	0.8	0.5	0	0.6	0.43	114.96 ± 22.36
5	0.8	0.7	0	0.6	0.53	78.37 ± 62.7
13	1.2	0.6	0.3	0.6	0.65	115.25 ± 56.35
27	1.0	0.2	0	0.6	0.53	72.23 ± 41.57
30	1.1	0.9	0.3	0.9	0.55	55.01 ± 6.79
65	0.5	0.6	0	0.5	0.40	114.59 ± 24.15
67	0.9	0.6	0	0.6	0.53	121.42 ± 32.37
72	0.8	0.6	0	0.7	0.53	105.32 ± 38.72
73	0.8	0.6	0	0.6	0.60	69.1 ± 30.9
85	1.2	0.6	0	0.5	0.58	97.35 ± 64.65
99	1.2	0.5	0	0.3	0.50	99.92 ± 45.7
114	0.9	0.6	0	0.5	0.50	21.36 ± 9.03
119	0.4	0.7	0	0.5	0.40	76.69 ± 3.55
120	1.0	0.7	0	0.5	0.55	71.16 ± 25.53
124	0.3	0.6	0	0.6	0.50	90.32 ± 42.07
128	0.8	0.7	0	0.6	0.58	68.36 ± 17.03
129	1.0	0.6	0	0.5	0.53	74.47 ± 12.67
131	0.8	0.6	0	0.6	0.50	83.2 ± 34.6
136	0.8	0.5	0	0.3	0.40	68.8 ± 1.8
155	1.2	0.6	0	0.4	0.35	90.41 ± 6.59
172	0.8	0.7	0	0.6	0.53	41.07 ± 10.63
180	1.2	0.6	0	0.5	0.58	78.2 ± 18.8
Inbred A	–[2]	1.2	4.1	–	1.33	–
Hybrid 622	2.2	1.0	1.6	1.1	1.48	42 ± 42
Pwani Hybrid	1.2	0.9	1.7	0.8	1.30	42.4 ± 42.4
Hybrid 511	1.0	1.0	1.0	1.0	1.00	28.97 ± 6.22
	(4.7)[3]	7.8	(17.8)	(48.8)		

[1] MIRT — Multiple Insect Resistance Tropical.
[2] Dashes indicate complete damage.
[3] The values within the parenthesis for Pwani Hybrid 511 are the actual data means used for calculating the relative values.

several entries did not show any deadheart, thereby reflecting high resistance to this type of damage. Of these, the entry nos. 65, 119 and 136 were resistant in other components as well, so that these three MIRT entries showed highest overall resistance.

1.2.2 Resistance in maize genotypes to C. partellus *in relation to larval rearing media*

This aspect was studied in the screenhouse. Two maize genotypes, Inbred-A (susceptible) and MP 704 were grown in the screenhouse in a completely randomised row of 10 plants each in two separate sets. Each set consisted of three replicates. Each genotype was represented by three rows in as many replicates in each set. Each plant in the first set was infested with 20 neonate *C. partellus* obtained from a culture maintained on artificial diet at 3 weeks after the emergence. Each plant in the second set was infested with 20 neonates of *C. partellus* obtained from a culture maintained continuously on the plants of resistant genotype MP 704 for two complete generations.

At 3 weeks after the infestation, the plants in both the sets were rated for foliar damage. Thereafter, the plants were dissected and stem tunnelling was assessed. The percentage of larvae recovered from each plant were also recorded. The recovered larvae were kept in the labelled glass vials and dried at 60°C for 36 hours.

The results (Table 1.6) show that the genotype MP 704 infested with MP 704-reared *C. partellus* larvae suffered significantly more foliar damage and stem-tunnelling than that infested with larvae reared on artificial diet. The larval establishment was also higher on MP 704 infested with MP 704-reared larvae than that of artificial diet reared larvae. The MP 704-reared larvae also gained a significantly higher biomass (dry wt.) on MP 704 than artificial diet reared larvae.

The foliar damage, stem-tunnelling and deadhearts damage caused by MP 704-reared larvae on the susceptible genotype Inbred A were as high as by the artificial diet-reared larvae. However, establishment as well as dry weights of MP 704-reared larvae on Inbred A were significantly lower than the artificial diet-reared larvae. These observations suggest that *C. partellus* larvae undergo some changes in the form of adaptation/induction when reared on the resistant maize genotype MP 704. The study shows that the resistance/ susceptibility levels of maize genotypes would differ with respect to the artificial diet reared insects as well as those prevalent in nature. This aspect needs further study.

1.2.3 Mechanisms of resistance in maize to C. partellus

Of the different behavioural responses of *C. partellus* involved in the initial selection or rejection of plants, oviposition by the moths plays a key role in discriminating resistant maize genotypes from the susceptible ones. The plant factors which deter oviposition by the moths are the trichomes on the upper leaf surfaces. Even though the upper leaf surfaces are studded with trichomes in many resistant cultivars, lower leaf surfaces are practically devoid of these structures. Consequently, moths non-preference for oviposition is mostly exhibited partially on different resistant cultivars. It is therefore desirable and important to have maize cultivars with pubescence not only on the upper leaf surfaces but also on the lower surfaces to deter oviposition by *C. partellus*. The role of such a maize cultivar having pubescence on both the leaf surfaces, in determining oviposition by *C. partellus* has been elucidated and the results are presented here.

The maize cultivars studied were Inbred A (highly susceptible), V-37 (resistant) and ICZ-T (resistant). The first cultivar originated in Kenya, while the second was obtained from CIMMYT. The third cultivar was obtained as a result of single plant selection from the population V-37 of CIMMYT as follows: A single plant of the population V-37 was observed to differ from the remaining plants of the population V-37 in a plot in having high pubescence on the upper as well as lower surfaces of the leaves. The plant was selfed. The seeds collected were planted in the subsequent season. The individual plants were examined and those with high trichome density on both the leaf surfaces were selected and selfed. The seeds collected from the selected plants were bulked to generate the experimental line ICZ-T (Inbreeding coefficient, F= 0.75) for the present study.

The tests were conducted in the screen house using a 3-sector test chamber as well as in the laboratory using a circular test chamber, as described previously (*ICIPE Annual Reports, 1985, 1986*).

Table 1.7 shows the trichome density on the upper and lower surfaces of the first fully opened leaves of the cultivars V-37 and ICZ-T. The number of trichomes on

Table 1.6 A comparison of the resistance/susceptibility levels of two maize genotypes in relation to the *C. partellus* larvae reared on artificial diet and on a resistant maize genotype

Rearing medium	Maize genotype	Foliar damage ratings	% Plants showing deadheart	% Stem length tunnelled	Larval establishment (%)	Larval dry wt. mg/l
Artificial diet[1]	Inbred A	7 ± 0.2[a]	55 ± 12[a]	48 ± 5[a]	83 ± 4[a]	23 ± 2[a]
	MP 704	3 ± 0.2[b]	0[a]	2 ± 1[b]	15 ± 4[c]	3 ± 0.5
MP 704[2]	Inbred A	7 ± 0.2[a]	53 ± 10[a]	51 ± 5[a]	91 ± 3[b]	30 ± 1.0[b]
	MP 704	5 ± 0.5[c]	0[a]	18 ± 5[c]	43 ± 8[d]	8 ± 0.1[d]

[1]*C. partellus* neonates used was reared on artificial diet. Numbers with similar letters are not significantly different.
[2]*C. partellus* reared on MP 704 for two generations.

Table 1.7 Trichome density on various sections of the upper and lower surfaces of the first fully opened leaves of two maize cultivars

Leaf portion	No. of trichomes/cm² of the leaf[1] (Mean ± S.E.) V-37 Upper	V-37 Lower	ICZ-T Upper	ICZ-T Lower
Terminal	106 ± 6	0	251 ± 11	54 ± 5
Middle	NC	0	NC	46 ± 6
Basal	NC	0	NC	34 ± 4

[1]Data based on mean for 10 leaf surfaces per section in each cultivar.
NC, not counted.

the upper leaf surface of ICZ-T was almost three times higher than that on V-37. The lower surface of V-37 had no trichomes but that on ICZ-T varied according to leaf portions examined. The mean trichome density declined from almost 54 ± 5/cm² on terminal portions to 34 ± 4/cm² on the basal portions of the leaves of ICZ-T.

When the whole plants of the susceptible cultivar Inbred A were presented as a choice with those of ICZ-T inside the 3-sector chamber in the screen house, the moths showed a strong ovipositional preference for the former cultivar. The number of eggs laid on ICZ-T was almost one eighth of that on the susceptible cultivar ($t = 6.34$; $P < 0.01$) (Table 1.8). Even in the choice tests, the moths did not show any preference for ICZ-T since the number of egg-masses laid on the plants (15 ± 0.5) was as high as elsewhere (18 ± 0.5) in the chamber.

On contact with the lower surfaces of the leaves of the test cultivar offered on a choice against the susceptible Inbred A inside the circular test chamber, the cultivar ICZ-T was less effective than the susceptible one in eliciting oviposition by *C. partellus* . A comparison of the lower leaf surfaces of V-37 and ICZ-T revealed an ovipositional non-preference for the latter. Thus ICZ-T was less effective than the population V-37 from which it was derived, in eliciting oviposition by *C. partellus*.

In no-choice tests, when the lower leaf surface of Inbred A was presented against wax paper, the moths showed a strong preference for the leaf. A comparison of V-37 leaves with wax paper also revealed a slight ovipositional preference for the leaf though not significantly so. On the contrary, when ICZ-T leaves were compared with wax paper, the moths showed a strong ovipositional non-preference for leaves; significantly more eggs were laid on the wax paper than the leaf.

Since lower leaf surfaces of the line ICZ-T are covered with trichomes, the non-preference for oviposition by *C. partellus* could be due to their presence. In order to demonstrate their role in eliciting oviposition, the trichomes on the lower leaf surface of ICZ-T were carefully rubbed off with thoroughly washed muslin cloth from one side of the central midrib of the leaf, leaving the other side intact. The leaf was then presented to the moth in the circular chamber for the oviposition tests. The number of eggs laid by the moths on the hairless side (ICZ-TL) was significantly greater than that on the hairy side. Thus trichomes on the lower surfaces of the leaves inhibited oviposition by *C. partellus*.

A regression of the oviposition by the moths on the trichome density of the lower leaf surfaces of ICZ-T revealed a significant negative correlation between the two ($r^2 = 0.534$, $P < 0.01$). Thus, trichomes inhibited oviposition by the moths.

These behavioural observations show clearly that due to the presence of trichomes on the lower leaf surfaces of ICZ-T, the moths showed an ovipositional non-preference for this experimental maize line. Since the trichome density on upper leaf surface of ICZ-T is almost 4–5 times greater than the lower surface and that the trichomes on the lower leaf surfaces inhibited oviposition as demonstrated above, the additive effect of the two leaf surfaces would deter oviposition by *C. partellus* appreciably. That is why, a very strong ovipositional non-preference was displayed towards the whole plants

Table 1.8 Oviposition responses of *Chilo partellus* to certain cultivars of maize, their excised leaves and some non-plant surfaces

Experiment[1]	Test material A	Test material B	No. eggs laid (Means ± S.E.) A	No. eggs laid (Means ± S.E.) B	% Ovipositional preference[4] (Means ± S.E.)
1	Inbred A[2]	ICZ-T	1646 ± 170**	249 ± 65	72.3 ± 7
2	Inbred A[3]	ICZ-T	168 ± 21**	69 ± 17	45.7 ± 14
3	V-37	ICZ-T	126 ± 19*	79 ± 14	23.1 ± 11
4	Inbred A[3]	Wax paper	190 ± 13**	62 ± 23	56.0 ± 16
5	MBR-8637	Wax paper	108 ± 23ns	80 ± 19	9.0 ± 22
6	ICZ-T[3]	Wax paper	40 ± 12**	104 ± 15	-49.6 ± 12
7	ICZ-TL[3]	ICZ-T	161 ± 16**	40 ± 6	60 ± 6

[1] Plants used 3–5 weeks after germination.
[2] Responses to whole plants presented inside the 3-sector chamber.
[3] Responses to first fully opened leaves presented inside the circular chamber.
[4] Calculated as A-B/A+B x 100. Mean number of eggs in column "A" bearing single or double asterisks is significantly different from the corresponding mean in column "B" at $P = 0.05$ or $P = 0.01$ respectively.

Table 1.9 Effects of incorporating whorl leaf juices of certain maize genotypes in the artificial diet on growth of *C. partellus*

Treatment†	Per cent larvae surviving	Per cent larvae in different instars		
		3	4	5
SLBPDD + cellulose	0	0[a]	0[a]	0[a]
SLBPDD + LPA	83 ± 6[bc]	0[a]	25 ± 5[a]	75 ± 6[a]
SLBPDD + LPA + LJA	88 ± 4[bc]	0[a]	55 ± 5[b]	45 ± 5[b]
SLBPDD + LPA + LJMP	82 ± 4[bc]	44 ± 7[b]	56 ± 7[b]	0[a]
SLBPDD + LPA + LJSVR	96 ± 2[ab]	0[a]	43 ± 4[c]	56 ± 2[b]
SLBPDD + LPA + LJV37	88 ± 6[bc]	0[a]	76 ± 4[d]	24 ± 2[c]
SLBPDD + LPA + LJPR	99 ± 1[a]	0[a]	40 ± 3[c]	60 ± 3[b]

†SLBPDD, Artificial diet devoid of sorghum leaf powder and bean powder; LPA, Leaf powder of Inbred A incorporated into SLBPDD equivalent to sorghum leaf and bean powder; LJ, Leaf juices equivalent to 104 ml of water; A, MP, SVR, V37 & PR; denote the maize genotypes Inbred A, MP 704, ER 29 SVR, V-37, Poza Rica 7832.

of ICZ-T when they were compared with Inbred A in the 3-sector chamber.

In conclusion, the S_2 line, ICZ-T, with high trichome density on both the leaf surfaces can be of tremendous practical utility in breeding Programme on maize resistance to *Chilo partellus*. Such a line can be used directly for breeding purposes or can be selfed further towards homozygosity provided the line does not undergo severe inbreeding depression.

1.2.4 Role of nutrition in antibiosis

In the previous annual report (*ICIPE 1990 Annual Report*), the effects of dry leaf powder of different maize genotypes incorporated in the artificial diet on the growth of *C. partellus* was studied. In the present study, the fresh juices of the whorl leaves of various maize genotypes were incorporated in the sorghum leaf-bean powder of the susceptible maize genotype Inbred A.

For preparing leaf juices, plant whorls of 3 weeks old plants were harvested, and trimmed to approximately 20 cm. The whorl leaves were chopped, converted into a slurry in an electric blender and squeezed in between the double folds of a muslin cloth to extract the juice. The volume of juice added was equivalent to that of water used in the preparation of diet.

The results (Table 1.9) show that leaf juices of different maize genotypes did not have any significant effect on the survival of *C. partellus* larvae. Of the recovered larvae, the percentages of larvae reaching fifth instars on the artificial diet containing leaf juices of Inbred A, Poza Rica 7832 and ER-29SVR were significantly greater than on the artificial diet containing leaf juices of MP 704 and V-37. These observations show that the leaf juices of maize genotypes MP 704 and V-37 had some toxin or antifeedant to the growth of *C. partellus* larvae. These toxins or antifeedants seem to be of very mild nature because hexane extracts of MP 704 did not inhibit growth of *C. partellus* larvae when the extracts were incorporated into the complete artificial diet containing all the ingredients in optimum quantities.

1.3 COWPEA RESISTANCE TO LEGUME POD BORER

S. Oghiakhe

1.3.1 Mechanism of cowpea resistance to the legume pod borer, Maruca testulalis: *Role of pubescence (trichomes) on larval settling preference and adult oviposition*

Further studies were carried out to determine the role of cowpea pubescence (trichomes) on *Maruca testulalis* larval settling preference and adult oviposition as part of efforts to elucidate the role of biophysical factors in cowpea resistance to this pest. The role of cowpea pubescence in determining feeding and mobility of *M. testulalis* had earlier been reported (see *ICIPE 1990 Annual Report* pp. 22–23).

Settling preference of third instar larvae of M. testulalis. Three cultivars with known levels of resistance to *M. testulalis* were used: TVnu 72 (highly resistant), TVu 946 (resistant) and IT82D-716 (susceptible). Settling preference of third instar larvae of *M. testulalis* on test cultivars was determined using whole and sliced pods in petri-dishes measuring 11 cm diameter x 2 cm depth. Six third instar larvae were released at the centre of each petri-dish and the total number settled on or in each cultivar recorded after 24 hours. There were 10 replicates in each case and the whole set up was covered with a piece of black cotton cloth. Temperature and relative humidity during the experimental period varied between 25–27°C and 50–55%.

No-choice and free-choice oviposition tests. In the no-choice test, one 3-week-old plant of each of the three cultivars grown in plastic pots (diameter 27 cm) in the screenhouse was transferred into a 57.5 x 57.5 x 105 cm cotton mesh wooden cage into which a total of 10 pairs of *M. testulalis* adults that had emerged the previous night were introduced. Moths were allowed to oviposit for 5 days, at which time the plant was removed. Ovipositional preference for the test plants was then

determined by counting the total number of eggs on different parts of the cowpea cultivars (i.e., on abaxial and adaxial leaf surfaces, terminal shoots, branches, stem and stipules).

In the free-choice test, 3-week-old potted plants (one from each cultivar) were arranged together in a triangular form in cotton mesh wooden cages measuring 99 x 99 x 97 cm into which 30 pairs of freshly emerged *M. testulalis* adults were introduced. Moths were similarly allowed to oviposit for 5 days, at which time the plants were removed. Egg count to determine ovipositional preference was determined as described in the no-choice test. All experimental cages were left outside the laboratory at ambient temperature and relative humidity conditions. Each test was replicated 10 times using a completely randomised design.

The trichome characteristics of test cultivars were examined using a scanning electron microscope (SEM). Data were collected on trichome density and length on pods and abaxial and adaxial leaf surfaces at desired periods in each experiment.

Significant differences ($P < 0.05$) were observed in the settling preference of larvae on whole and sliced pods of test cultivars, with IT82D-716 being the most preferred and TVnu 72 the least preferred.

Sliced pods of TVnu 72 and TVu 946 had a higher number of larvae than unsliced pods, however, the reverse was the case for IT82D-716.

In free-choice and no-choice oviposition tests with whole plants, the highest number of eggs were laid on IT82D-716, followed by TVu 946 and TVnu 72 and these differences were significant ($P < 0.05$). In the free-choice test, IT82D-716 received about 14 times the number of eggs laid as did TVnu 72, while in the no-choice test, it received about eight times more.

With the exception of TVnu 72 (no-choice test), a significantly higher ($P < 0.05$) number of eggs were laid on the abaxial surface of leaves of all cultivars than on other plant parts in free-choice and no-choice tests. This was followed by the adaxial surface of leaves, stem, branches and terminal shoots (Table 1.10). However, the numbers of eggs deposited on the abaxial surface of leaves in free-choice and no-choice tests were not significantly different.

The length of glandular trichomes on the abaxial and adaxial leaf surfaces of the cultivars was not significantly different, but it was significant ($P < 0.05$) for non-glandular trichomes. On the adaxial leaf surface, TVnu 72 had significantly longer non-glandular trichomes ($P < 0.05$) than IT82D-716 and TVu 946. Similarly, TVnu 72 had the longest non-glandular trichomes on the abaxial leaf surface, followed by TVu 946 and IT82D-716 with significant differences between cultivars.

The density (no./mm^2) of glandular trichomes on the adaxial leaf surface of the three cultivars was not different ($P > 0.05$) although there were differences ($P < 0.05$) for the abaxial surface. The numbers of non-glandular trichomes on abaxial and adaxial leaf surfaces were higher in TVnu 72 and significantly different ($P < 0.05$) from TVu 946 and IT82D - 716. However, IT82D-716 and TVu 946 did not show any difference ($P > 0.05$) in the density of non-glandular trichomes. Significant negative correlations ($r = -0.99^{**}$ and $r = -0.99^{**}$) were found between the mean number of eggs laid on the abaxial surface of leaves (where most eggs were laid) and the length and density of non-glandular trichomes, respectively. Correlations between number of eggs laid and density and length of glandular trichomes were, however, not significant. *M. testulalis* larvae prefer sliced to unsliced pods because of the ease of boring and feeding through the cut ends. Slicing of the pods enables the larvae to circumvent the pericarp and trichomes.

Adult female *M. testulalis* showed strong ovipositional preference for the susceptible cultivar, IT82D-716, while the highly pubescent and resistant wild species, TVnu 72, was distinctly less acceptable. It is clear from the results that the greater length and higher density of non-glandular trichomes are responsible for the strong antixenotic effect of TVnu 72 on *M. testulalis* adult oviposition.

Within each cultivar, *M. testulalis* exhibits oviposition preference hierarchies, the abaxial leaf surface being the most preferred and the terminal shoots the least.

Because pubescence appears to be an effective character against larval settling preference and adult oviposition in *M. testulalis*, it would be advantageous to use the highly pubescent cultivar, TVnu 72 or similar wild cowpeas

Table 1.10 Mean percentage[1] of eggs laid by *Maruca testulalis* on different parts of three cowpea cultivars under choice and no-choice tests

Cultivar	Treatment	Adaxial leaf surface	Abaxial leaf surface	Terminal shoot	Branches	Stem	Stipules
TVu 946	choice	3.59 ± 1.81	13.83 ± 4.94	0.85 ± 0.34	1.03 ± 1.03	1.08 ± 0.31	0.59 ± 0.19
	no-choice	2.70 ± 1.40	19.25 ± 14.05	0.00 ± 0.00	0.00 ± 0.00	0.78 ± 0.78	0.00 ± 0.00
TVnu 72	choice	1.62 ± 1.22	3.79 ± 1.62	0.00 ± 0.00	0.00 ± 0.00	0.65 ± 0.14	0.00 ± 0.00
	no-choice	4.17 ± 4.16	0.26 ± 0.26	0.00 ± 0.00	0.00 ± 0.00	4.17 ± 4.17	0.00 ± 0.00
IT82D-716	choice	10.00 ± 4.61	47.94 ± 0.90	3.66 ± 3.66	3.79 ± 0.96	4.12 ± 0.76	3.48 ± 2.45
	no-choice	7.80 ± 7.80	47.14 ± 2.87	0.52 ± 0.52	4.95 ± 4.95	6.51 ± 6.51	3.91 ± 3.91

[1]Percentage egg data subjected to arcsine transformation before analysis.

in a breeding programme to incorporate pubescence into high-yielding commercial cultivars. This study and the previous one, shows for the first time, a holistic picture of the important role of pubescence in cowpea resistance to *M. testulalis*.

1.4 COWPEA RESISTANCE TO FLOWER THRIPS

S. Oghiakhe

1.4.1 Evaluation of cowpea germplasm for resistance to the flower thrips, Megalurothrips sjostedti *Trybom (Thysanoptera: Thripidae)*

In a preliminary effort to identify sources of resistance to the cowpea flower thrips, *Megalurothrips sjostedti*, a total of 95 diversified germplasm lines comprising of 14 ICV cultivars from ICIPE, 79 cultivars from IITA and two local cultivars were screened under natural field population pressure during the 1990 short rains season at ICIPE Mbita Point Field Station (MPFS).

First stage evaluation in single row plots. Test cultivars were planted three seeds per hole in single row plots each 2 m long with an inter-row spacing of 0.75 m. Distance between plants was 0.2 m and 1 m between adjacent blocks. Entries were planted to fit a randomised block design (RBD) with two replications planted at 2 week intervals. TVx 3236 was used as the resistant check while the susceptible check, Ife Brown was planted once in every 10 entries. Thinning to one seedling per hill was carried out approximately 10 days after planting (DAP). Two weeks prior to planting the test material, a susceptible cultivar (ICV 5), was planted around the border of the experimental plots and across the end of each block to serve as a reservoir of the test insect, *M. sjostedti*. 35 days later the spreader rows were uprooted and plants laid between rows of the test plants. This forces the thrips to move away from the drying plants to those of the test rows. No insecticide was sprayed due to the very low population of pre-flowering pests and *Maruca testulalis* which did not interfere with the assessment of thrips damage.

Visual rating scores based on a scale of 1–9 representing slight to heavy damage was carried out at 45 days and again at 55 DAP. Rating was based on the following components of resistance — a combination of varying intensities of browning of the stipules and racemes/flower buds, non-elongation of peduncles, and flower bud abscission.

Second stage evaluation in multi-row plots. During the 1991 long rainy season, 15 promising cowpea lines were selected from those previously evaluated in single-row plots at MPFS during the 1990 short rains for multi-row evaluation under natural field population pressure. These comprised of four ICV cultivars from ICIPE and 11 cultivars from IITA, Ibadan, Nigeria.

Test cultivars were planted three seeds per hole in four row plots each 2 m long with an inter-row spacing of 0.6 m. Entries were planted to fit a randomised block

Table 1.11 First stage evaluation[1] of cowpea cultivars for resistance to *Megalurothrips sjostedti* in single row plots under natural infestation (short rains 1990)

Cultivar	Damage parameters			Damage index[2]	Tolerance index[3]	Antibiosis index[4]
	Stipules	Flower buds	Flowers			
TVx 3236 (RC)	5.8	6.2	8.6	6.2	0.69	0.31
IT82D-885	3.8	6.2	7.0	5.6	0.63	0.37
IT83D-219	4.8	7.0	7.0	6.1	0.69	0.31
IT83S-728-5	6.6	8.6	5.8	7.0	0.79	0.21
ICV 2	8.2	6.6	7.0	7.2	0.81	0.19
IVC 3	8.6	7.0	6.2	7.2	0.81	0.19
IT82F-3132	7.4	7.8	7.8	7.7	0.87	0.13
IT83D-237	8.2	7.8	7.4	7.8	0.88	0.12
ICV 1	8.6	8.2	6.6	7.8	0.88	0.12
ICV 14	9.0	7.8	7.0	7.9	0.89	0.11
IT85F-2769	9.0	9.0	5.8	7.9	0.89	0.11
IT85F-3098	9.0	9.0	6.6	8.2	0.92	0.08
IT85F-2674	9.0	9.0	6.6	8.2	0.92	0.08
IT84D-522	8.2	8.6	7.8	8.2	0.92	0.08
IT84S-2155	9.0	9.0	7.4	8.5	0.76	0.04
TVx 1948-01F	9.0	9.0	7.4	8.5	0.96	0.04
Ife Brown (SC)	8.6	9.0	9.0	8.9	–	–

[1] Scale of 1–9, representing slight to heavy damage.

[2] Damage index = $\frac{\Sigma \text{indices for } n \text{ replications}}{\text{No. of replications}}$

[3] Tolerance index = $\frac{\textit{M. sjostedti} \text{ damage rating on test cultivar}}{\textit{M. sjostedti} \text{ damage rating on susceptible cultivar}}$

[4] Antibiosis index = 1 – tolerance index.

Table 1.12 Second stage evaluation[1] of cowpea cultivars for resistance to *Megalurothrips sjostedti* in multi-row plots under natural infestation (long rains 1991)

Cultivar	Damage index[2]	Tolerance index[3]	Antibiosis index[4]
TVx 3236 (RC)	3.0	0.37	0.63
IT82D-885	7.0	0.87	0.13
IT83D-219	7.0	0.87	0.13
IT83S-728-5	5.0	0.62	0.38
ICV 2	4.0	0.50	0.50
ICV 3	7.0	0.87	0.13
IT85F-3132	6.0	0.75	0.25
IT83D-237	6.0	0.75	0.25
ICV 1	6.0	0.75	0.25
ICV 14	7.0	0.87	0.13
IT85F-2769	9.0	1.12	-0.12
IT85F-3098	9.0	1.12	-0.12
IT85F-2674	9.0	1.12	-0.12
IT84D-522	6.0	0.75	0.25
IT84S-2155	7.0	0.87	0.13
TVx 1948-01F	8.0	1.00	0.00
Ife Brown (SC)	8.0	–	–

[1,2,3,4] See Table 1.11 for definition.

design with two replications. Other materials and methods are the same as described for the first stage evaluation experiment.

First stage evaluation in single row plots. Out of the 95 cultivars screened, only one cultivar, IT82D-885 had a score of 5.6. Four cultivars had scores ranging from 6.1 to 6.8, 27 cultivars had scores of between 7 and 7.9 while 40 cultivars scored between 8.1 and 8.9. A total of 23 cultivars had the lowest score of 9. Two cultivars performed better than the resistant check, TVx 3236.

Based on the above results, 15 cultivars were selected for further evaluation. Most of the cultivars selected showed tolerance to flower damage although were susceptible to stipule and flower bud damage (Table 1.11).

Tolerance indices ranged from 0.63 in IT82D-885 to 0.96 in IT84S-2155 and TVx 1948-01F while antibiosis index ranged from 0.37 to 0.04 in the same cultivars. Thrips population at MPFS was extremely high during the 1990 short rains season. Materials selected were further evaluated in replicated multi-row plots during the 1991 long rains season.

Second stage evaluation in multi-row plots. Out of the 15 cultivars evaluated, only ICV 2 and IT83S-728-5 had scores of 4 and 5 respectively. Four cultivars had scores of 6, five cultivars scored 7 and one cultivar scored 8. Three cultivars had worse scores than the susceptible check, Ife Brown.

Tolerance indices ranged from 0.50 in IT83S-728-5 to 1.12 in IT85F-2769, IT85F-3098 and IT85F-2674 respectively. Similarly, antibiosis indices ranged from 0.50 to -0.12 in the same cultivars (Table 1.12).

Based on these results, the following six cultivars were selected as moderately resistant to *M. sjostedti* at MPFS. The mechanisms and bases of resistance will be determined in laboratory and screenhouse studies.

1.5 COWPEA RESISTANCE TO APHID, *APHIS CRACCIVORA*

S. Oghiakhe

1.5.1 Modification of existing screenhouse technique for evaluating cowpea resistance to Aphis craccivora

As part of our efforts to improve precision and reliability of resistance screening techniques to cowpea pests, the existing screenhouse technique for screening cowpea resistance to *Aphis craccivora* was modified. The most important drawback in the existing "continuous tray" technique is the movement of aphids from one cultivar to another especially from the less to the more preferred cultivars. This is as a result of the continuity offered by the soil surface and also due to either antibiosis or non-preference for feeding/or oviposition. An obvious outcome of this phenomenon is the erroneous exaggeration of resistance or susceptibility in selected cultivars, a factor which has serious implications in host plant resistance research. A "discontinuous tray" technique was therefore introduced to overcome these constraints in the existing "continuous tray" technique.

The existing technique involves the use of a metal tray 120 x 150 x 15 cm (Figure 1.1A) and filled with soil to about 12 cm depth. Test materials including resistance and susceptible checks are planted in single rows of 10 plants each. Intra and inter-row spacing are normally 9 cm and 15 cm respectively. About 10 days after planting, individual plants in each test row are infested with 10 apterous adult aphids with a camel hair brush. Infested trays are transferred to cages (230 x 200 x 175 cm) in the screenhouse covered with mosquito net of fine mesh, small enough to allow passage of air but not insects.

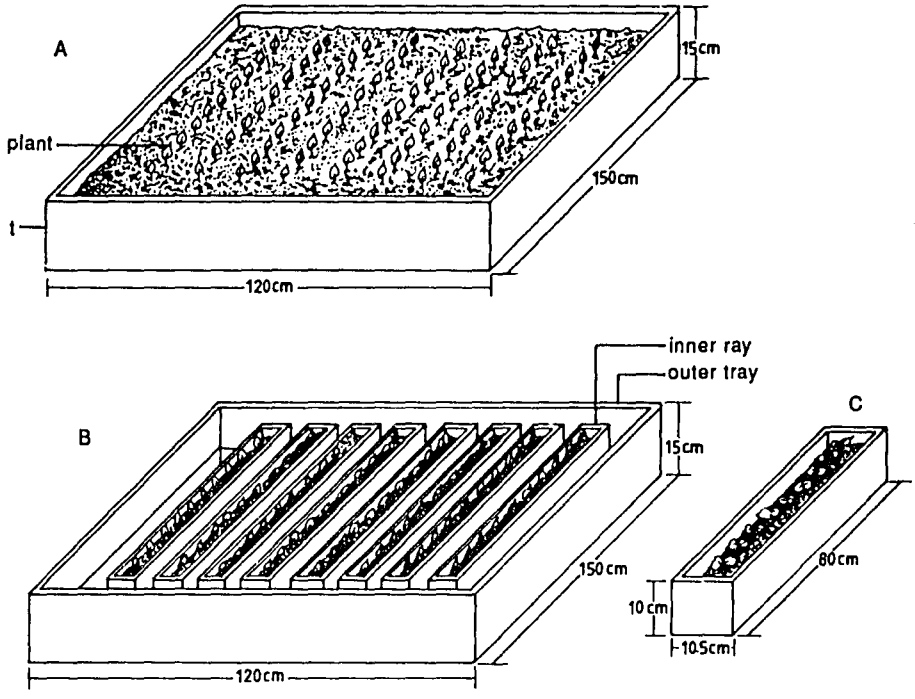

Figure 1.1 Metal tray used for studying cowpea resistance to aphid, *Aphis craccivora*. A, existing technique using metal tray with continuous soil; B, metal tray holding smaller trays in water; C, one of the smaller trays.

The new technique consists of a metal tray (120 x 150 x 15 cm) filled with water to about 5 cm depth. Eight smaller trays each measuring (80 x 10.5 x 10 cm) are arranged in single rows equidistant from each other inside the larger metal tray. They are filled with soil to about 7 cm depth and each test material including resistant and susceptible checks are planted in single rows in each tray (Figure 1.1B, and C).

1.6 GENETICS OF PLANT RESISTANCE TO INSECTS

R. S. Pathak and S. M. Othieno

1.6.1 Effect of plant vigour on expression of maize resistance to Chilo partellus

Previous studies on the inheritance of maize resistance to the spotted stem borer, *C. partellus*, have indicated that both additive and nonadditive genetic variances are important in the inheritance of resistance to *Chilo partellus*. However, the magnitude of nonadditive gene effects is much higher than that of the additive gene effects for the inheritance of deadhearts. The gene action for leaf-feeding and stem-tunnelling is predominantly additive. The estimates of the narrow sense heritabilities were low: 26.3% for stem-tunnelling, 30.6% for deadhearts and 33.3% for leaf-feeding, suggesting that expected selection gain for these resistance parameters would be slow in the intrapopulation improvement programmes. It was also observed that most of the F_1 hybrids between resistant and susceptible genotypes showed a high magnitude of heterosis for resistance to deadhearts. The other two resistance components, i.e. leaf-feeding and stem-tunnelling were not influenced. It would appear that the degree of resistance in F_1 hybrids was influenced by magnitude of heterosis in crosses between resistant and susceptible genotype. It was, therefore, decided to study the influence of plant vigour on expression of resistance components in different F_1 crosses between resistant and resistant, resistant and susceptible and susceptible and susceptible genotypes.

In view of the above, an experiment was carried out to determine the effect of heterosis for plant height on the expression of resistance components in a diallel cross between six genotypes; three resistant: ICZ1-CM, ICZ2-CM and MP 704, and three susceptible: Inbred A, Inbred G and OH43. Twenty-one progenies (15 F_1s and six parents) were planted in a randomised complete block design with three replications during long rainy season 1991 at the ICIPE Mbita Point Field Station. A 3 m long single row plot of each entry was planted at a spacing of 75 cm between rows and 30 cm between plants. Each plant was artificially infested with 30 blackhead stage eggs of *C. partellus* 18 days after emergence and was evaluated for three resistance parameters, namely leaf-feeding (1–9 scale), deadhearts (%) and stem-tunnelling (%). The details of evaluation methodology have been given earlier. Measurements of plant height were taken 3 weeks after plant emergence just before the plants were artificially infested. The results are given in Table 1.13. Significant

heterosis for plant height was recorded in all F_1 hybrids compared to the mean values of parents of a particular cross. On the other hand, it was observed that none of the F_1 hybrids particularly in susceptible x susceptible crosses were different from their respective parents or mid parent values for any of three resistance parameters measured. For example, all F_1 hybrids between susceptible parents — Inbred A, Inbred G and OH43 had significantly higher plant height compared to their parents and mid parent values but were similar to parents in their reaction to leaf-feeding, stem-tunnelling and deadhearts. These observations suggest that the degree of resistance in F_1 hybrids is not influenced by the degree of heterosis for plant height. In other words, the F_1 hybrids between susceptible and susceptible genotypes may express high degree of heterosis for plant characters such as plant height but will lack in resistance to insects. Hence, resistance to insects is conveyed only through the resistance genes contained in the parent involved in F_1 hybrids.

1.6.2 Germplasm enhancement in maize and sorghum
Programme on germplasm enhancement for resistance to *C. partellus* was initiated in 1990 with a view to broaden the genetic base of the sources of resistance. The population in maize included the resistant parents — ICZ1-CM, ICZ2-CM and MP 704. They were crossed to the susceptible but locally adapted and white seed colour genotype Inbred A. The sub-populations arising from crosses involving Inbred A with the resistant parents as well as between resistant parents were obtained. The F_2 populations of each were infested with 30 blackhead stage eggs 3 weeks after plant emergence. Only resistant plants were random mated within and between sub-populations. Further selection in S_2 generations will be pursued in populations with white grain colour and reasonable grain yield.

The germplasm enhancement programme in sorghum involved the crosses between resistant parents IS 1044, IS 2205, IS 2269, IS 12308 and the locally adapted commercial cultivar Serena. They were crossed to a common male sterile line Tx 624. All parents were crossed among themselves in a diallel fashion. The F_1s and mixture of different F_2s were planted in alternate rows with the male sterile line Tx624 to obtain BC_1F_1 and BC_1F_2, respectively. Equal quantities of these seeds from different crosses formed the initial (C_0) population which was grown during long rainy season of 1991. The male sterile plants have been tagged. All plants with good heads and seed set will be selected to form the new population (C_1) to be planted next season.

1.6.3 Cowpea resistance to aphid, Aphis craccivora
Significant progress has been made in understanding the genetic bases of resistance to aphid in cowpea. The resistance to aphid in cowpea is governed by a single dominant gene. So far two nonallelic dominant genes, *Rac* 1 and *Rac* 2 have been found. It would therefore be

Table 1.13 Means of parents and F_1 hybrids for resistance components and plant height in a diallel cross in maize

Progeny	Plant height (cm)	Leaf feeding (1–9)	Stem-tunnelling (%)	Deadheart (%)
Parent				
ICZ1-CM	46.53^{b-k}	6.29^{l-o}	31.45^{b-e}	0.7^{g}
ICZ2-CM	46.60^{b-i}	6.14^{h-p}	28.95^{c-i}	6.97^{fg}
MP 704	21.93^{v}	3.60^{v}	21.97^{i-n}	6.60^{fg}
Inbred A	30.73^{tu}	7.20^{abc}	45.14^{a}	38.07^{ab}
Inbred G	27.07^{u}	6.97^{a-f}	49.27^{a}	36.93^{abc}
OH43	31.80st	7.03^{a-e}	29.96^{b-h}	36.93^{abc}
F_1 hybrids				
ICZ1-CM x ICZ2-CM	50.00^{abc}	6.50^{c-l}	26.35^{d-n}	0.70^{g}
ICZ1-CM x MP 704	48.27^{a-f}	5.17st	26.04^{d-n}	0.70^{g}
ICZ1-CM x Inbred A	40.27^{l-q}	6.79^{a-i}	27.63^{d-k}	24.37^{b-e}
ICZ1-CM x Inbred G	40.33^{l-q}	6.93^{a-h}	24.86^{e-n}	6.60^{fg}
ICZ1-CM x OH43	46.87^{a-i}	6.60^{c-k}	27.32^{d-l}	0.70^{g}
ICZ2-CM x MP 704	44.40^{d-n}	5.73^{n-s}	25.82^{d-n}	0.70^{g}
ICZ2-CM x Inbred A	36.80^{o-r}	6.83^{a-h}	27.38^{d-k}	9.33^{efg}
ICZ2-CM x Inbred G	41.47^{l-p}	5.90^{e-q}	26.49^{d-n}	0.70^{g}
ICZ2-CM x OH 43	44.40^{d-n}	7.00^{a-f}	28.53^{c-j}	0.70^{g}
MP 704 x Inbred A	42.47^{g-n}	5.60^{o-t}	25.10^{e-n}	6.60^{fg}
MP 704 x Inbred G	46.53^{b-k}	6.10^{j-p}	30.72^{b-g}	6.60^{fg}
MP 704 x OH43	41.00^{j-p}	6.52^{c-j}	29.26^{c-i}	6.97^{fg}
Inbred A x Inbred G	33.33^{rst}	6.97^{a-f}	35.40^{bc}	35.00^{abc}
Inbred A x OH43	48.2^{a-f}	7.13^{a-d}	30.92^{b-f}	32.27^{a-d}
Inbred G x OH43	42.47^{g-n}	6.80^{a-i}	31.61^{b-e}	23.87^{b-e}

Column means followed by the same letter are not significantly different ($P > 0.5$), according to Duncan's Multiple Range Test.

possible to incorporate the resistance gene into high yielding and extra early maturing cultivar ICV 1 which is susceptible to aphid. A programme on improvement of ICV 1 for resistance to aphid was initiated using ICV 12 as a donor for resistance. BC_1F_2 population was artificially infested with five aphids 3 days after emergence. A number of resistant plants have been tagged and will be crossed to ICV 1 to obtain BC_2F_1. This population will then be grown as BC_2F_2 to select resistant plants following backcross-pedigree method.

1.7 IMPROVEMENT AND DEVELOPMENT OF RESISTANCE IN SORGHUM CULTIVARS AGAINST STEM BORERS

A. M. Nour

Throughout tropical countries, various insect pests attack sorghum causing great yield losses, and are a major constraint in achieving maximum yield potential for both varieties and hybrids. In view of this, work on sorghum improvement, aiming at developing high yielding cultivars with improved level of resistance to stem borers, has been undertaken jointly with the entomologist for the last 3 years. The study during the current crop season covers the following areas: (a) Testing and evaluating new promising sorghum hybrids for resistance to stem borers and grain yields under natural and artificial conditions; (b) Screening segregating generations for both agronomic traits and resistance to stem borers, and (c) Developing multiple resistance to stem borers and sorghum shootfly.

1.7.1 Evaluation of new sorghum hybrids

During the last season, 10 sorghum hybrids were identified as high yielding hybrids with improved level of resistance to stem borer. These hybrids and two local checks (Serena and IS-1044) were evaluated under artificial infestation. The objectives and the detailed procedures were outlined in the previous ICIPE Annual Reports.

The performance of the 10 elite sorghum hybrids with the standard checks are presented in Table 1.14. All the hybrids tested significantly outyielded the tolerant check (Serena). On the other hand, only three hybrids namely Tx623A x A-672, Tx623A x Plot108 and 1441A x IS-1044 significantly outyielded the resistant check (IS-1044). The hybrids Tx623A x IS-1044, 1441A x IS-1044, 1416A x IS-1044 and 1441A x Serena have significantly lower percentage deadheart and percentage stem-tunnelling than the tolerant check (Serena), thus identified as resistant hybrids. Foliar damage rating and larval and pupal population density showed no significant differences between the hybrids and the tolerant check.

On examining the correlation among the resistant parameters and yield components it was found that stem-tunnelling is positively and significantly correlated with deadheart, and negatively and significantly correlated with plant height. This indicates that short plants suffer severe stem damage by insects. The larval and pupal population density, on the other hand, showed negative and significant correlation with plant height which means that tall plants have less larval and pupal density.

1.7.2 Segregating generations

F_4 families. One hundred F_4 progenies, selected from last long rainy season, were planted, as F_5 families, on three non replicated rows of 3 m long. The variety IS-18363 (Swarna) was used as a check variety. Artificial infestation was done by placing 15–20 first instar larvae of *C. partellus* in the whorl of each plant 3 weeks after plant emergence. Observations were recorded on foliar damage, percentage deadheart, percentage stem-tunnelling

Table 1.14 Mean performance of 10 elite sorghum hybrids under artificial infestation of *C. partellus* at MPFS during long rainy season, 1991

Hybrids	Deadheart (%)	Foliar damage (1–9)	Stem-tunnelling (%)	Larvae and pupae (No.)	Plant height (cm)	Grain† yield (kg/ha)
Tx623A x IS-1044	2.59	2.30	13.83	3.38	261	4533
Tx623A x A-672	15.52	2.52	30.13	4.68	206	5539
Tx623A x Plot 108	18.20	2.59	30.86	5.39	202	4811
Tx296A x A-672	13.24	2.60	23.03	3.19	196	4732
Tx1416A x IS-1044	4.27	3.05	13.84	3.48	257	4627
Tx1416A x pp-29	10.97	3.31	32.82	3.44	147	4355
Tx1424A x A-672	13.08	2.86	23.60	4.66	200	4787
Tx1441A x IS 1044	5.00	2.63	14.09	4.47	268	5828
Tx1441A x Serena	2.64	3.12	24.51	6.04	269	4804
Tx1441A x A-672	10.14	2.85	22.62	4.41	192	4629
Serena (Check)	20.59	3.00	37.40	5.34	160	2689
IS-1044 (Check)	1.72	3.07	14.40	2.77	227	3272
LSD	10.20	ns	7.78	ns	17.50	1537

†Yield per plot. Plot size = 7.2 sq m.

and larval and pupal population density, using the methods already standardised by the collaborating entomologists at the ICIPE. Out of the 100 families, 40 were identified as promising and advanced to the next generation.

1.7.3 Developing population resistant to stem borer

The work on developing sorghum populations resistant to stem borer was started 3 years ago. A broad-based population was developed by crossing 15 resistant/tolerant sources to well known male sterile line. The objectives and the detailed methodology were outlined in the *ICIPE 1989 Annual Report*. During the current season, the second cycle of the population was planted in isolation plot of 40 x 30 m at MPFS. Selection was made on both male sterile and male fertile plants. Several male sterile plants with minimum insect damage were identified and tagged. Similarly, good looking fertile plants were selected and marked. At harvest, all the seeds from the selected male sterile plants and the seeds from selected fertile plants were bulked to form the basic seeds for the next cycle.

1.7.4 Developing multiple resistance to stem borer and sorghum shootfly

The work on developing multiple resistance to both stem borer and sorghum shootfly was started last season by crossing several resistant sources to three well adapted varieties. The objectives and the detailed procedure was outlined in the *ICIPE 1990 Annual Report*. In this season, 14 F_2 populations, generated during the off season, were planted at MPFS. Each population was grown on a plot of 20 rows 5 m long and 60 cm between the rows. Fishmeal was used to enhance the shootfly infestation. For stem borer, artificial infestation with first instar larvae of *C. partellus* was applied 3 weeks after emergence (WAE). Data were recorded on deadheart, foliar damage and stem-tunnelling.

The mean percentage of deadheart in the 14 populations ranged from 0–6 % (mean 2.0) and from 3–20 % (mean 11.1) for shootfly and stem borer, respectively. On the other hand, foliar damage rating ranged from 1–4 (mean 2.3). The mean percentage of stem-tunnelling ranged from 14–33 % (mean 21.7). The families IS-1044 x IS-2269, N-13 x IS-5469 and IS-1044 x IS-5469 scored the lowest percentage of deadheart for both shootfly and stem borer.

1.8 IMPROVEMENT AND DEVELOPMENT OF MAIZE FOR RESISTANCE TO STEM BORERS

S. O. Ajala

Maize improvement objectives and strategies for the period under review continued as previously described (*ICIPE 1990 Annual Report*). Specific activities include (1) improvement in levels of resistance through appropriate selection methods, (2) line development through inbreeding and (3) development of experimental varieties.

1.8.1 Improvement in levels of resistance

Mass selection. A selection programme was initiated in each of five maize populations. The selection procedure was earlier described (*ICIPE 1990 Annual Report*). Both the original (C_0) and Cycle 1 (C_1) from each population are being evaluated for possible gains by the collaborating entomologist. Concurrent with the evaluation is the advancement of C_1 to C_2. However, preliminary observation from the evaluation suggests that to a large extent, some form of progeny testing should be carried out before recombination.

1.8.2 Reciprocal recurrent selection

It is generally agreed that genotype by parameter interaction exist such that a genotype may be highly resistant to foliar damage but less for deadheart or stem-tunnelling and vice versa for another genotype. Therefore, to develop genotypes with improved levels of resistance, a reciprocal recurrent selection programme involving candidates that differ reciprocally for resistance parameters and whose combining ability (gca, general or sca, specific combining ability) are known *a priori*, can be used. This approach was investigated in a study involving seven populations earlier identified as possessing some levels of resistance.

The gca effect in most cases, was less than twice the corresponding standard errors (S.E.) for the three resistant parameters while the reverse was the case for grain yield (Table 1.15). However, both PR 7832 and MMV 400 had negative gca effects for each resistance parameter. PR 7832 also had positive effects for grain yield. A few crosses namely; ICZ1-CM x Katumani, PR 7832 x Nyamula and Nyamula x Katumani had negative sca effects for

Table 1.15 The gca effect for seven maize populations evaluated in diallel crosses for resistance parameters and grain yield (t/ha)

Population	Foliage damage	Deadheart	Stem-tunnelling	Yield
1. ICZ1-CM	0.09	0.09	-0.66	-0.92
2. ICZ2-CM	-0.01	0.83	-0.59	-0.22
3. PR 7832	-0.04	-0.83	-0.23	0.85
4. MMV 400	-0.02	-0.47	-1.35	-0.15
5. V-37	0.06	0.57	0.10	-0.03
6. Nyamula	-0.03	0.07	2.44	1.81
7. Katumani	-0.05	-0.26	0.28	-1.34
S.E.	0.03	0.84	0.59	0.05

Table 1.16 The sca and reciprocal effects for each of the three resistant parameters and grain yield among seven maize populations evaluated in diallel crosses

Cross[†]	Foliage damage		Deadheart		Stem-tunnelling		Grain yield	
	sca	rec	sca	rec	sca	rec	sca	rec
1 x 2	-0.17	0.02	-2.14	-1.34	0.55	-0.90	0.54	-0.101
1 x 3	0.10	0.02	-0.47	1.34	-1.92	1.69	-0.12	0.26
1 x 4	0.02	0.09	-0.83	1.34	-0.21	1.40	-0.14	0.16
1 x 5	-0.15	-0.12	0.63	-3.85	0.10	0.73	1.55	-0.03
1 x 6	0.03	-0.08	5.02	-5.05	-0.57	-2.85	-1.52	-0.31
1 x 7	-0.02	0.05	-2.38	0.00	-0.45	1.02	1.97	-0.40
2 x 3	0.19	-0.14	0.13	2.69	4.33	-4.40	0.36	-0.55
2 x 4	0.20	-0.06	-1.58	1.34	0.21	1.85	0.01	-0.09
2 x 5	-0.12	0.11	0.64	-1.93	0.25	0.38	1.16	0.27
2 x 6	0.15	0.10	-2.11	-1.34	-4.16	1.20	-4.53	-0.08
2 x 7	-0.05	0.04	5.80	2.40	1.14	1.92	2.28	-0.85
3 x 4	0.04	-0.04	-1.25	0.00	0.59	0.09	-0.37	-0.07
3 x 5	-0.02	-0.02	1.73	4.03	0.05	1.62	-1.99	-0.90
3 x 6	-0.05	0.08	-1.78	0.00	-1.36	-0.47	0.47	0.12
3 x 7	0.10	-0.05	0.94	2.40	0.59	-0.09	0.75	-0.25
4 x 5	-0.15	-0.11	-1.31	-1.34	-1.76	-2.25	-0.32	-0.36
4 x 6	0.04	-0.05	-0.81	-1.34	-2.40	1.78	-0.11	-0.36
4 x 7	-0.05	-0.05	1.45	-1.17	3.47	2.16	-0.45	-0.67
5 x 6	0.06	0.12	-0.51	2.69	-3.84	-0.02	-0.26	0.03
5 x 7	-0.09	0.07	1.16	1.35	5.36	3.26	0.11	-0.99
6 x 7	-0.03	0.03	-2.36	0.00	-0.01	0.04	0.67	0.22
S.E.	0.06	0.07	1.66	2.04	1.17	1.43	0.33	0.41

[†]See Table 1.15 for entry names.

Table 1.17 Phenotypic correlations (above diagonal) and correlations among gca effects (below diagonal) for the resistant parameters for a, inbred and b, population crosses

Trait		Foliage damage	Deadheart	Stem-tunnelling
Foliage damage	a.		0.28*	0.55**
	b.		0.18	0.41**
Deadheart	a.	0.53		0.28*
	b.	0.47		0.09
Stem-tunnelling	a.	0.75	0.70	
	b.	-0.25	0.10	

*Significant, $P < 0.05$; **Significant, $P < 0.01$.

the resistance parameters (Table 1.16) and positive effect for grain yield. MMV 400 x V-37 had negative sca effect for the resistance parameters and grain yield. Thus, it appears that some populations can be paired in a reciprocal recurrent selection aimed at developing maize genotypes with reduced foliage damage, deadheart and stem-tunnelling and that produce good yield.

1.8.3 Relationship between resistance parameters

Correlation coefficients among the three resistant parameters for both inbred and population-cross diallel are presented in Table 1.17. Correlations among gca effects especially for single-crosses were much higher than their corresponding phenotypic correlations suggesting that simultaneous selection of second generation inbreds possessing improved levels of resistance to the three resistance parameters, is feasible.

1.8.4 Line extraction

Taking account of the three resistant parameters (foliage damage, deadheart and stem-tunnelling), and utilising remnant seeds of the selfed progenies from the mass selection programme, a number of S_3 lines currently being advanced to S_4 generation of inbreeding, have been isolated (Table 1.18). Other lines isolated were from crosses among resistant genotypes. Each of the isolated lines has a foliage damage rating of <3, deadheart and stem-tunnelling values of less than or equal to 2.68 and 18.85 respectively, on the arcsine transformed scale.

Some maize genotypes obtained from the International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria, were evaluated for resistance to *C. partellus* and two new sources of resistance identified. TZBR-ELD-1 C3 was developed for resistance to *Eldana saccharina* while DMR-LSR-W is a downey mildew resistant variety. Both maize populations are white grained and of medium maturity. S_1 lines were extracted from each of the populations and evaluated under artificial infestation for resistance to *C. partellus*. Desirable lines are currently being advanced to the S_2 generation of inbreeding.

Table 1.18 Isolated resistant S_3 lines and their sources currently being advanced to S_4 generation of inbreeding

Source	Number
ICZ1-CM	10
ICZ2-CM	11
PR 7832	18
V-37	28
MMV 400	17
Within crosses	96
Mochore†	1

†Mochore is a local Kenyan population from Kisii District.

1.8.5 Development of resistant germplasm

Two germplasms were also developed; IC-90-W1 and IC-90-Y1 earlier formed as experimental varieties, are composites derived from resistant genotypes and later separated along colour lines to form white (EV-90-W1) and yellow (EV-90-Y1), respectively. Both are of medium maturity and give grain yield of about 5 t/ha.

S_3 lines identified as resistant are being topcrossed to a common tester. Lines identified from the topcross evaluations will also be used to generate synthetics. The genetic base of IC-90-W1 is being broadened by the inclusion of selections from recently identified sources of resistance such as Pop 10, ER 29 SVR and MMV 600.

Our objective at the initiation of this programme was to isolate lines and develop germplasms that can be used by the National Agricultural Research Systems (NARS) to breed for resistance to the spotted stem-borer *C. partellus*. Apparently, we have been able to achieve initial progress. The utilisation of these resistant materials by NARS in partnership, is our next focus, which we hope to achieve through the Pest Management Network of the ICIPE. Currently, on-going collaboration exists between the ICIPE and national programmes in Kenya, Zambia, Rwanda and Somalia. Efforts are on-going to increase the collaboration with other countries of East Africa where the pest problem occurs.

BIOLOGICAL CONTROL (BC)

The Biological Control Section aims at developing strategies for an efficient utilisation of natural enemies (predators, parasitoids and pathogens) of target pests of crops for pest management.

In the period covered by this report, further work was carried out in order to elucidate the factors that would lead to the enhancement of the efficiency or efficacy of the biological control agents when used in the field.

1.9 EFFICACY OF *BACILLUS THURINGIENSIS* IN THE CONTROL OF *CHILO* SPP. ON MAIZE IN THE COASTAL PROVINCE OF KENYA

M. Brownbridge, M. O. Odindo and T. Onyango

Bacillus thuringiensis has been demonstrated to be highly effective for the control of *Chilo partellus* in the laboratory, screenhouse and controlled field conditions. In order to validate this efficacy under true field conditions in an area of high natural *Chilo* infestation, it was necessary to carry out a series of investigations in Mtwapa, approximately 18 km north of Mombasa, in coastal region of Kenya.

The first small scale field trials were undertaken during the short rains of 1989. A novel *B.t.* strain, M44-2, identified as *B.t.* var. *kurstaki* by the Institute Pasteur (Paris, France), was used. The bacterium was produced in shake flasks and preserved as an acetone powder. The powder was re-suspended at a 1% w/v concentration in a 1% w/v sugar solution. Crude cotton seed oil was added to the preparation to act as wetter at a 1% v/v concentration.

High natural infestations of the stem borers *C. orichalcociliellus* and *C. partellus* are regularly observed at the coast. The area was therefore, an excellent experimental site. The experimental work was done at the KARI Mtwapa Experimental Research Station, and were conducted during the long rains cropping period (March–August) of 1990.

The *B.t.* preparation used was based on a novel *B.t. kurstaki* strain produced by BMP Inc. as a liquid formulation with a calculated toxicity of 8500 ITU/mg. The maize variety Coast Composite (Kenya Seed Company) was grown in a field site measuring 52 x 90 m. The site divided into 16 plots in a 4 x 4 Latin square design, each plot measuring 13 x 22. 5 m, Four treatments were applied to crop, each treatment being replicated four times. The following treatment regimes were used:

A — Control, no treatment
B — *B.t.* spray, 4% v/v concentration
C — *B.t.* spray, 2% v/v concentration
D — Dipterex granules

The plants were naturally infested with *Chilo* spp. at the time of treatment. The first treatments were applied 4 weeks after plant emergence (WAE) and repeated at 6 WAE. The *B.t.* treatments were prepared in a 1% w/v sugar solution, and applied using knap sack sprayer with a coarse spray nozzle. The spray was directed into the leaf funnels of the plants at 4 WAE, and at the developing flower head at 6 WAE. These were observed to be the major sites of larval infestation in the trials undertaken during the short rains of 1989. Dipterex is a granular insecticide produced by Bayer EA Ltd (Nairobi, Kenya) containing 2.5% by weight of Trichlorphon, a contact/stomach poison. The granules are supplied in a shaker applicator and were directed into the leaf funnels or developing head of the maize plants, 4 and 6 WAE.

External damage symptoms were recorded every 2 weeks to harvest from a total of 25 plants per replicate. Five plants per replicate were dissected (total 20/treatment/sampling) and plant damage levels recorded.

At harvest, 25 plants were randomly selected from each replicate and dissected to determine the final damage levels according to the treatment applied. For yield assessment, cobs from 250 plants per replicate were sampled from six 3 x 3 m blocks. The cobs were shelled and the actual grain yield per replicate sample taken.

Table 1.19. Grain yield/1000 maize plants (var. Coast Composite) after treatment with an insecticide and a novel *B.t.* var. *kurstaki* formulation at two concentration levels

Treatment applied	Grain yield/ 1000 plants (kg)	Per cent yield increase	Projected yield increase/ha (kg)
Control	143.0	–	–
B.t. 4% v/v	150.0	4.8	486.0
B.t. 2% v/v	152.0	6.3	625.0
Dipterex	144.5	1.0	70.0

Throughout the experiment, plant damage in the *B.t.* treated plots were markedly lower than in both the control plots and the Dipterex treated plots. There was no difference between the damage levels observed in the plants in the *B.t.* 2% v/v or the *B.t.* 4% v/v treated plots.

The best representation of the relative efficacy of these different treatments in controlling *Chilo* populations may be seen by comparison of grain yields in Table 1.19. Modest increases in yield were obtained for all the plant protection treatments. The highest increase in yield over the non-treated plots was recorded for the *B.t.* 2% v/v treatment. If the data are extrapolated, this represents an increase of approximately 625 kg/ha. The *B.t.* 4% v/v produced a lower grain increase of 486 kg/ha, but this is still favourable when compared to the 70 kg/ha increase calculated for Dipterex treatment.

1.10 *NOSEMA MARUCAE* AND *BACILLUS THURINGIENSIS* FOR THE CONTROL OF CEREAL STEM BORERS OF MAIZE AND SORGHUM

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

In previous reports, we have shown that both the microsporidian pathogen *Nosema marucae* and *Bacillus thuringiensis* can control the cereal stem borers *Chilo partellus* infestations on maize and sorghum. Subsequently field investigations were carried out on the interaction of some maize and sorghum varieties with *N. marucae* and *B. thuringiensis* in the control of the stem borer. The major objectives of this research were:

(1) To investigate the level of control of *C. partellus* with *N. marucae* and *B. thuringiensis* when sprayed on various varieties and hybrids of maize and sorghum.

(2) To determine the level of interaction of pathogen and the environment, and investigate the efficacy of *N. marucae* and *B. thuringiensis* in various ecological zones.

Three maize composites and hybrids (Hybrid 511, Hybrid 512, Katumani Composite, Coast Composite, and Pwani Hybrid), as well as three sorghum varieties (Serena, LRB 5 and LRB 8) were planted in three locations in Kenya representing three ecological zones: Mbita Point Field Station in western Kenya to represent the medium altitude, single rainy season zone with low humidity and high temperature; Mtwapa in Coast Province with two rainy seasons, high humidity, and high temperature, and Alupe, Busia in western Kenya which has two rainy seasons, and medium humidity and temperature. These ecological zones represent the climate conditions that occur over most of Africa. The fourth ecological zones of high altitude, two rainy seasons, low temperatures and humidity (Embu, Kenya highlands) has been used in earlier trials. The fields were infested with natural populations of *C. partellus*. There was a mixed population of *C. partellus* and *C. orichalcociliellus* in Mtwapa. There were three treatments (*Nosema*-treated plot, *B.t.*-treated plot, plot treated with Dipterex (tricholorophon) or Furadan (carbofuran) as well as a non-treated plot. There were three replicates, and the plots were treated in a two-factorial with split plot design.

The results obtained from all the investigation sites showed that the agents controlled the cereal stem borers in all the sites, and in both maize and sorghum but in this report, we present data from Mtwapa. There were no

Table 1.20 Foliar damage at 4 weeks after treatment in sorghum sprayed with aqueous formulations of *Nosema marucae* and *Bacillus thuringiensis*, Mtwapa, Coast Province, Kenya

Sorghum variety	Proportion of plants showing foliar damage (%) at indicated treatment			
	Nosema	*B.t.*	Dipterex	Control
Serena	5.7[a]	4.9[a]	5.1[a]	92.8[b]
LRB 5	2.8[a]	4.1[a]	3.6[a]	73.5[b]
LRB 8	4.5[a]	3.3[a]	3.4[a]	69.1[c]

[a]Means are not significantly different either between treatments, or between varieties ($P = 0.05$).
[bc]Means are significantly different from treated plots, and between varieties ($P = 0.05$).

Table 1.21 Larval infestation at 8 weeks after treatments in sorghum sprayed with aqueous formulations of *Nosema marucae* and *Bacillus thuringiensis*, Mtwapa, Coast Province, Kenya

Sorghum variety	Mean number of larvae/plant at indicated treatment			
	Nosema	*B.t.*	Dipterex	Control
Serena	1.2[a]	0.8[a]	0.5[a]	12.3[b]
LRB 5	0.9[a]	0.5[a]	0.7[a]	9.5[c]
LRB 8	0.6[a]	0.9[a]	1.1[a]	8.4[c]

[a]Means are not significantly different either between treatments, or varieties ($P = 0.05$).
[b,c]Means are significantly different from treated plots, and between varieties ($P = 0.05$).

Table 1.22 Yield of maize (Coast Composite) in plots treated with *Nosema marucae* as compared within plots treated with Furadan (carbofuran) and non-treated plots infested with *Chilo partellus*, Mtwapa, Coast Province, Kenya

Treatment	Yield of clean seed/plant in kg (Mean ± S.E.)[†]
Nosema spray	35.9 ± 4[a]
Carbofuran	37.2 ± 2.6[a]
Control plot	29.9 ± 2.7[b]

[†] Numbers with similar letters are not significantly different (P=0.05).

differences in level of control between the varieties (Tables 1.20 and 1.21). Further, both *Nosema* and *B.t.* gave control level equivalent to the chemical insecticides tested i.e. carbofuran or trichlorophon. Yield of maize (Coast Composite) was significantly higher in the pathogen and insecticide-sprayed plots than in the non-treatment plots (Table 1.22).

1.11 EVALUATION OF FORMULATIONS OF *BEAUVERIA BASSIANA* FOR CONTROL OF THE STEM BORER, *CHILO PARTELLUS*

N. K. Maniania

Beauveria bassiana (isolate ICIPE 35) which was isolated from soil at MPFS in Kenya was demonstrated to be highly effective against larvae of *Chilo partellus* in the laboratory (*ICIPE 1990 Annual Report*) and in field trials during 1990 short rains and 1991 long rains. We report here on the evaluation of three types of formulation of this strain for the management of the stem borer *C. partellus*.

Maize (Katumani Composite cultivar) was planted (30 November 1990) in a 20 x 15 m area at MPFS. The experiment was a split-plot design with four replications. Each plant was artificially infected by placing one blackhead stage egg mass of *C. partellus* (30–40 eggs), obtained from Insect Mass Rearing Technology Unit (IMRTU), into the whorl 2 weeks after plant emergence. Each of the three formulations was then applied as a single treatment. Controls consisted of infested and untreated plants.

The following formulations were used:

(1) Dry rice grain-based inoculum in which the sporulation has been stopped (treatment 1, T_1);

(2) Dry rice grain-based inoculum in which the sporulation has been stopped, but was soaked before application (treatment 2, T_2);

(3) Aqueous conidial suspension (treatment 3, T_3).

Conidia in T_3 were produced in trays (35 x 25 x 3 cm) filled 1 cm deep with autoclaved rice grains. The substrate was inoculated with a blastospore broth of *B. bassiana*, and incubated for 10 days in a controlled room temperature (25 ± 2°C; 50–60% r.h.). The culture was then air-dried overnight in a laminar flow cabinet. The substrate was suspended in distilled sterile water containing a 0.05% Triton X-100 and stirred in a Kenwood Major mixer. The conidia were separated by sieving. The suspension was then diluted to 5 x 10^8 conidia/ml. Nutrient agar (0.1%) and Triton X-100 (0.1%) were added to the inoculum to complete the formulation. Aqueous conidial suspension (T_3) was applied on the maize plants with a knapsack sprayer. The fungus in T_1 and T_2 was prepared following similar procedure with the exception that the culture was allowed to grow for only 3 days. The substratum formed a mycelial mat which was sprayed with a liquid semi-synthetic medium, and left to air-dry overnight. The culture was then transferred into plastic bags and stored in a refrigerator until just before field application. The fungal materials were distributed by hand into maize leaf funnel at the rate of about 1 g per plant. In T_2, the fungus mat was soaked in water for 24 hours prior to application.

At weekly intervals, five plants were randomly picked from each treatment/block to assess foliar damage (scale from 1 to 9), number of larvae, and stalk borer tunnel lengths within the plants. Living stalk borer larvae were monitored for fungal mortalities in the laboratory. Therefore, insects were placed in plastic petri dishes with maize leaf or stalk, and maintained in a controlled temperature room. The larvae were checked every 2 days for mortality. Dead insects were kept in petri dishes lined with wet filter paper to allow possible mycosis development.

Dead rice grain based-inoculum formulation was formed of mycelia mostly, and of scattered conidia. One gram of culture contained about 2.7 x 10^7 conidia/ml. In viability tests, mycelial growth started within 8–10 hour after incubation on moist filter paper, and conidial

Table 1.23 Mortality ($x \pm$ S.E.) of *Chilo partellus* larvae due to fungal infection at 1, 2 and 3 weeks after treatment

Treatment	Days after treatment†		
	7	14	21
Control (untreated)	0	0	0
Treatment 1	23.3 ± 8.6[b]	24.6 ± 6.9[b]	9.4 ± 9.4[a]
Treatment 2	8.8 ± 3.4[ab]	10.9 ± 4.2[a]	3.5 ± 3.5[a]
Treatment 3	5.4 ± 3.2[ab]	0	5.2 ± 5.2[a]

†Percentage mortality transformed in arcsine. Means within a column followed by the same letter are not significantly different ($P < 0.05$; Duncan's multiple range test).

Table 1.24 Grain yield ($x \pm$ S.E.) obtained in maize infested with *Chilo partellus* and treated with *Beauveria bassiana*

Treatment	Mean grain yield† (g/plant)
Control (untreated)	65.9 ± 10.9[a]
Treatment 1	111.7 ± 0.6[b]
Treatment 2	96.1 ± 4.5[b]
Treatment 3	116.4 ± 11.7[b]

†Means within column followed by the same letter are not significantly different ($P < 0.05$; Duncan's multiple range test).

production within 48 hours after incubation.

A good level of control of *C. partellus*, in terms of foliar damage, stalk tunnel length, and grain yield was achieved by application of aqueous conidial suspension (T_3) and of dried rice grain-based inoculum in which sporulation was stopped (T_1). For example, the number of *C. partellus* larvae observed within the stalks 2 weeks after treatment (WAT) accounted for an average of 15 larvae/plant in the control, while it accounted for 3 larvae/plant and 5 larvae/plant in T_1 and T_3, respectively. A tunnel length of 17 cm, 5 cm and 8 cm/plant was found in the control, T_1 and T_3, respectively, being recorded 8 WAT.

Mortalities caused by the fungus in the laboratory were extremely low. The highest rates were obtained with T_1, mortalities being 16% (23.3 ± 8.6) and 17% (24.6 ± 6.9) at 1 and 2 weeks after treatment, respectively (Table 1.23).

Grain yield in treated plots was significantly higher than in the untreated plots ($P < 0.05$) (Table 1.24). Treatments T_1 and T_3 accounted for 59 and 77% higher grain yield respectively, than in the control plots. Even T_2 produced a higher grain yield than did the control.

The small-scale farmer in developing countries may easily adopt microbial pesticides if appropriate technology of production and application is developed. Aqueous conidial and dry rice grain-based inoculum formulations showed similar performance in the field tests. However, dry rice grain formulation does not require any preliminary preparation, and the inoculum can persist in the axils of maize leaves. Therefore, this formulation should be tested advantageously for the management of *C. partellus* by the small-scale farmer. However, further investigations are necessary to perfect this preparation, and to evaluate the use of other cheap, locally-available raw materials and fungal viability under ambient conditions.

1.12 DISCOVERY CAPACITY BY PARASITOIDS AND PREDATORS OF *CHILO PARTELLUS* EGGS

E. F. Dwamfour, J. Owino and M. Andere

Crop diversification has the advantage of attracting and retaining natural enemies as well as reducing pest numbers in agroecosystems. In generating predictive strategies for pest suppression in agricultural systems, the compatibility of cropping patterns (with varietal differences) with predator-prey and parasitoid-host interactions should be assessed on a case to case basis. In some cases poly-cultures may adversely affect the searching behaviour, efficiency and reproduction of natural enemies. At MPFS trials were conducted with the aim of assessing the discovery capacity of borer egg batches by the egg parasitoid *Trichogramma bournieri* Pintureau & Babault and some naturally-occurring predators in fields cropped with five genotypes of sorghum (Serena, IS 1044, IS 18363, LRB 5 and LRB 8). Dr. A. B. Polaszek (IIE) is thanked for identifying the parasitoid formerly believed to be *T.* sp. nr. *mwanzai*.

1.12.1 Parasitic activity of T. bournieri *in different genotypes of sorghum*

Trichogramma bournieri performance in locating and attacking egg batches of the maize and sorghum stem borer *C. partellus* was studied on a farmer's field at Mbita, western Kenya during the long rains of 1991.

There were five sorghum varieties (Serena, IS 1044, IS 18363, LRB 5 and LRB 8) in monocrops.This represented the number of treatments. Each was replicated five times in 6 x 5 m plots. A single, freshly-laid host egg mass was placed on 25 randomly selected cereal plants on each plot and 400 mated individual *T. bournieri* were released at the centre of the plot. Observations commenced 5 weeks after plant emergence (WAE) and continued till harvest (18 WAE).

Host egg batch discovery (proportion of egg batches parasitised out of the number recovered 48 hours later) by *T. bournieri* in the field was low (10.7–13.5%) (Table 1.25).

No significant differences in parasitic activity (synonymous with discovery capacity) was observed in the five different treatments. None of the five sorghum genotypes was superior in attracting and retaining parasitoids. Levels of parasitism compared well with values obtained during the LR and SR season of 1990 (9.6–19.2% and 4.9–17.8% respectively, (see *ICIPE 1990 Annual*

Table 1.25 Discovery capacity by *T. bournieri* of egg batches of *C. partellus* in different genotypes of sorghum

Sorghum genotype	Mean number of egg masses attacked[1]
IS 1044	13.531 ± 1.297[a]
LRB 5	12.585 ± 1.380[a]
LRB 8	12.402 ± 1.314[a]
Serena	10.730 ± 1.283[a]
IS 18363	10.722 ± 1.294[a]

[1]Data transformed with arcsine square root transformation. Means followed by the same letter are not significantly different at $P = 0.05$.

Report). It is assumed that *T. bournieri* have a low dispersal capacity; eggs placed in maize and cowpea pots adjacent to the experimental plots were not found by parasitoids released in the treatments. Levels of parasitism in the adjacent maize and cowpea plots were 0.6 and 1.7%, respectively.

1.12.2 *Response of varying densities of* T. bournieri *to* C. partellus

This study was designed to determine the numerical response of the parasitoid to its host *C. partellus*. It has been reported elsewhere (see *ICIPE 1990 Annual Report*, section 1.22) that the parasitic activity of *T. bournieri* is not density-dependent i.e. no significant differences in parasitism were observed when 200 parasitoids were offered varying densities of the host.

To study the response of *T. bournieri* to a constant host population, 25 host egg masses were placed on 25 sorghum (cultivar Serena) plants in plots measuring 5 x 5 m. Three parasitoid densities (400, 800 and 1200) were chosen for the trials. For each density five replications were made. Host infestations and parasitoid releases were made once every week 5 WAE till harvest 18 WAE. The exposed host egg batches were recovered 48 hours later.

Generally, levels of parasitism were low and did not increase significantly with increasing parasitoid densities. At parasitoid densities of 400, 800, and 1200 mated individuals/plot, 9.2, 11.3 and 11.1% of host egg batches respectively were found to be either partially or fully parasitised. It has been ascertained that *T. bournieri* cannot effectively exert any suppressive pressure on the population of *C. partellus*.

1.12.3 *Role of naturally-occurring predators in regulating population of* C. partellus

Observations were made to assess the importance of naturally-occurring predators in regulating numbers of *C. partellus*. The study assessed the performance of predators (mainly generalists) under different sorghum genotypes.

Predation of *C. partellus* egg masses by predators (predominantly the earwigs, *Diaperasticus erythrocephalus* and *Forficula auricularia*, the coccinellids, *Cheilomenes sulphurea*, *C. propinqus* and a *Cheilomenes* sp., the ants, *Pheidole* sp. and *Camponotus* sp. and many spiders) was observed in the plots where studies were conducted on *T. bournieri*.

The combined activity of naturally-occurring predators was significantly higher in the sorghum varieties Serena, IS 18363 and LRB 5 than in IS 1044 and LRB 8 (Table 1.26) Egg batch discovery by predators was twice higher in hedges 2–3 m away from the experimental plots. As the season progressed, natural enemy activity increased. Naturally-occurring predators would consume less than 2 days old parasitised *C. partellus* eggs or even prey eggs which had turned black as a result of *T. bournieri* parasitism. Levels of predation for the two different types of eggs were not significantly different. The proportion of parasitised egg batches attacked by predators was similar to that of freshly-laid, unparasitised borer egg masses. In the absence of suitable and acceptable prey these predators will feed on host egg batches that contained a developing parasitoid.

Table 1.26 Discovery capacity of *C. partellus* egg batches by naturally-occurring predators

Treatment	Mean number of egg batches attacked ± S.E.[1]
Serena	33.79 ± 1.86[a]
LRB 5	32.08 ± 1.83[a]
IS 18363	31.88 ± 1.92[a]
IS 1044	28.46 ± 1.86[b]
LRB 8	28.06 ± 1.58[b]

[1]Data transformed with arcsine square root transformation. Means followed by the same letter are not significant at $P = 0.05$.

It has been confirmed through laboratory assessments that among the naturally-occurring predators earwigs and ants may be the major mortality factors of *C. partellus* eggs in the field. The lady-bird beetles may add very little impact to pest regulation since these are predominantly aphidophagous and may select aphids which are abundant on both cereal and legume plants on the experimental plots.

1.13 FIELD EVALUATION OF *HIRSUTELLA THOMPSONII* FOR THE CONTROL OF CASSAVA GREEN SPIDER MITE, *MONONYCHELLUS TANAJOA*

M. O. Odindo, L. W. Ochogo, J. O. Obilo, J. A. Ongoma and J. A. Ogwang

Previously, we reported that the Hyphomycete *Hirsutella thompsonii* can spread in the cassava field infested with the cassava green spider mite (CGM) *Mononychellus tanajoa*. In the present study we report on trials carried out in the field on the foliar application of *H. thompsonii* spores for CGM control.

1.13.1 *Pathogen suspension*

H. thompsonii spores were produced either on sabouraud

dextrose agar (SDA) or a simple medium prepared from boiled potatoes and sucrose. The fungus was scraped from the surface of the solid growth medium, and the fungal spores and mycelial mat was blended in a kitchen blender. The spore concentration was determined in a Neubauer chamber counter and made upto 1.3 x 10^{13} spores/ml.

1.13.2 Cassava field plots

Research fields were prepared and planted with cassava according to standard agronomic practice in major cassava growing area at Ambira, Siaya District, Nyanza Province, Kenya. The field was ploughed and planted for the short rains in August 1989. The research plot was located adjacent to other cassava fields, all of which were highly infested with *M. tanajoa*, and acted as a source of CGM for natural infestation of the research plots. The main field (40 x 60 m) was divided into three blocks, each with two plots of 20 x 20 m. Each plot was planted with either var. Black or var. Red — two cassava varieties popularly grown for food in the area. Rate of planting was 1 m between plants and 1 m between rows. Each plot was divided into two sub-plots.

1.13.3 Application of H. thompsonii

Foliar sprays of *H. thompsonii* were applied on the fields of cassava at 4 months after planting. The pathogen was sprayed only on one of the two sub-plots of cassava varieties Black or Red, while the other plot was sprayed with clean tap water and was the control (unsprayed) plot. The pathogen was applied using a 15 l shoulder-held Solo sprayer at the rate of 1.3 x 10^{13} spores/ha. There were two spray applications — the first at 4 months after planting (December 1989), and the second 1 month later (January 1990).

1.13.4 Monitoring cassava mite populations

Sampling of cassava for CGM started from 1 month after planting, in October 1989. Samples of the first five open leaves were taken from three plants selected at random for each sub-plot. The number of mites on each leaf as mite mortality was determined in the laboratory by examining the leaves in a Wild M8 stereomicroscope. All dead mites were examined directly for the presence of *M. thompsonii*. Further, mite cadavera were placed on approximately marked filter paper, which had been wetted with sterile distilled water and placed in a sterile sterilin petri dish. The cadavers were examined at 7 and 10 days after preparation. The growth of the typical *H. thompsonii* sporulation with phialides bearing terminal conidia was recorded. Any other fungal growth was noted, and the microorganism was isolated on plants of PDA tubes according to standard mycological techniques.

Records on mite mortality were taken for all plots, from the first month after planting for 12 months.

The application of *H. thompsonii* gave a high increase in the level of mortality of CGM (Figure 1.2), especially in the period of February 1990, that is 2 months after the initial pathogen application. The fungal infection also spread to the unsprayed control plots where by April 1990, *Hirsutella* infection of 13.7% was recorded. The high level of infection and mite mortality resulted in collapse of CGM population from about 2 months after pathogen applications. By April 1990, the level of mite infestation on the two varieties of cassava had fallen to 2.5 mites/leaf on Black, and 8.2 mites/leaf on Red (Figure 1.3).

H. thompsonii has been established as a pathogen of mites for some time. Described from the citrus rust mite *Pyllocoptruta oleivora* some 40 years ago, it has since been isolated from various species of Acari throughout the world. A successful large-scale production of the pathogen may be carried out in submerged culture. *H. thompsonii* is therefore, a well established pathogen for application against plant mites. Our present observations are an indication that this pathogen may be applied in tropical root crops as well.

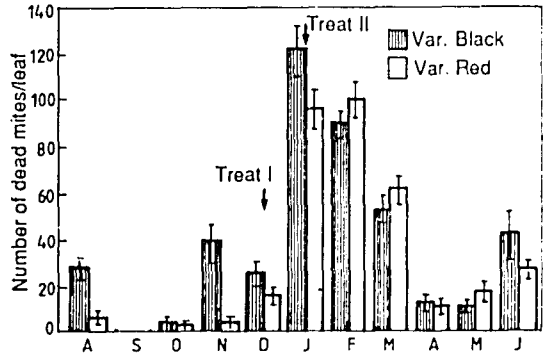

Figure 1.2 Mortality of cassava green mite after treatment with *Hirsutella thompsonii*. Ambira Farmers Field, August 1989 – June 1990.

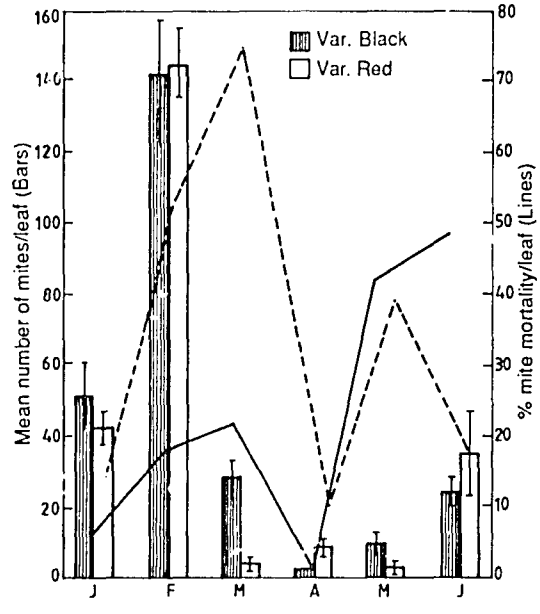

Figure 1.3 Variation in cassava mite population and mite mortality on two varieties of cassava after application of *Hirsutella thompsonii*. Ambira Farmers Field, January to June 1990.

The long period in which *H. thompsonii* continued to exert high CGM mortality in the cassava field in the present studies is an indication of the sustainability of this pathogen in the field environment. Mortality of 43 mites/leaf was recorded in June 1990, which was about 6 months after the pathogen was applied in the field, compared to 4.7 mites/leaf in unsprayed plots. More than 23% of the cadavers had died due to *H. thompsonii* infection according to the results from the isolations and the wetted filter papers. In the earlier part of the season (January to April 1990), mite mortality was higher in the sweet cassava variety (Red) than Black, and reached a peak of 77% in March, 1990, compared to 15% in Black (Figure 1.3). These differences were not maintained in the latter part of the growing season however.

H. thompsonii appears therefore to continue to control CGM throughout the growing season of cassava, as this crop may be harvested anytime from 6 months after planting. Our harvesting period (1 year after planting) is the standard period for most cassava growing areas of Kenya.

1.14 SUPERPARASITISM IN *TRICHOGRAMMA BOURNIERI*

M. J. Chacko

Superparasitism or a superabundance of parasitoids of a single species developing in an individual host insect is of common occurrence in insect parasitoids, particularly in many *Trichogramma* spp. when cultured in the laboratory. It adversely affects the development of the immature stages and fecundity, longevity, sex ratio and size of the progeny. In order to determine whether or not superparasitism occurs in *T. bournieri* the following studies were conducted.

To induce superparasitism in the laboratory, 50 freshly laid eggs of *Sitotroga cerealella* were exposed to about 50 freshly emerged *T. bournieri* for 4 hours. (*Chilo partellus* eggs were not used as it was difficult to isolate them singly from an egg mass.) When the host eggs turned black, each parasitised egg was kept in an individual vial for development and emergence. Survival of the parasitoid to the adult stage occurred as follows: A single male or female from one host egg; two females or two males; a male and a female; three parasitoids; no adult emergence.

When one or two individuals emerged from a single host, they appeared healthy, but when two emerged they were smaller than those emerging singly; when three emerged from one egg, they were not only weak and undersized but some had only partly or ill-developed wings. There was no emergence from many eggs, but these, on dissection, revealed partly-developed dead individuals, up to four in a single egg, or disintegrated remains of parasitoids. These observations clearly show that when *T. bournieri* is cultured in the laboartory superparasitism occurs.

The fecundity, longevity and sex ratio of the progeny of *T. bournieri* emerging from superparasitised eggs were compared with those emerging singly. The fecundity of a female that developed singly was significantly higher than that of a female that developed with a male or another female (Table 1.27). Also, the fecundity of a female that developed with a male was significantly less than that of one that developed with another female. Though the longevity of a female developing alone was not significantly different from that of one developing with another female (Table 1.27), it was significantly higher than that of a female developing with a male. No significant difference was observed between the longevity of a female developing with a male or a female. Thus the effect of superparasitism on longevity was not as adverse as it was on fecundity. The sex ratio of the progeny of a female that developed alone was significantly better than that of a female that developed with a male or another female (Table 1.27). There was, however, no significant difference between the sex ratios of the progeny of a female that developed with a male or another female.

When two or more individuals develop in a host suitable for the development of only one, the available amount of food is shared among the developing larvae with the result that none gets sufficient nourishment for development into a normal adult. This results in reduced size, fecundity and longevity.

Dissection of host eggs exposed to *T. bournieri* showed that when one female was confined with five host eggs for 1 hour or 2 hours and two females with five eggs for 1 hour, no superparasitism occurred. But when five eggs were exposed to two parasitoids for 2 hours, one egg was superparasitised. Significantly higher levels of superparasitism occurred with one and two parasitoids when the time of exposure was increased to 4, 8 and 16

Table 1.27 Fecundity, longevity and sex ratio of *Trichogramma bournieri* developing alone, and with another female and with another male in an egg of *Sitotroga cerealella*

Type of development	Fecundity Mean ± S.E.	Longevity Mean ± S.E.	Sex ratio Mean ± S.E.
Single female	82.100 ± 3.383[a]	7.300 ± 0.411[a]	3.968 ± 0.440[a]
A female with a female	46.350 ± 3.059[b]	6.650 ± 0.494[ab]	3.233 ± 0.162[b]
A female with a male	33.400 ± 3.589[c]	5.450 ± 0.495[b]	3.160 ± 0.203[b]

Means ± S.E. followed by the same letter within a column are not significantly different at $P = 0.05$ (Duncan's new multiple range test).

Table 1.28 *Sitotroga cerealella* eggs (Mean ± S.E.) with more than one egg of *T. bournieri*

Duration of exposure of five host eggs in hours	Number of host eggs with more than one parasitoid egg when exposed to	
	one parasitoid	two parasitoids
1	0.0000 ± 0.0000^{bx}	0.0000 ± 0.0000^{cx}
2	0.0000 ± 0.0000^{bx}	0.0200 ± 0.0200^{cx}
4	0.0400 ± 0.0280^{abx}	0.1000 ± 0.0429^{cx}
8	0.0600 ± 0.0339^{aby}	0.6600 ± 0.0677^{ax}
16	0.1200 ± 0.0464^{ay}	0.5000 ± 0.0714^{bx}

Values followed by the same letters are not significantly different ($P = 0.05$, Duncan's new multiple range test). Columnwise difference indicated by a, b and c and row-wise by x and y.

hours (Table 1.28). Between one and two parasitoids, there was however no significant difference in superparasitism for 1, 2 and 4 hours, but significant difference occurred when exposure was for 8 and 16 hours. Thus it is seen that *T. bournieri* has the ability to discriminate between parasitised and unparasitised host, but this ability breaks down when there is a scarcity of host eggs.

1.15 INFLUENCE OF *CHILO PARTELLUS* DIET *ON TRICHOGRAMMA BOURNIERI*

M. J. Chacko and P. Agwaro

Studies were conducted in the laboratory to compare the fecundity, longevity and sex ratio of *Trichogramma bournieri* developing on eggs of *Chilo partellus* raised on artificial diet and sorghum. Parasitoids were cultured on eggs of *C. partellus* that developed on artificial diet and sorghum. Thus the treatments were: (1) Host developing on artificial diet and parasitoid on eggs of moth raised on artificial diet; (2) Host on diet and parasitoid on eggs of moth on sorghum; (3) Host on sorghum and parasitoid on eggs of moth on diet; and (4) Host on sorghum and parasitoid on eggs of moth on sorghum.

Twenty parasitoids, fed on 20% aqueous solution of honey, were maintained for each treatment. Fresh host eggs were offered daily till the death of the female parasitoids and the exposed batches of eggs were collected and reared in individual vials. Data were collected on fecundity, longevity and sex ratio (Table 1.29).

There were no significant differences in fecundity or sex ratio between the various treatments. However, longevity was significantly higher in treatment 1 than in the other treatments, least being in treatment 3.

Table 1.29 Fecundity, longevity and sex ratio of *Trichogramma bournieri* developing on eggs of *Chilo partellus* raised on synthetic diet and sorghum

Treatment	Fecundity (Mean)†	Longevity (Mean)	Sex ratio (Mean)
1. Host egg and parasitoid on diet	23.20^{a}	6.65^{a}	2.651^{a}
2. Host on diet and parasitoid on sorghum	30.75^{a}	4.50^{b}	3.147^{a}
3. Host on sorghum and parasitoid on diet	22.60^{a}	2.80^{c}	3.656^{a}
4. Host and parasitoid on sorghum	29.70^{a}	3.50^{bc}	3.365^{a}

†Means in columns followed by the same letter are not significantly different. ($P = 0.05$, Duncan's new multiple range test).

1.16 DISCOVERY EFFICIENCY OF *TRICHOGRAMMA BOURNIERI*

M. J. Chacko, E. F. Dwumfour and K. Ogedah

The studies on efficiency of *Trichogramma bournieri* in discovering its host were continued during the short rainy season (1990–91) on a farmer's field just outside MPFS. The field measuring 500 m^2 was divided into 20 plots, each of 25 m^2, where sorghum (Serena) was grown. (Details of the treatments and procedures are presented (see *ICIPE 1990 Annual Report*)). The number of parasitoids released was increased to 400 (from 200 during the long rainy season) and the trial was repeated six times between November 1990 and January 1991.

Parasitism of egg batches continued to be low. There were no significant differences between percentages of parasitism of egg batches with increasing numbers of the latter. Also, when data were pooled for the entire season for each host density, no significant differences in the percentages of egg masses parasitised were observed as in the long rainy season, clearly indicating that parasitism by *T. bournieri* was not host density-dependent (Table 1.30).

Levels of percentage parasitism of egg masses with release of 200 parasitoids (during the long rainy season) or 400 (during the short rainy season) were also not significantly different (Table 1.31).

Mortality of egg batches caused by generalist predators like ants, spiders, earwigs, etc. was higher than that caused

Table 1.30 Per cent of *Chilo partellus* egg masses parasitised by *Trichogramma bournieri* during the long and short rainy seasons

Treatment (egg masses)	Per cent egg masses parasitised by 200 *Trichogramma* (long rains) Mean ± S.E.	Per cent egg masses parasitised by 400 *Trichogramma* (short rains) Mean ± S.E.
13	19.078 ± 3.327[a]	22.982 ± 2.821[a]
25	25.740 ± 1.743[a]	24.350 ± 2.192[a]
50	22.733 ± 1.622[a]	22.233 ± 2.229[a]
100	18.637 ± 1.338[a]	23.097 ± 2.422[a]

Means ± S.E. followed by the same letter in a row and in a column are not significantly different at $P = 0.05$.
Data transformed with arcsine square root transformation.

Table 1.31 Parasitism by *Trichogramma bournieri* and predation of all egg masses of *Chilo partellus* during the long and short rainy seasons

Season	Per cent parasitism (Mean ± S.E.)	Per cent predation (Mean ± S.E.)
Long rains	21.547 ± 1.099[a]	28.583 ± 1.373[b]
Short rains	23.165 ± 1.201[a]	44.028 ± 1.247[a]

Means ± S.E. followed by the same letter within a column are not significantly different at $P = 0.05$. Data transformed with arcsine square root transformation.

by the parasitoid. Predation was significantly higher during the short rainy season than during the long rainy season (Table 1.31).

1.17 FIELD EVALUATION OF *TRICHOGRAMMA BOURNIERI* FOR THE CONTROL OF *CHILO* SPP. AT MTWAPA

K. Ogedah, E. F. Dwumfour and M. J. Chacko

A field experiment was conducted at Mtwapa on the Kenya coast during 1990-91 short rainy season to find out whether inundative releases of *T. bournieri* would reduce incidence of *Chilo* spp. The experiment was conducted at Mtwapa on maize (Coast Composite).

The field was divided into four plots (50 x 50 m) and each plot into four sub-plots (25 x 25 m). Two plots were maintained for treatment and the other two plots, 75 m away, were maintained as check. Two sub-plots from each treated and check plot were demarcated for sampling (sampling sub-plots, SP) and the other sub-plots for yield estimation. The date of planting was 12 September, 1990 and the plants emerged on 17 and 18 September.

T. bournieri was released in the two plots for treatment at the rate of 4500 parasitoids per sub-plot eight times at weekly intervals from 24 September to 25 November

Table 1.32 Number of healthy *Chilo* spp. egg batches (Mean ± S.E.) in treated and check plots

Sampling date	Treated	Check
1990		
24 September	6.75 ± 0.48[a]	6.25 ± 0.63[a]
29 September	5.75 ± 0.48[a]	8.00 ± 0.41[a]
9 October	3.75 ± 0.48[a]	3.75 ± 0.48[a]
15 October	3.75 ± 0.48[a]	5.00 ± 0.82[a]
21 October	4.50 ± 0.29[a]	6.25 ± 0.63[b]
5 November	4.75 ± 0.25[a]	5.25 ± 0.25[a]
13 November	3.50 ± 0.65[a]	3.25 ± 0.48[a]
25 November	2.00 ± 0.41[a]	2.75 ± 0.48[a]

Means ± S.E. followed by the same letter in a row are not significantly different at $P = 0.05$.

Table 1.33 Proportion of egg masses parasitised (Mean ± S.E.)

Date of sampling	Treatment	Check
1990		
24 September	0.00 ± 0.00[a]	0.00 ± 0.00[a]
29 September	5.55 ± 5.55[a]	0.00 ± 0.00[a]
9 October	14.79 ± 8.58[a]	13.52 ± 7.90[a]
15 October	37.90 ± 2.76[a]	33.94 ± 5.12[a]
21 October	46.76 ± 2.82[a]	27.95 ± 2.88[b]
5 November	34.41 ± 1.32[a]	34.41 ± 1.32[a]
13 November	33.72 ± 5.01[a]	6.64 ± 6.64[b]
25 November	7.50 ± 7.49[a]	0.00 ± 0.00[a]

Means ± S.E. followed by the same letter in a row are not significantly different at $P = 0.05$.

1990. Fifty randomly selected plants were sampled eight times from each of the eight SP from 24 September to 25 November to assess the number of healthy and parasitised egg masses on them. From 12 November 1990 to 8 January 1991, 10 randomly selected plants each from the eight SP were sampled nine times by dissection to determine the level of borer infestation. At harvest yield was assessed from the plots maintained for this purpose.

No significant differences between the mean number of healthy egg masses were observed except on 21 October 1990 when significantly more egg masses were found in check plots than in treated plots (Table 1.32). Significantly more egg masses were parasitised in treated plots than in check plots only on 21 October and 13 November (Table 1.33). As the season progressed, the number of egg masses in both treated and check SP reduced considerably. Over the entire season an average of 4.34 and 5.06 healthy egg masses were found in the treated and check plots respectively. Egg batch discovery over the entire season by *T. bournieri* did not differ significantly in both treatment and check.

No significant difference between mean larval infestation levels was observed in treatment and check at any particular sampling date except on 18 December, 1 January and 8 January. Over the entire period, no significant difference was observed between treatment

Table 1.34 Dynamics of *Chilo* spp. infestation in *Trichogramma* treated and check plots

Sampling date	Levels of borer infestation (%) ± S.E.	
	Treated	Check
1990		
12 November	18.50 ± 3.80[a†]	9.00 ± 3.70[a]
23 November	11.50 ± 5.04[a]	3.50 ± 0.96[a]
27 November	4.00 ± 1.78[a]	7.75 ± 2.53[a]
4 December	2.00 ± 1.35[a]	4.25 ± 1.44[a]
11 December	3.50 ± 0.50[a]	5.00 ± 2.27[a]
18 December	4.50 ± 0.87[a]	1.00 ± 0.71[b]
25 December	5.50 ± 1.21[a]	3.25 ± 0.86[a]
1991		
1 January	1.75 ± 0.16[a]	0.75 ± 0.31[b]
8 January	2.00 ± 0.27[a]	0.25 ± 0.16[b]
Weighted mean	5.21 ± 0.88[a]	4.03 ± 0.58[a]

†ANOVA, Tukey's Studentised Range (RSD) $P = 0.05$
Means in a row with the same letter are not significantly different.

and check (Table 1.34). Borer numbers were highest in treatment and check on the first sampling date and thereafter reduced as the season progressed.

An assessment of the yield at harvest showed that releases of *T. bournieri* did not result in increase in yield, the yield in both treated and check plots (0.25 ha each) being 353 kg.

1.18 BIOLOGY AND DEVELOPMENT OF *CHRYSOPA* SP., A PREDATOR OF CEREAL STEM BORERS

C. O. Omondi

The green lacewing, *Chrysopa* sp., are among the most important insect predators. Species of *Chrysopa* have been found to be associated with cereal stem borers, but while the larvae are known for their predaceous habit, not much has been studied concerning their activities with respect to the cereal stem borers. In view of this, studies were initiated to determine the biology and development of *Chrysopa* sp. in the laboratory at Mbita Point Field Station and to have additional information on the ability of this predator to consume *Chilo partellus* eggs before field releases can be considered.

Fifty glass vials (25 x 75 mm) were used to confine the various life stages while obtaining records on the life history and habits. Eggs of *C. partellus* were used as food in all larval rearing and tests. Feeding tests were conducted to determine the number of eggs of *C. partelius* consumed by larvae of *Chrysopa* sp. Known numbers of eggs were introduced into the vials each of which contained a single larva. The vials were plugged with cotton wool Eggs consumed every 24 hours were counted. The remaining eggs were removed and fresh eggs offered to the predator daily. This procedure was repeated with the fifty predators each day throughout the feeding period of the larvae, considering each individual as one replicate.

Table 1.35 Duration of the developmental stages of *Chrysopa* sp.

Stage	Duration in days	
	Range	Average
Incubation	3–7	3.7
First instar	2–4	2.4
Second instar	2–6	2.3
Third instar	2–7	3.0
Pre-pupa	2–6	2.7
Pupa	8–15	11.0

The cocoons were separated for adult emergence. Observations were made on the consumption of *C. partellus* eggs, development period of the different larval instars, pupae and on the fecundity and longevity of the adult *Chrysopa* sp. A suitable diet consisting of a mixture of yeast extract and honey plus 20% sugar solution was used to maintain adult cultures of *Chrysopa* sp.

The duration of the developmental stages of *Chrysopa* sp. is summarised in Table 1.35. The incubation period of the eggs ranged from 3 to 7 days with an average of 4 days. The first two larval instars were found to be of about equal duration averaging slightly over 2 days.

After the second moult, the larvae feed for 2 to 7 days and then begin to spin a cocoon. The duration of the pupal stage averaged 11 days. The time of development from hatching to adult emergence ranged from 16 to 38 days with an average of about 21 days.

The females used in the oviposition studies were confined with males soon after emergence and mating was observed to occur within the first 2 days in most cases. Fifty *Chrysopa* sp. females deposited 1562 eggs in a total of 192 oviposition days giving an average of 31 eggs per female. The greatest number of eggs deposited over a 24 hour period by female was 11 and one individual deposited 87 eggs over a period of 27 days. The newly hatched larvae began feeding soon after emerging from eggs. The adult lived for about 24 days on average with a range of 8 to 45 days.

The number of eggs of *C. partellus* consumed during the first, second and third instars of the predator averaged 186, 398 and 946 respectively. A total of 1530 eggs were consumed by the predator during the entire larval developmental period. The data also indicates that the second and third instars were more voracious feeders on the eggs of *C. partellus* with the third instar being most active. Hence the second and third instars could be used for field studies.

1.19 ICIPE/WAU CROP PESTS BIOLOGICAL CONTROL: CLASSICAL BIOLOGICAL CONTROL OF *CHILO PARTELLUS*

W. A. Overholt

ICIPE and Wageningen Agricultural University (WAU), with funding from the Dutch Government, have recently established a collaborative project on classical biological control of crop pests. Initially, the project will focus on

Chilo partellus, a stem borer which attacks maize and sorghum in East Africa.

Chilo partellus was accidentally introduced into East Africa from Asia earlier this century, and as is often the case with introduced species, became a major pest in its new home. The distribution of *C. partellus* in Africa has recently expanded into West Africa, and there is little doubt that this pest will eventually invade all of sub-Saharan Africa. A pest management tactic that has been used with numerous successes against introduced pests is classical biological control. Classical biological control involves the identification of natural enemies of the introduced pest in its aboriginal home, and the introduction of these natural enemies to the area the pest has invaded.

The objective of the project is to reunite *C. partellus* with natural enemies collected from its aboriginal home in Asia. The establishment of an effective exotic natural enemy will permanently regulate the density of *C. partellus* at a lower level than presently occurs. The project will follow a rigorous scientific approach by investigating the ecology of the host population in the field before and after colonisation of exotic natural enemies, and by examining the performance and behaviour of exotic and indigenous natural enemies in the laboratory. Natural enemies will be evaluated one species at a time in order to thoroughly examine their potential for regulating *C. partellus* before other species are considered.

One promising natural enemy, *Cotesia flavipes*, has been imported from Pakistan. *C. flavipes* is a gregarious endoparasitoid of medium and large instar larvae of *C. partellus* which has been successfully used in biological control programmes in many areas of the world. The project is currently examining the host range, host finding mechanisms, and taxonomy of *C. flavipes* in the laboratory. Field releases are tentatively planned for 1993.

Summaries of the various research activities being pursued by the project are provided below.

1.19.1 Intensive survey of maize and sorghum stem borers on Kenya Coast

Before releasing exotic parasitoids, baseline studies on the population dynamics of stem borers are being conducted on the Kenya Coast. Field plots of maize and sorghum were planted at KARI/Mtwapa in May and July and sampled weekly from emergence to the end of 1991. Preliminary analysis of the data from the plots planted in May indicates that three species of stem borers commonly occur: *C. partellus*, *C. orichalcociliellus* and *Sesamia calamistis*. *Busseola fusca* was also found but in very low numbers (2/2446 stem borer larvae collected). Of the three common species, *C. partellus* was the most abundant accounting for > 80% of total stem borers on all sampling dates. *C. orichalcociliellus*, which was reportedly equal in adundance to *C. partellus* in earlier studies, never accounted for > 10% of the total population. *S. calamistis* was approximately equal in adundance to *C. orichalcociliellus*.

Sorghum was more heavily attacked by *C. partellus* than maize with ca. 80% of the population in sorghum. The numbers of plants infested increased throughout the season to October when a maximum of 86 and 35% of sorghum and maize plants were infested, respectively.

Initial analysis of the data from the plots planted in July has given similar results. *C. partellus* was the predominant stem borer species until October when it was surpassed in abundance by *S. calamistis*. *C. orichalcociliellus* accounted for < 10% of the borer population on all sampling dates. However, in contrast to the crop planted in May, the majority of the populations of all three stem borer species were found in maize.

A surprisingly low number of parasitoids were reared from the stem borers collected from the field plots in both the early and late crops. *Cotesia sesamiae* was the most common larval parasitoid but parasitism of *C. partellus* never exceeded 4.7% in the early crop or 6.0% parasitism in the late crop. Seasonal per cent parasitism by *C. sesamiae* on *C. partellus* is approximately 2.0% in both early and late planted crops. Parasitism of *C. partellus* by the predominant pupal parasitoid, *Pediobius furvus*, was also quite low accounting for 5.4% and 5.9% parasitism in the early and late crops. Although other parasitoids were occasionally recovered, they were rare. The low level of larval and pupal parasitism strongly suggests that there is a wide open niche for more effective natural enemies, and provides sound justification for the introduction of exotic species.

1.19.2 Monitoring the fate of newly deposited egg masses

This study is designed to monitor the fate of *Chilo* spp. egg masses in the field. Newly laid egg masses were marked and then observed every day for eight consecutive days to monitor parasitism, predation, disappearance, and successful eclosion. Parasitism by Trichogrammatids ranged from 50–55% and predation and disappearance from 10–35%. Only 21–39% of eggs successfully eclosed.

1.19.3 Extensive sampling on the coast and in western Kenya

Surveys are being conducted to obtain a broader knowledge of the distribution and population dynamics of stem borers and their natural enemies over a wide geographic area. These studies will provide baseline information necessary to evaluate the impact of exotic natural enemy species eventually introduced. Moreover, *C. flavipes*, the first exotic parasitoid which will be introduced, was previously released in Kenya, Uganda and Tanzania. It is important to determine whether *C. flavipes* may have already established from these earlier releases.

The initial data from these studies is currently being analysed, and therefore only broad generalisations can be made at this time. The parasitoids that have been recovered in these surveys and identified by the International Institute of Entomology (IIE) are given in Table 1.36. It is important to note that all the *Cotesia* sent to IIE have been identified as the indigenous *C. sesamiae*. This result, together with collections made by other workers, provides strong evidence that *C. flavipes* did not establish from the earlier releases.

1.19.4 Morphological and biochemical taxonomy of Chilo *spp. and* Cotesia *spp.*

This study is being conducted to resolve difficulties in the identification and taxonomy of the stem borers, *C.*

Table 1.36 Stem borer parasitoids identified by IIE

Identification	Host record	Location
Cotesia sesamiae	*C. partellus, B. fusca*	Coast and western
Pediobius furvus	*C. partellus, B.fusca*	Coast and western
Dentichasmias busseolae	*C. partellus*	Coast and western
Xanthopimpla sp.	*C. partellus*	Coast
? Xanthopimpla sp.	*C. partellus*	Coast
Mysoma nyanzaensis	*C. partellus*	Coast
Tetrastichus sp.	*Cotesia?*	Coast
Unidentified Tachinidae	*C. partellus*	Coast
Bracon sp.	*C. partellus*	Western
Euvipio rufa	*C. partellus*	Western

partellus and *C. orichalcociliellus* and the parasitoids, *C. sesamiae* and *C. flavipes*. The two *Chilo* spp. are currently very difficult to differentiate, particularly during aestivation when the larvae lose cuticular pigmentation. The systematics of the *C. flavipes* species complex, which includes at least three species, is unclear. Moreover, it is extremely difficult to distinguish the indigenous *C. sesamiae* from *C. flavipes* which will be introduced. Because of the importance of the *C. flavipes* complex to biological control worldwide, it is felt that a thorough investigation using all appropriate techniques will be of immediate use to the project and to biological control workers elsewhere.

As this study only recently began, there is little progress to report. Initial isoenzyme analysis using electrophoresis indicates that there are distinct differences between the few individuals of the two *Chilo* spp. and the two *Cotesia* spp. that have been assayed. However, a better understanding of the interspecific variation is needed before further interpretation of these results.

1.19.5 Host finding behaviour of C. flavipes *and* C. sesamiae

Studies to investigate the host finding behaviour and elucidate the chemical mediation of host finding of *C. flavipes* and *C. sesamiae* have recently been initiated. Preliminary work is focusing on the development of assays to quantify the parasitoids response to various stimuli (host plants, hosts and host products). Although further refinement is necessary, initial results using an olfactometer are encouraging.

1.19.6 Laboratory colonisation of C. flavipes

The parasitoid *C. flavipes* from Pakistan has been imported as a candidate biological control agent for *C. partellus*. The first shipment arrived in Kenya in late September and was released to ICIPE in mid-October after being reared through one generation at the International Institute of Biological Control sub-station at Muguga near Nairobi. A laboratory rearing procedure has been established which has resulted in a strong colony of the parasitoid. Studies are currently being conducted to optimise the rearing procedure.

CULTURAL CONTROL (CC)

During 1991, the Bionomics and Applied Ecology (BAE) Section was reorganised into two separate sections: Cultural Control (CC) Section and the Integrated Pest Management and Population Biology (IPB) Section. The Cultural Control Section has the following objectives:

- *To identify, design and study agronomically, socio-economically feasible cultural practices that reduce target insect pests' attack and yield losses.*
- *To determine microhabitat-microenvironmental effects of cultural practices on insect pest and natural enemies to enable a more precise definition of potential beneficial-detrimental impacts of cultural practices on biodiversity.*
- *To study the inter-relationship between crops, pests, natural enemies, environments, and cultural practices for the development and refinement of system level crop pest models.*

1.20 MANAGEMENT OF CULTURAL PRACTICES FOR INSECT PEST CONTROL

K. Ampong-Nyarko and R. Nyang'or

Since 1991 thrust in intercropping research has been focused on quantifying the yield loss advantage due to low insect pest incidence in intercropping and improvement in the agronomic productivity and economic profitability of the system. Other areas of research included the mechanisms for the low insect incidence in intercropping so that generalisations can be made about the system.

1.20.1 Compatibility of stem borer resistant/tolerant sorghum lines for intercropping

The compatibility of resistant/tolerant sorghum lines for intercropping was studied in field experiments in the short rains of 1990 at ICIPE's Ungoye field site. Sorghum lines LRB 5, LRB 6, LRB 8, IS-1044, IS-2269, 2Kx17, Gaddam El Hamam and Serena were grown as monocrops and as intercrops with cowpea (cultivar ICV 2). Intercropping reduced the number of *Chilo partellus* in both resistant and tolerant lines and also significantly

reduced the number of flower thrips *Megalurothrips sjostedti*. Resistance in sorghum to stem borers was not affected by intercropping. Intercropping further reduced stem borer attack and number in resistant lines. Resistant/tolerant lines were all compatible with intercropping in terms of insect pest reduction. There were, however, differences in agronomic productivity. Grain yield of intercropped sorghum was positively correlated with the number of tillers per harvestable head. The main criteria for differences between cultivars were agronomic characteristics. The desired agronomic characters for intercropping in sorghum include intermediate plant height, intermediate leaf area (9–10 leaves) and high tillering capacity.

1.20.2 Suitability of hybrid maize for intercropping

Maize hybrids are more vigorous and therefore offer intense competition for the legume component in intercropping. The suitability of hybrid maize cultivars for intercropping was therefore studied at MPFS in 1990 short rains. Two hybrid maize cultivars (H-511, H-622) were intercropped with either beans (GLP 2) or cowpea (ICV 2). Intercropping reduced stem borer incidence in the hybrid maize. However, the yield advantage in the system was not significant. This suggests that optimum spacing, plant density and row arrangements need to be established to improve the agronomic productivity of the system.

1.20.3 Cropping system for pest management: Effect of plant density and row arrangement on insect pest and yield

In our continuing efforts to fine tune recommendations on intercropping and to increase the agronomic productivity and economic profitability of the system, various plant densities and row arrangements were examined. The experiment combined three plant populations (22,000, 37,000 and 55,555 plants/ha) and four cropping patterns (sorghum and cowpea in the same hole, single alternate row (SAR), double alternate row (DAR) arrangement and strip cropping) were conducted at Ungoye and in Ogongo in 1991 long rains. At the low and medium density single, alternate row arrangement was the most effective in reducing stem borer incidence and damage whilst the same hole arrangement gave the highest number of borers. At 55,555 plants/ha, single alternate row arrangement was the least effective (Table 1.37). There was no difference in yield between the high and medium density as the number of productive tillers decreased with increasing plant density. Cowpea yield tended to decrease with increasing sorghum density. Double alternate row arrangement allowed for better light interception by the understorey cowpea and was reflected in better yields of the cowpea than the traditional single alternate row or having both sorghum and cowpea in the same hole. Manipulation of plant density to attain monocrop density of the cereal is difficult to achieve.

1.20.4 Effect of plant density on stem borer incidence

Plant density and row width frequently affect the suitability of a crop for colonisation by pest populations. A study on plant density, row arrangement in sorghum monocrop and their possible role in IPM was initiated. Plant spacing (45 x 40 cm, 75 x 24 cm, 90 x 20 cm, 120 x 15 cm and 60 x 30 cm) one plant/hill to give a population of 55,555 plants/ha was compared to similar spacing but two plants/stand and a population of 111,111 plants/ha. The effect of having 1, 2, 3, or 4 plants/hill on stem borer incidence was also studied. The lowest stem borer damage was obtained with the near square row arrangement of 45 x 40 cm. There were no differences between the other row arrangement. Doubling the number of plants/hill led to the reduction of stem borer damage by 32% in the rectangular arrangements but had no effect on the square arrangement. The optimum number of plants/hill and stand

Table 1.37 The effect of cropping pattern and plant density on stem borer incidence, grain yield and tillers of sorghum

Treatment	Parameters			
Cropping pattern[1] (sorghum and cowpea)	Density plants/ha cumulative	Larvae + pupae	Grain yield kg/ha	Tillers no./plant
Same hole	22,000	41.8	1840	1.9
Same hole	37,000	31.2	2400	1.4
Same hole	55,000	26.8	1985	1.0
SAR	22,000	14.95	2039	1.1
SAR	37,000	22.9	2071	1.1
SAR	55,555	37.8	1829	1.0
DAR	22,000	25.5	1537	1.1
DAR	37,000	27.5	2302	0.8
DAR	55,555	27.6	2424	0.7
STRIP	22,000	32.6	1700	1.6
STRIP	37,000	30.4	2187	1.2
STRIP	55,555	37.4	2037	0.8

[1]SAR, single alternate row; DAR, double alternate row; STRIP, strip cropping.

density need to be established before its full benefits can be exploited in IPM.

1.20.5 Effect of nitrogen and shading on Chilo partellus *incidence*

Cultural practices designed to manage insect pest populations are essentially habitat modifications and alter within crop environment. The effect of nitrogen fertilisation on micro-environmental modification and pest and natural enemy complex was studied in the long rains of 1991 at MPFS. Two sorghum cultivars (IS-1044, Serena) two light intensities (full sunlight, 40% sunlight) and three nitrogen levels (20, 60, 160 kg/ha) in factorial combination were examined. Nitrogen increased the number of stem borer larvae and pupae, stem-tunnelling and damage. Shaded sorghum plants suffered more damage from stem borer than the unshaded plants at low nitrogen levels. Shading had the effect of increasing nitrogen content of the sorghum plants. This suggests that differences in plant nitrogen content could play a role in the mechanism of plant resistance to stem borers.

1.21 EFFECT OF *CHILO PARTELLUS* INFESTATION ON STALK DAMAGE AND GRAIN YIELD LOSSES IN THREE COMMERCIAL MAIZE CULTIVARS

K. V. Seshu Reddy and K. O. S. Sum

Previous work on crop losses was conducted mainly with the ICIPE's maize cultivars. Further work on the subject was extended to some commercial cultivars with the objective of quantifying the effect of different *Chilo partellus* larval densities infested at two selected growth stages on maize stalk damage and grain yield losses in three commercial maize cultivars, viz: Hybrid 511, Hybrid 622 and Katumani. At MPFS, maize plants were grown in plots of 5 x 4 m and were artificially infested with newly hatched *C. partellus* larvae at the densities of 0, 2, 6 and 10 larvae/plant of 21 and 35 days after crop emergence (DAE). One plot was left for natural infestation and another one was protected using Dipterex granules applied at 21 DAE in the plant leaf whorls. The zero density cited

Table 1.38 Stalk damage levels and grain yield losses in three commercial maize cultivars infested with *C. partellus* at two plant growth stages

Variety	Treatment	Foliar damage rating	Exit holes	Tunnelling	Grain yield/plant (g)	% Yield losses
HYB 511	2L 21 DAE	2.2	1.63[bc1]	16.03[b]	168.13[ab]	11.00
	6L 21 DAE	2.5	4.07[a]	37.30[a]	108.67[cd]	43.04
	10L 21 DAE	2.6	4.00[a]	42.37[a]	95.60[d]	49.28
	2L 35 DAE	2.3	0.83[cd]	10.27[bc]	169.70[ab]	11.45
	6L 35 DAE	2.3	1.43[bc]	13.33[b]	147.17[b]	22.86
	10L 35 DAE	2.3	1.87[b]	18.17[b]	122.33[c]	35.88
	Nat. Inf.[2]	1.4	1.03[bcd]	10.83[b]	169.17[ab]	11.32
	Dip. x 1[3]	2.1	0.80[cd]	10.73[bc]	175.23[ab]	8.87
	Un. Inf. Control[4]	1.0	0.13[d]	1.97[c]	190.77[a]	0
HYB 622	2L 21 DAE	2.2	2.70[bc]	28.5[bc]	152.63[a]	11.42
	6L 21 DAE	2.4	3.40[ab]	33.7[b]	117.2[b]	31.9
	10L 21 DAE	2.5	4.20[a]	50.77[a]	105.0[b]	38.7
	2L 35 DAE	2.0	2.1[de]	14.53[cd]	155.23[a]	9.9
	6L 35 DAE	2.2	2.43[cd]	16.1[bcd]	142.93[b]	21.08
	10L 35 DAE	2.5	2.43[cd]	19.1[bcd]	119.43[b]	30.0
	Nat. Inf.[2]	1.4	1.80[cde]	13.13[cd]	139.63[ab]	23.4
	Dip. x 1[3]	1.0	1.43[de]	17.93[bcd]	153.90[a]	10.70
	Un. Inf. Control[4]	1.0	1.167[e]	2.87[d]	172.30[a]	0
Katumani	2L 21 DAE	2.1	2.07[cd]	14.27[c]	105.33[cd]	28.94
	6L 21 DAE	2.4	3.03[ab]	21.83	87.93[ef]	40.08
	10L 21 DAE	2.4	3.17[a]	29.77[a]	78.33[f]	47.15
	2L 35 DAE	2.1	2.23[cd]	15.00[bc]	130.08[b]	12.24
	6L 35 DAE	2.2	1.70[de]	13.60	101.77[cde]	31.45
	10L 35 DAE	2.2	1.17[e]	22.23[b]	91.97[def]	35.95
	Nat. Inf.[2]	1.6	1.16[e]	11.87[c]	101.85[cde]	31.30
	Dip. x 1[3]	1.0	1.93[de]	11.53[c]	128.13[b]	13.56
	Un. Inf. Control[4]	1.0	0.00[f]	0.02[c]	148.23[a]	0

[1]Means in the same column followed by the same letters are not significantly different according to DMRT at $P < 0.05$.
[2]Natural infestation.
[3]Dipterex applied once.
[4]Uninfested control.

above represented the uninfested control. The experiment was conducted in a split plot design with three replications.

Analysis of variance procedure performed on the data showed the existence of significant differences among cultivars in terms of stalk damage levels and grain yields realised. Generally Hybrid 511 registered higher yields than Hybrid 622 and Katumani (Table 1.38) in order of magnitude. However in terms of grain yield losses, there appeared to be higher losses in Hybrid 511 than in 622 regardless of the densities infested. Stalk damage levels assessed in terms of borer exit holes, foliar damage and % stem-tunnelling were also found to be higher in Hybrid 622 than Hybrid 511 and Katumani. Important in determining the magnitude of yield reduction and stalk damage were the levels of infestation and the crop stage at the time of infestation. Table 1.38 shows that grain yield losses and stalk damage levels were directly proportional to the densities infested, for instance with 10 larvae/plant in all the cultivars and stages greatest losses were realised though the effect was more pronounced in the younger stage i.e. at 21 DAE about 50% losses were realised in Hybrid 511 compared to 35% at 35 DAE for the same cultivar. Natural infestation was not so high in Hybrid 511 as was significantly noted in Hybrid 622 and Katumani. However all the varieties almost responded equally well to the insecticide protection as is evidenced by the low values of grain yield losses which were almost equal. This ascertains and further confirms that one insecticide application at the most sensitive stage in the crop is just effective enough to provide adequate protection against the borer.

1.22 DEVELOPMENT OF THE WEEVIL, *COSMOPOLITES SORDIDUS* ON CERTAIN BANANA CULTIVARS

K. V. Seshu Reddy

Studies were conducted on the development of the weevil, *C. sordidus* on the rhizomes of eight banana cultivars under laboratory conditions at MPFS. The eight banana cultivars selected were: Mbidde, Gonja, Kivuvuu, Nakyetengu and Lusumba (cooking); Sukali Ndizi, Bogoya Giant and Kayinja (sweet). Three equal sized rhizomes of about 4 months old were placed in each 80 litres capacity plastic container for each variety and replicated four times. In each container, 10 females and 10 males were placed and after 2 weeks the adult weevils were removed. Later after 40 days the rhizomes were sampled for the weevil population.

The mean population density of various life stages of the weevil 54 days after infestation is given in Table 1.39. There were significant differences in the larval, pupal and adult development in the eight cultivars tested. Weevil density on Mbidde, Gonja, Kivuvuu and Nakyetengu which are the cooking types was significantly different from those on other cultivars. However, the density on another cooking cultivar, Lusumba along with Sukali Ndizi and Bogoya Giant was significantly different from Kayinja which is a sweet type (Table 1.39). Although, there was a significant variation in the development of weevil, in general the cooking cultivars are good hosts of the weevil. Among the eight cultivars studied, the weevil population was significantly low, on Kayinja which is a tolerant cultivar to the weevil.

1.23 DEVELOPMENTAL RESPONSE OF *COSMOPOLITES SORDIDUS* TO DIFFERENT BANANA CULTIVARS

B. E. M. A. Uronu

A test was initiated to study developmental responses of the banana weevil, *Cosmopolites sordidus* (Germ.) in four different banana cultivars. The cultivars used in the test included Nshakara and Nyoya (cooking type), Bokoboko and Kijoge, both multipurpose types.

A randomised complete block design with four replicates were used. Each replicate had 16 experimental units. One experimental unit was one sword sucker (plant) planted in a 30 cm diameter and 20 cm deep plastic bucket. Each sword sucker was implanted with 10 eggs (laid between a 0 and 5 day period) a day before planting. Destructive sampling was carried out at 10 day intervals for 50 days. Percentage hatchability, larval weights, tunnel lengths and average tunnel diameters were recorded.

Both percentage hatchability and larval weights were

Table 1.39 Development of *C. sordidus* on eight banana cultivars

	Mean weevil population density 54 days after infestation					
Cultivar	1st–4th larval instars	5th–6th larval instars	Pre-pupae	Pupae	Adults	Total
Mbidde	0.25	2.50	3.75	19.25	19.50	45.25[a]
Gonja	3.75	6.00	3.00	13.50	15.25	41.50[a]
Kivuvuu	4.50	3.25	5.75	12.50	10.00	36.00[a]
Nakyetengu	0.25	0.75	2.25	13.75	18.50	35.50[a]
Lusumba	0.25	1.00	2.50	9.00	7.00	19.75[b]
Sukali Ndizi	4.00	1.75	2.25	8.00	3.00	19.00[b]
Bogoya Giant	1.50	4.50	3.00	1.75	1.50	12.25[bc]
Kavinja	1.25	0	0.25	0	0	1.50[c]

Means with the same letter are not significantly different (DMRT).

significantly different at $P > 0.05$ and $P > 0.01$ respectively. Lower percentage hatchability (not more than 40%) was observed in Kijoge while cultivars Nyoya, Nshakara and Bokoboko had 50% and above. Superior developmental responses were observed in cultivars Nyoya and Nshakara depicting a higher level of susceptibility to the banana weevil borer. The different developmental responses might have been due to differences in antibiotic and nutrient contents of the banana cultivars. Also, the fibric and hard nature of Kijoge and Bokoboko, respectively, might have provided some physical resistance to weevil attack.

1.24 PREDATORS OF THE BANANA WEEVIL

A. M. Koppenhöefer

Endemic predators of the banana weevil, *Cosmopolites sordidus* (Germar) detected in the banana growing areas of western Kenya were studied in the laboratory and in cages under controlled quasi-field conditions to determine their potential for an impact on weevil populations. Since the adult weevil evades predation or parasitisation by arthropod natural enemies having a very strong cuticle, only eggs, larvae and pupae of the pest can be affected in its different breeding sites.

1.24.1 Predation in the pseudostem

The pseudostem after the harvest of the bunch if left standing or lying on the ground in bigger pieces forms a breeding place for the weevil. Predators especially with the increasing state of decomposition can penetrate these materials and prey on weevil eggs, larvae and pupae.

In caged experiments with very high weevil population levels on pseudostem pieces four species of predators were tested of which the hydrophilid beetle *Dactylosternum abdominale* was the most effective with average reductions of 40 to 90% depending on the number of predators released. The highest reduction occurred at predator densities two to three times as high as the densities found in the plantations. The staphilinid, *Thyreocephalus interocularis* reduced the population of weevil developmental stages by 40% which was equivalent to the impact of a histerid beetle, *Hololepta striatidera*. A labiid earwig, *Labia curvicauda* though feeding on eggs and larvae of the pest in laboratory experiments and showing some searching capacities did not induce any significant reduction.

1.24.2 Predation on banana suckers

Three species of predators were tested on 6 month old suckers planted in oildrums under controlled conditions for their efficiency as egg predators. Both for weevil and predators initially very high population densities were as compared to field observations. After 3 weeks the suckers were uprooted and the numbers of eggs and young larvae counted. The hydrophilid, *Dactylosternum abdominale* reduced their number by 50%, the carcinophorid earwig, *Euborellia annulipes* by 28% and the tenebrionid *Eutochia pulla* by 19%. In further experiments, over longer periods, with lower pest and predator densities, the hydrophilid was also able to reduce the growth of the weevil populations by up to 50%.

1.25 POPULATIONS OF *PRATYLENCHUS GOODEYI* IN CERTAIN BANANA CULTIVARS

S. W. Waudo

Tests were established in nematode-infested fields at the Agricultural Research Institute, Bukoba, Tanzania to monitor populations of the lesion nematode *Pratylenchus goodeyi* Sher and Allen, in different banana cultivars. The initial nematode density before planting was 30 *P. goodeyi*/cm³ of soil. Each planting material, a 1 m high sucker, was planted in a 60 cm deep hole with 3.5 and 4 m spacing between plants (mats) and rows respectively. A randomised block design with four replications was used. Nematodes were extracted from roots using the maceration-sieving technique.

Numbers of *P. goodeyi*/10 g wet root of banana are depicted in Table 1.40. The 18 banana cultivars supported significantly ($P = 0.01$) different populations of *P. goodeyi* 540 days after planting. Cultivars Kunda Kundi and Ngumba supported the largest and lowest populations of *P. goodeyi*, respectively. The significant ($P = 0.05$) difference in numbers of *P. goodeyi* extracted from the roots of the banana cultivars is a good indicator of different levels of susceptibility of the cultivars to the nematode that can be exploited in its management.

Table 1.40 Mean numbers of *Pratylenchus goodeyi*/10 g wet root weight of 18 banana cultivars 540 days after planting in nematode-infested field: Test 5. Tanzania

Cultivar	Type	Mean no. of *P. goodeyi*
KundaKundi	Brewing	26,125[a]
Ntali Mbwambuzi	Brewing	20,600[ab]
Enkundi-1	Brewing	19,500[ab]
Entagalaza	Cooking	15,750[ab]
Nsowe	Brewing	3025[ab]
Enkunku	Brewing	2733[ab]
Nkazi Mgumba	Cooking	2100[ab]
Entagalza	Cooking	1700[bc]
Embile	Brewing	1100[bc]
Enkundi-2	Brewing	1057[bc]
Entabula	Brewing	850[bcd]
Rwabugenda	Brewing	745[bcd]
Nshagya	Brewing	665[bcd]
Nyamaizi	Brewing	570[bcd]
Eushazi	Brewing	425[bcd]
Nshashambile	Brewing	300[bcd]
Entemae	Cooking	100[cd]
Ngumba	Cooking	75[d]

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

1.26 CULTURAL CONTROL OF THE LESION NEMATODE *PRATYLENCHUS GOODEYI*

A. S. S. Mbwana

Banana (*Musa* sp.) is a primary carbohydrate source to about 30% of the people in Tanzania. Banana yields began to decline in the 1970s, in part, due to the lesion nematode, *Pratylenchus goodeyi*. Two experiments, 1 and 2, were initiated at the Agricultural Research Institute-Maruku, Bukoba, Tanzania to investigate efficacy of seed cleaning and fallowing respectively in the management of the nematode. In experiment 1 planting materials (suckers and corms) were subjected to carbofuran (nematicide) dip, solarization, hot water and paring singly or in combination. Non-treated planting materials served as controls. Planting materials were planted in a *P. goodeyi*-infested field. Nematode populations were monitored periodically.

In experiment 1, the treatments, paring + solarisation and paring + carbofuran dip had the lowest numbers of *P. goodeyi* while the untreated sucker had the highest. In experiment 2, the lowest *P. goodeyi* populations were obtained from weeds, polythene 1000G and carbofuran-treated plots and the highest were obtained from dry grass mulched and banana plots.

These results indicate that weeds, polythene 1000G and carbofuran, used in the fallowing experiment, have high efficacy against *P. goodeyi* like hot water and carbofuran dip in the seed cleaning experiment.

1.27 RELATIONSHIP BETWEEN *PRATYLENCHUS GOODEYI* AND *FUSARIUM OXYSPORUM* IN TWO BANANA CULTIVARS

P. R. Speijer

Studies were undertaken to determine whether a complex disease interaction involving the plant parasitic nematode, *Pratylenchus goodeyi* and a soil-borne pathogenic fungus *Fusarium oxysporum* is responsible for root-rotting and subsequent toppling of two cultivars of upland banana in Kenya. The banana cultivars selected were Nakyetengu, a cooking cultivar, and Sukali Ndizi, a sweet cultivar. The two cultivars had shown different levels of susceptibility to the banana root rot complex during a survey in Oyugis and Kisii in 1990.

Inoculation studies on banana plants were carried out with *P. goodeyi* and *F. oxysporum*. Equal sized suckers were selected from a nursery. The plants were pared and heat treated before planting into heat sterilised sand. Liquid fertiliser was applied with each watering. Approximately 22,000 *P. goodeyi* per plant were applied by pouring a 75 ml suspension over the roots of the plants, 6 weeks after planting. In case of a combined application, 2.4 x 10^6 *F. oxysporum* spores were added to the inoculation suspension of 75 ml with 22,000 *P. goodeyi* for each plant, *F. oxysporum* strain had been isolated from a necrotic lesion in a Nakyetengu root.

Thirty days after inoculation of young banana plant parasitic nematodes were extracted from the roots. The higher density of *P. goodeyi* was found in the primary roots of both cultivars. The densities did not differ between the cultivars. High density of *P. goodeyi* was associated with necrosis in primary and secondary roots of the cultivar Nakyetengu. This association was only found in the secondary roots of the cultivar Sukali Ndizi. Addition of *F. oxysporum* spores to the inoculation suspension reduced the density of *P. goodeyi* in the necrotic secondary roots of the cultivar Nakyetengu and it induced an association between high density of *P. goodeyi* and necrosis in primary roots in the cultivar Sukali Ndizi.

The results demonstrated an intimate relationship between the nematode and the fungus in a root-rotting complex depending on the banana cultivar.

INTEGRATED PEST MANAGEMENT AND POPULATION BIOLOGY (IPB)

Major objectives of the IPB Section are to develop methods for arthropod population monitoring, including the use of kairomones, population surveillance and forecasting, population dynamics and modelling, crop loss assessment (in relation to pest population density, crop phenology, crop cultivars, and agroecology), determination of economic injury levels and control thresholds, development of a conceptual framework for IPM, including the identification of candidate IPM menus for a given crop, a given socio-economic community or a given agroecological area, study of interactions of different IPM components, development and testing, validation, and demonstration of selected IPM menus (farmer-managed, researcher-supervised on-farm trials).

1.28 ICIPE-IRRI COLLABORATIVE PROJECT OF UPLAND AND RAINFED LOWLAND RICE IMPROVEMENT

Z. Harahap, J. C. Olela and R. C. Saxena

Since 1989, improvement of upland rice has been the focus of ICIPE-IRRI Collaborative Project. However, since January 1991 improvement of rainfed lowland rice has become a priority following the ICIPE's agreement with the Lake Basin Development Authority (LBDA) to develop swampy areas in western Kenya for rice production.

Approximately 30,000 ha of wasteland swampy areas in western Kenya can be brought under rice cultivation, provided adaptable technologies can be made available. The swampy areas in the Lake Basin area can be categorised into lake shore plains, valley bottoms, and plateaus with temporary submergence of 5 to 50 cm for 1–2 months during the long rains and 5 to 20 cm for 1 month during the short rains. Unfortunately, at present only Sindano variety, which is highly susceptible to blast *Pyricularia oryzae* (Cav.), is available for cultivation.

During the long rains 1991, upland rice trials were conducted at the Mbita Point Field Station (MPFS), Ungoye, and Oyugis, while rainfed lowland trials were conducted at Kimira, Obera, and Utange in South Nyanza.

1.28.1 Upland rice trials

Pedigree nursery. Selections were made of 250 early maturing, drought-tolerant lines originated from the progenies of F_6 Ble Chai x Dourado Precoce. Evaluation of these lines is being continued during 1991/92 short rainy season. Some drought-tolerant lines obtained from out-crossed populations matured in 80 days.

International upland rice observational nursery (IURON). The IURON of 92 entries was tested at MPFS for drought tolerance along with the check variety, Dourado Precoce. The entries were planted in two rows, each 5 m long, with 30 cm spacing between rows. IRAT 216, REWA 352-2, IRAT 312, IRAT 318 and IRAT 330 were rated as drought-tolerant; IR 57899-29, IAC 136/76, IAC 43/76, RP 2423-5-77/6, Arias Halus, and KMP 34 were moderately drought-tolerant.

International upland rice yield nursery — medium (IURYN-Medium). Twenty entries of IURYN-Medium were planted at Ungoye on 3 x 5 m plots, with 30 cm distance between rows, using randomised block design and replicated thrice. Most of the entries were late-maturing, i.e. 135 days after emergence (DAE). Five best selected entries were: BR20, IRAT 216, IR 55411-50, Tondano, and TOX 936-8-4-1-2 with yield potential of 4.3 to 5.7 t/ha, compared with Nam Roo's 4.8 t/ha.

International upland rice yield nursery — early (IURYN-early). Sixteen entries of IURYN-Early also were planted at Ungoye with the same experimental procedures as IURYN-Medium. Dourado Precoce was the local check. Promising lines BR 4290-3-1-10, BR 4290-3-3-5, RP 1714-111-7-3-2, RP 2220-111-84-20, and IET 1444 with yield potential of 3.9 to 5.7 t/ha, were selected for retesting; the local check, Dourado Precoce yielded 3.3 t/ha. IET 1444, the highest yielder (5.7 t/ha), matured in 135 days.

Advanced yield trials. Twenty promising cultivars of upland rice were selected for advanced yield trials at MPFS and at Ungoye in the long rains, 1991. The cultivars were planted in rows, 30 cm apart, on 3 x 5 m plots, in randomised block design, and replicated four times. Calcium ammonium nitrate (26% N) was applied at 60 kg N/ha at 45 DAE. Yields were good at MPFS. IRAT 112 yielded the highest (4.4 t/ha), while IAC 150/79, 3290, IRAT 283, EAC 233/79, CNA 762069, and Dourado Precoce yielded between 3.4 to 4.3 t/ha. Yields were high (4.8 to 8.9 t/ha) at Ungoye (Table 1.41). IRAT 112 yielded 8.9 t/ha, significantly higher than 6.9 t/ha by Dourado Precoce. Cultivars IAC 220/79, CNA 762069, GIC 165-80, IAC 233/79, IRAT 144, IAC 150/76, IRAT 283, and 3290 out-yielded Dourado Precoce.

1.28.2 Varietal reactions of upland cultivars to the weed, Striga hermonthica

Ten upland rice cultivars were tested on 3 x 5 m plots for their reactions to *S. hermonthica* at Ungoye in the long rains 1991, using a randomised block design with four replications. Cultural practices were the same as for other upland trials. *Striga* plants taken from each plot at 90 DAE were dried and weighed. Cultivars IR 49255-B-B-5-2, IR 47697-4-3-1, IR 47255-B-B-5-4, IR 3847-B-B-7-2-2, and Ble Chai, apparently identified as resistant to *Striga* at Ogutu's Farm in short rains 1990/91, also resisted *Striga* at Ungoye in the long rains 1991.

Table 1.41 Agronomic data of 16 upland rice cultivars of advanced yield trial at Ungoye, LR 1991

Cultivar	Height (cm)	Maturity (days)	Grain[1] yield (t/ha)
IRAT 112	92	118	8.9[a2]
IAC 220/79	117	115	8.6[ab]
CNA 762069	126	118	8.6[ab]
GIC 165-80	119	112	8.0[abc]
IAC 233/79	119	118	7.9[abcd]
IRAT 144	117	135	7.7[abcd]
IAC 150/76	126	123	7.6[abcd]
IRAT 283	133	98	7.4[bcd]
3290	110	115	7.1[bcd]
Dourado Precoce (check)	128	110	6.9[bcde]
IRAT 236	118	98	6.8[cde]
IRAT 229	107	97	6.3[cdef]
ITA 257	106	116	6.2[def]
IRAT 2	121	132	5.3[ef]
Ble Chai	139	132	5.3[ef]
Nam Roo	144	135	4.8[f]

[1] At 14% moisture content.
[2] Within column means followed by the same letter do not differ significantly ($P > 0.05$); CV 14.4%.

1.28.3 Rainfed lowland rice trials

Rice germplasm evaluation. A germplasm of 450 accessions, assembled from various international institutions (IRRI, IRAT, IITA), was tested on rainfed lowland area at Kimira plain during the long rains 1991. The accessions were direct-seeded in single rows of 5 m long each and unreplicated. Ninety accessions have been selected for further testing in 1992 long rains.

During the long rains of 1991, 73 selected rice cultivars were tested in two different rainfed lowland ecologies: the lake shore plains in Kimira and the valley bottom in Obera. The cultivars, planted as upland rice in early March 1991, were dry-seeded in rows (30 cm apart) on unreplicated 3 x 7 m plots; Sindano was the check cultivar planted between every 10 plots. Several promising cultivars have been selected for yield trials during the long rains of 1992.

The Obera site was not representative of the valley bottom, but rather a hydromorphic ecology. There was no standing stagnant water during the rainy season. Management operations were poorly done, yet several cultivars yielded between 2 to 4.3 t/ha. Nam Roo, Ble Chai, IRAT 144, IAC 272/78, IAC 220.79, IAC 233/79, GIC 165-80, IREM 190, Tondano, B3623-TB-58, and TGR 94 were the promising cultivars.

Kimira valley was a suitable ecosystem for rainfed lowland rice. In that area, farmers have been growing rainfed rice for the last three seasons. During the long rains of 1991, the farmers planted Sindano variety on about 50 ha early January. The crop suffered severe moisture

Table 1.42 Agronomic data of 10 selected rainfed lowland rice cultivars, Kimira, long rainy season, 1991

Cultivar	Height (cm)	Maturity (days)	Grain[1] yield (t/ha)
Nam Roo	146	115	5.2
IAC 220/79	119	110	4.7
IR 49255-B-B-5-2	95	135	4.6
Sindano (check)	126	140	3.8
Tondano	103	123	3.8
GIC 165-80	110	108	3.8
IAC 272/78	112	121	3.6
S 431-B-5-1	99	120	3.5
IAC 230/79	117	112	3.4
IRAT 289	114	105	3.4
IAC 25	104	110	3.3

[1]At 14% moisture content.

stress due to prolonged drought. We initiated our preliminary trial at Kimira in early March 1991. Severe drought experienced immediately after seeding caused late emergence and delayed weeding affected rice plant growth at tillering stage. However, the plants quickly recovered 2 weeks after weeding. Early maturing varieties were harvested in mid-July 1991, about the same time as Sindano planted by farmers in early January 1991.

A high incidence of leaf- and neck-blast decimated yield of Sindano planted by farmers. Consequently, many farmers abandoned their rice fields. In contrast, several cultivars in our experimental plots yielded 2 to 5.2 t/ha. These cultivars were blast-resistant and also were early maturing (Table 1.42). Selected cultivars will be retested.

Apparently, a drastic change in climate occurred in the area in August which did not favour blast infection. Nine check plots of Sindano variety, harvested in late August, produced yields of 3.5 to 4 t/ha, compared with negligible yield for July harvest. Nonetheless, local farmers would prefer to grow promising cultivars selected by ICIPE scientists, rather than blast-susceptible Sindano.

1.29 RICE AGRONOMY

K. Ampong-Nyarko and R. C. Saxena

We identified the production constraints limiting rainfed rice production in western Kenya. In the long rains of 1991, we conducted four trials at three sites — Kimira, Obera, and Oyugis. Low soil fertility and drought were the main abiotic stresses; weeds and rice blast were the biotic stresses; insects did not cause any economic loss to rice cultivars tested.

In another study, we tested rice crop intercropped with maize, sorghum, beans, finger millet and cowpea in different combinations. All the upland crops survived in the periodically flooded lowland areas where rice was grown. In sites with low rainfall, intercropping rice with traditional upland crops is a good strategy.

1.30 INSECTS AFFECTING RAINFED UPLAND RICE IN WESTERN KENYA

J. C. Olela, Z. Harahap and R. C. Saxena

Populations of insects infesting rainfed rice ecologies were monitored. Pest infestations at different stages of crop growth were generally low. They included leaf folders *Cnaphalocrocis medinalis* and *Marasmia* sp., the stalk-eyed shootfly *Diopsis thoracica*, the earwig *Forficularia auricularia*, stem borers *Chilo partellus* and *Maliarpha separatella*, the rice skipper *Pelopidas mathias*, short-horned grasshoppers *Oxya* sp., long-horned grasshopper *Caulopsis cuspidata*, the grain stink bugs *Timbraea limbaterentis*, and black stink bug *Scotinophora* sp. Varietal reactions to *Marasmia* sp., *D. thoracica*, and *C. partellus* recorded in the multilocation yield trial conducted during the long rains of 1991 are given in Table 1.43. Levels of infestations differed on promising cultivars Dourado Precoce, IAC 233/79, IAC 220/79, Ble Chai, and Nam Roo. Ants were a problem at the seedling stage. Spiders, lacewings, giant stink bugs, and several hymenopterous species comprised the natural enemies of insects affecting upland rice.

Table 1.43 Varietal reactions of selected upland rice cultivars and insect damage recorded at various sites in western Kenya, long rains, 1991[1]

	Damage by *Marasmia*	Deadhearts (%) by *C. partellus*[2]				Tillers (%) damaged by stalk-eyed shootfly			
Entry	MPFS	MPFS	Kimira	Oyugis	Ungoye	MPFS	Kimira	Oyugis	Ungoye
Dourado Precoce	5.5	0.5	2.0	1.7	1.3	6.7	26.0	17.4	27.3
IAC 233/79	2.8	1.0	2.7	1.3	2.0	11.3	29.2	20.4	28.8
IAC 220/79	4.0	0.0	2.0	1.1	1.5	9.3	24.0	18.1	25.0
Ble Chai	4.5	2.8	2.1	2.3	3.2	8.7	19.0	12.9	16.5
Nam Roo	6.5	1.0	1.9	1.4	3.0	2.2	21.0	12.7	24.0

[1]Avg of four replications.
[2]Deadhearts based on counts per m^2.

LIVESTOCK TICKS RESEARCH PROGRAMME

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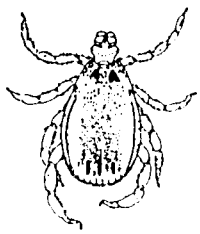

2 Livestock Ticks Research Programme

In 1991 research on various components of integrated tick management was undertaken both in the laboratory and in the field. The ecological work was conducted at Rusinga island, Kuja river and Nairobi and focused mainly on off-host and on-host tick population dynamics, collection of baseline data on tick-borne diseases, ecto- and endo-parasites of cattle at Kuja river (a new field research site) and on tick pick-up rates by cattle at Nairobi. Work on factors affecting productivity of indigenous zebu cattle in Rusinga island, initiated in previous years, continued during 1991. Research on cost effective application of acaricides under range management was undertaken at Mgeno ranch in Taita-Taveta district. Work on tick biology focused on tick feeding performance in relation to tick age and host resistance status. Studies on acquired resistance against Amblyomma variegatum *in cattle and on* in vitro *feeding techniques for* Rhipicephalus appendiculatus *were also undertaken. The anti-tick vaccine work was mainly on further purification of tick-derived antigens previously shown to be promising vaccine candidates.*

Tick biological control research included field studies on seasonal incidence of tick parasitoid at Kuja river, pathogenicity of entomogenous fungi for ticks in the laboratory and on predation of ticks by indigenous chickens. Studies on natural products and indigenous plants possessing acaricidal activities were also undertaken.

2.1 DIURNAL AND SEASONAL ACTIVITY OF IMMATURE OFF-HOST TICKS ON RUSINGA ISLAND

S. M. Hassan, D. K. Punyua and P. O. Ngoko

The experiment was started in October 1989. Ticks were collected monthly from the top of the vegetation by blanket dragging method from three sites: homestead, roadside and grazing areas. Each site was sampled three times during the day (0800–0900, 1200–1300 and 1600–1700 hours).

Diurnal activity of ticks in the years 1990 and 1991 are shown in Figures 2.1 and 2.2, respectively. The seasonal activity for both years is shown in Figure 2.3. The diurnal activity differed from one month to another although considering both years it was evident that ticks were more active in the mornings and evenings and less active at noon. Seasonally, ticks were more abundant in the months of August and September. However, the small peak of activity in March 1991 was due to a higher activity of *A. variegatum* larvae. *R. appendiculatus* larvae were the most predominant ticks followed by *A. variegatum* and fewer numbers of *R. evertsi evertsi* and *Boophilus decoloratus* larvae.

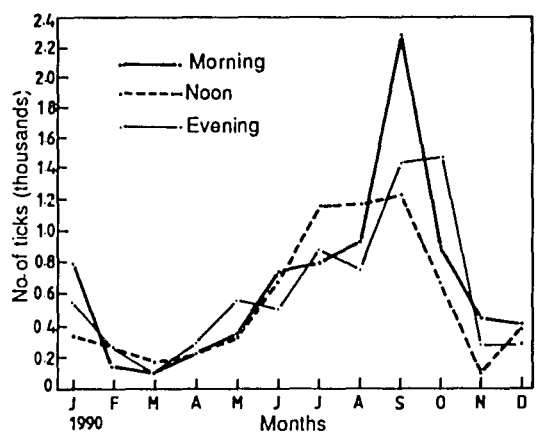

Figure 2.1 Diurnal and seasonal activity of off-host immature ticks on Rusinga Island during 1990: · —· morning; · - - · noon; · — · evening.

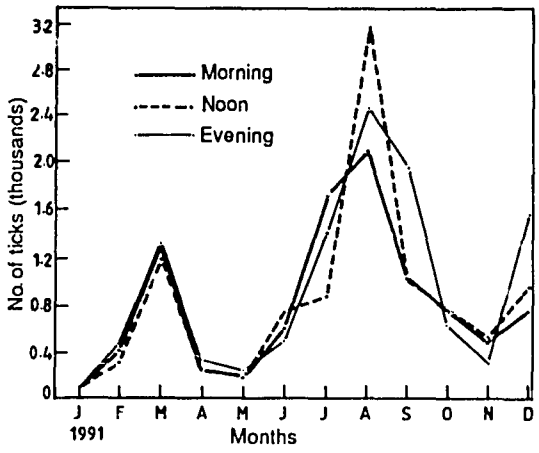

Figure 2.2 Diurnal and seasonal activity of off-host immature ticks on Rusinga Island during 1991: · — · morning; · - - - noon; · — · evening.

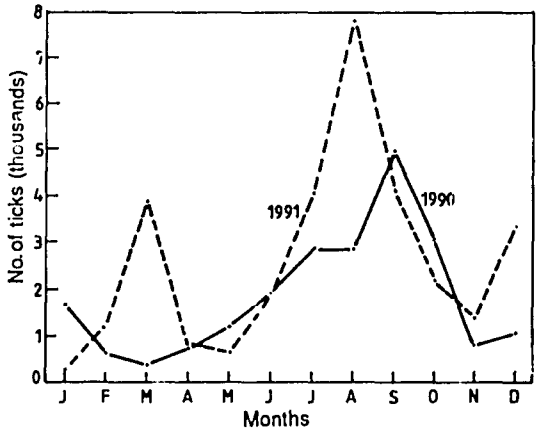

Figure 2.3 Seasonal activity of off-host immature ticks on Rusinga Island during 1990 and 1991: · — · 1990; · - - - · 1991.

2.2 POPULATION DYNAMICS OF ON-HOST TICKS AT KUJA RIVER FIELD RESEARCH SITE

S. M. Hassan, M. J. Wabombo, D. K. Punyua and P. O. Ngoko

The experiment was started in August 1990 to study the abundance and repeatability of the common ixodid tick species on the local cattle in Kuja river. Five head of cattle were selected from each of six farms for monthly tick collection. The results so far obtained are presented in Figure 2.4. *R. appendiculatus* was the most dominant tick species. It was found abundant in October 1990, dropped to a low level in January 1991 and started to increase to a smaller peak in March and dropped again in May. Thereafter, the activity increased steadily to a higher peak in October 1991.

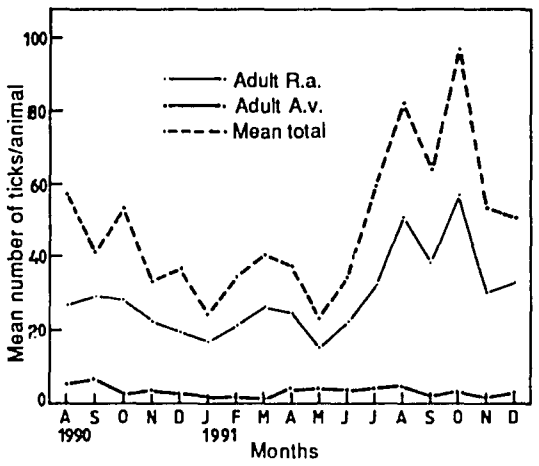

Figure 2.4 Population dynamics of ticks at Kuja River field site, 1990/91: · — · adult *Rhipicephalus appendiculatus*; · — · adult *Amblyomma variegatum*; · - - - · mean total.

The activity pattern of adult *A. variegatum* is not yet quite clear. However, a small peak was observed in September 1990. *B. decoloratus* and *R. e. evertsi* were collected in very low numbers. The experiment is in progress to determine the repeatability of the population pattern of each tick species in the following years.

2.3 TICKS, TICK-BORNE DISEASES AND OTHER PARASITES OF CATTLE IN KUJA RIVER

M. J. Wabomba

A preliminary survey of ticks, tick-borne diseases and other parasites of cattle in Kuja river was started and is still in progress. So far 640 specimens have been analysed for ticks, tick-borne diseases and internal parasites of cattle. Preliminary results revealed that 329 specimens were positive for *Theileria* parasites, 72 *Anaplasma marginale*, 37 *Babesia bigemina*, 18 *Borrelia theileria*, 4 *Eperythrozoon teganoides*, 1 Sarcospondiosis, 3 for *Trypanosoma vivax*, 1 *T. theileri* and 25 mineral deficiency anaemia. Faecal samples examined revealed 384 specimens were positive for helminths although most of the egg counts were below significant levels, with highest count being 326 eggs per gram of faeces in only one case out of 640 samples. Preliminary analysis indicates that mineral deficiency anaemia may be the major cause of poor health in calves. Apart from *R. appendiculatus*, *A. variegatum*, and *B. decoloratus*, other tick species identified include *Rhipicephalus simus*, *R. brevas*, *Hyalomma rufipes* and *Amblyomma nuttali* from tortoise. Biting flies of the genus *Stomoxys* spp., *Haematopota* spp. and *Tabanus* spp. have also been observed. Lice of the genus *Lignognathus* spp., *Haematopinus* spp. were very prevalent in calves. Mites of the genus *Sarcoptes scabie* were the cause of acute dermatitis in goats. *Psoroptes caprae* mites were also isolated from cases of otitis in goats on three farms.

2.4 TICK PICK-UP RATE BY CATTLE IN THE FIELD

D. K. Punyua

The rate at which hosts pick-up ticks from the vegetation determines their infestation levels. Pick-up rate is, however, influenced by many environmental as well as host factors. These include, host density, host resistance, tick activity behaviour, which in turn is controlled by such factors as environmental temperatures, the tick's physiological state, and others.

An experiment was started to determine the rate of daily tick pick-up by cattle in a one-acre paddock. The paddock which was tick-free was seeded with 20,000 adult *R. appendiculatus*. Five tick-free zebu steers were introduced into the paddock and left to graze freely. All the animals were deticked daily and the ticks collected were put in a bottle containing 70% alcohol and later counted.

After three weeks of the study, about 30% (5660) of the seeded ticks had been collected at the rate of about 1.7% per day.

2.5 EFFECT OF DIFFERENT TREATMENT REGIMENS ON THE PRODUCTIVITY OF CATTLE IN RUSINGA ISLAND

S. M. Hassan, D. K. Punyua and P. O. Ngoko

An experiment was designed to elucidate the role of different treatment regimens as factors limiting the productivity of cattle in Rusinga Island (*ICIPE 1989 Annual Report*). Calves born in 1989 and 1990 were allocated, at birth, randomly to five treatment groups. The first group was protected from ticks, tick-borne diseases and helminths, the second from ticks only, the third was treated against tick-borne diseases only and the fourth was protected from helminths only. The fifth group was left as an untreated control.

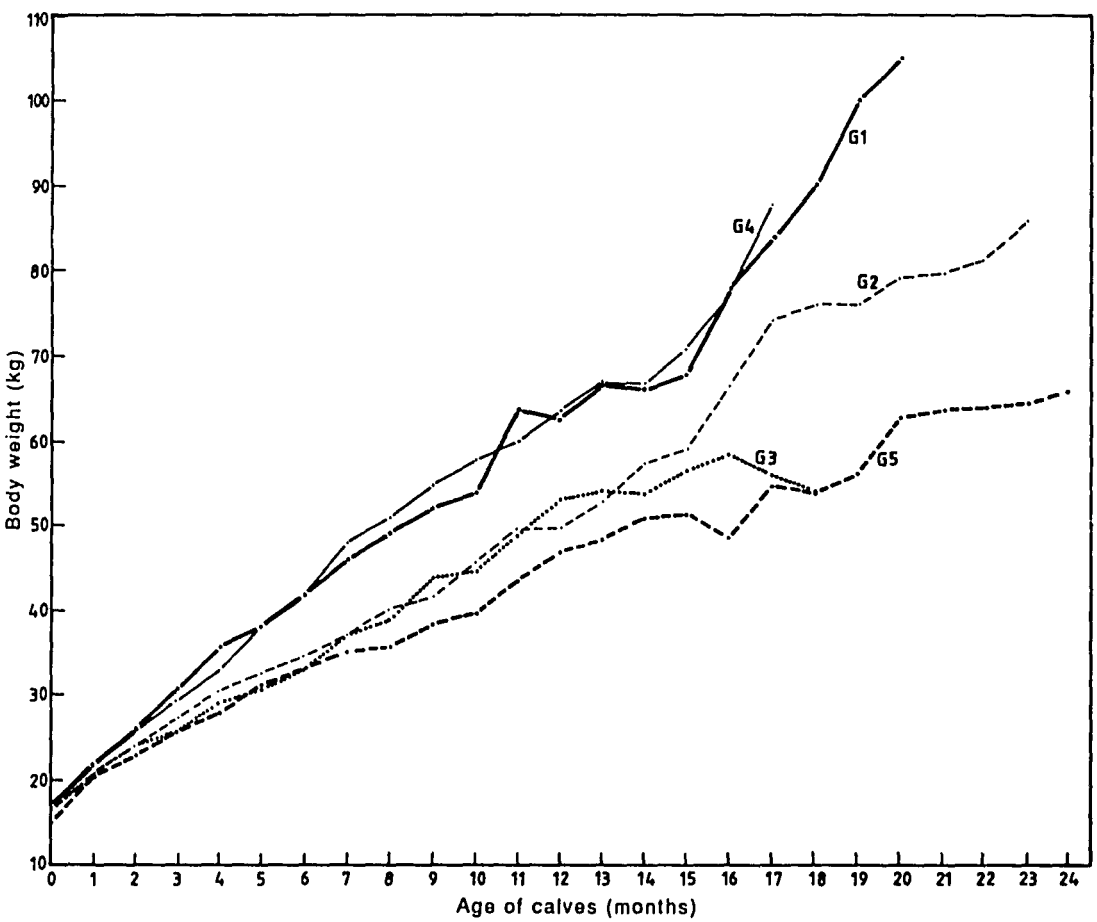

Figure 2.5 Effect of various treatment regimens on the body weight of cattle on Rusinga Island; 1, protected from ticks, tick-borne diseases and helminths; 2, protected from tick only; 3, treated against tick-borne diseases; 4, protected from helminths; 5, untreated control.

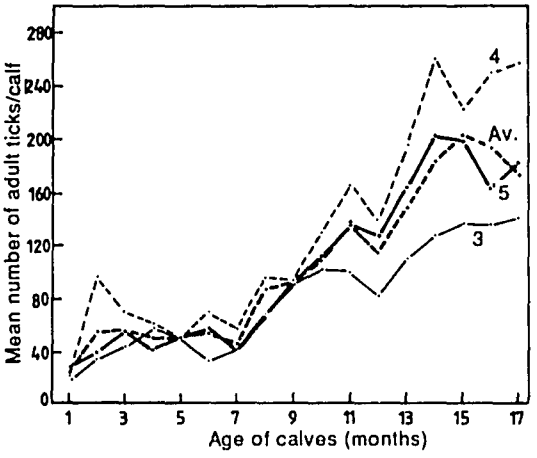

Figure 2.6 Tick infestation of calves treated against tick-borne diseases (3); helminths (4) or untreated (5); Av, average of the mean.

Data collected monthly included liveweight gain and total body tick collection. Blood, lymph node smears and faecal samples were routinely examined. Preliminary results of the liveweight gain are presented in Figure 2.5. It is obvious that from the second month of age, calves in the first and the fourth groups gained the highest body weights followed by the second and the third groups. However, calves of the second group started to put on weight better after 15 months of age. Calves that were left untreated had a retarded growth rate.

Mean monthly collected ticks from calves are presented in Figure 2.6. Up to 7 months of age tick infestation was stable for all the calves. Thereafter, the infestation started to build up steadily. Calves treated against helminths carried the highest ticks number.

The experiment is in progress and the results so far obtained are probably inconclusive. However, ticks and helminths appear to be the main factors retarding the growth rate of calves in Rusinga Island.

2.6 TICK CONTROL IN KENYA: DEVELOPING MODELS FOR COST-EFFECTIVE ACARICIDE APPLICATION IN DIFFERENT FARMING SYSTEMS

A. O. J. Amoo, O. O. Dipeolu and L. N. Gichuru[1]

Chemical control of ticks by intensive acaricide application either through dipping or spraying has been the only method of tick control in Kenya and in most other African countries. These chemical acaricides constitute an external input in tick control as most of these chemicals are imported; therefore, purchasing these chemicals results in substantial drain in the hard currency reserve of most African nations, the economies of which cannot support such expenditure. Consequently, any measure taken to reduce the overall dependence on the use of chemicals for tick control should prevent depleting foreign currency and should be cost-effective for the farmers since they produce the bulk of the livestock in the continent.

Trials on the effect of ticks on the productivity of cattle under different regimes of dipping were initiated at three farming systems, namely: (a) dairy farm with East Coast fever-immunised cattle, (b) rangeland farm with improved zebu cattle for beef, and (c) a farm at the resource poor level. Animals in farms (b) and (c) were not immunised. Results of study conducted on the dairy farm had been reported earlier (*ICIPE 1990 Annual Report*). The following is a report on (b).

2.6.1 *The effect of varying the intensity of acaricide application on ticks and weight gain in zebu steers under range management*

At Mgeno ranch (eco-climatic zone V) in Taita-Taveta district, 1 year old steers were subjected to varying intensity of acaricide application as follows: Group 1, dipped weekly; Group 2, dipped every 2 weeks; Group 3, dipped every 4 weeks; Group 4, dipped every 6 weeks; Group 5, undipped. Experimental procedures were as for the similar study in dairy cattle (*ICIPE 1990 Annual Report*).

The tick species encountered in the study site were, in the order of decreasing abundance, *Rhipicephalus pulchellus*, *R. parvus*, *R. appendiculatus* and *Amblyomma gemma*. No Boophilid was found. Figure 2.7 shows the mean monthly ticks (all species) and the cumulative weight gains of the various dipping groups and the rainfall (mm) in the study area. While tick load on the control group was not significantly different from group 2, it was statistically lower than each of the other groups (Table 2.1). The cumulative weight gains of all the animals in the various dipping groups show that no differences exist in all the groups within the first 5 months. Thereafter, the undipped group gained less weight than any of the other groups. The percentage weight increase as shown in Table 2.2 reveals that group 1 cattle (control) had the highest weight increase as compared to each of the other groups. But, at what price? A preliminary cost benefit analysis of production with respect to the different dipping regimes (Table 2.3), shows that the profit/animal was highest for groups 3 and 4 which were dipped monthly and every 6 weeks respectively. The marginal benefit of tick control as per weekly dipping when compared to the undipped group was $52.5 per animal. However, groups 3 and 4 under a monthly and six weekly regime of acaricide use had higher marginal benefits of $33.1 and $57.7 respectively than the control animals which were dipped weekly.

In conclusion, this study has shown that under range management, beef cattle can be maintained productively with relaxed acaricide exposure. In this situation, enzootic stability is apparently effective, since animals are exposed to ticks and tick-borne diseases early in life. Though there might be a high incidence of morbidity and presumably high mortalities at these early stages, survivors become carriers and they help to ensure constant low level infection rate in ticks and thus parasite challenge

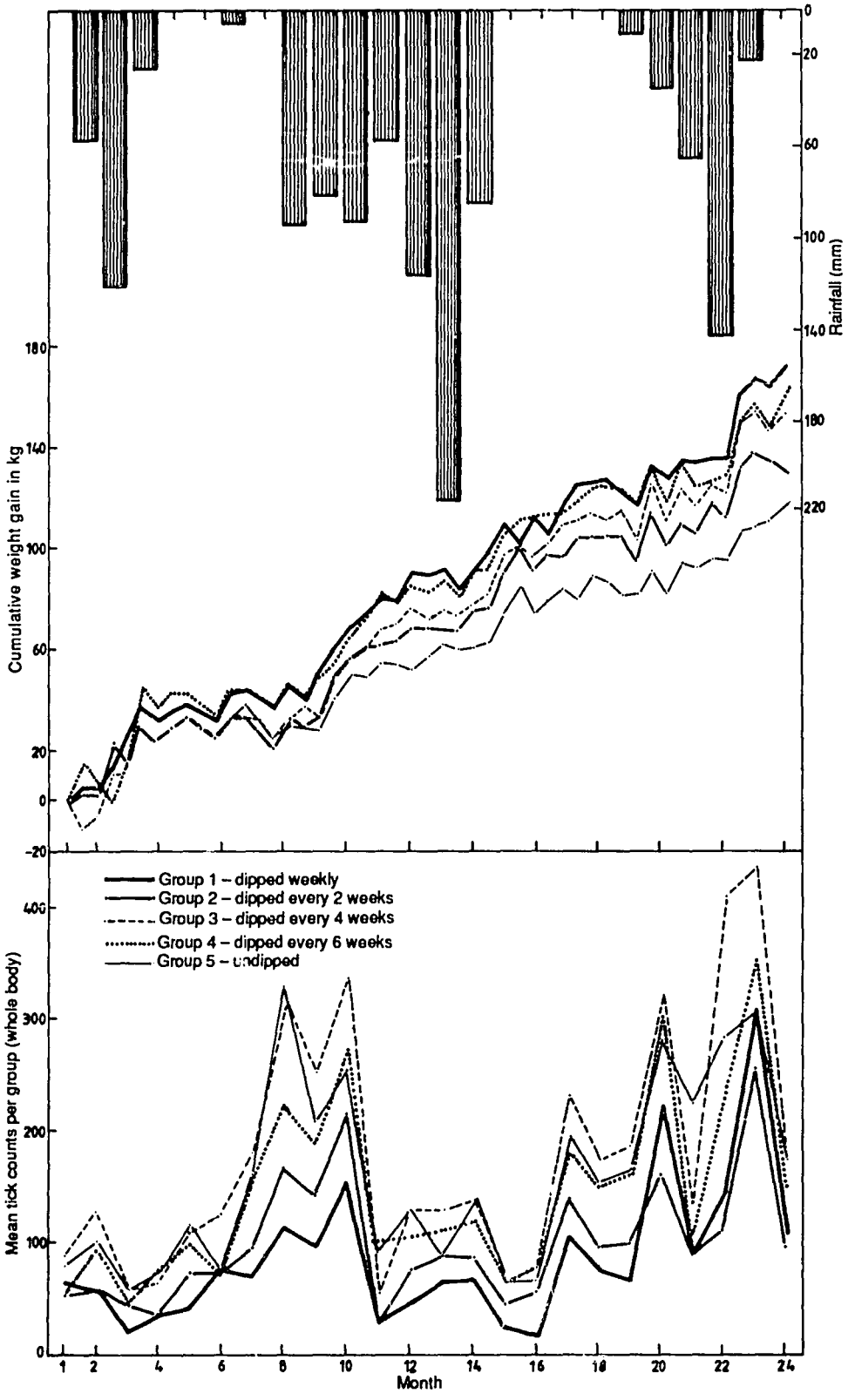

Figure 2.7 Comparison of tick load and weight gains in beef cattle under different dipping regimens.

Table 2.1 Comparison of tick counts (all species) on beef cattle under different dipping regimes

Treatment group	Dipping interval	Mean number of ticks[1]
1	Weekly	87.3 ± 66.0[a]
2	Every two weeks	99.6 ± 56.2[a]
3	Every four weeks	180.5 ± 110.9[b]
4	Every six weeks	146.5 ± 80.8[b]
5	Undipped	159.6 ± 84.1[b]

[1]Means ± S.E. — Means with the same letter in a column are not significant.

to animal hosts after tick infestation. Subsequently, relaxation of the dipping intensities allows animals to develop resistance to ticks and hence to tick-borne diseases. A more rational tick control policy in such situation would be to determine the economic threshold levels and then apply control measures by dipping or spraying when that threshold level is reached. Finally, a reduction in the level of acaricide usage will ensure higher marginal gains as well as reducing environmental pollution, acaricide toxicity and the development of acaricide resistance.

[1]*Kenya Agricultural Research Institute, Kabete, Nairobi.*

Table 2.2 End of trial weight gains of beef cattle under different dipping regimes

Treatment group	Number of cattle at start	Number of cattle at end	Total weight of surviving cattle (kg)	Mean weight of surviving cattle (kg)	Mean weight of all cattle (kg)	Per cent weight increase[1]
1	6	6	1740	290	290	145.1
2	6	6	1650	275	275	89.7
3	6	6	1855	309.2	309.2	98.4
4	6	6	1970	328.3	328.3	98.0
5	6	5	1440	288	240	64.6

[1]Per cent weight increase = $\frac{\text{Total final liveweight - Total initial liveweight}}{\text{Total initial liveweight}} \times 100$

Table 2.3 Preliminary cost/benefit analysis of production in beef cattle under different dipping regimes

	Dipping groups 1	2	3	4	5
(A) CATTLE					
Number at start	6	6	6	6	6
Number at end	6	6	6	6	5
Deaths from ECF[1]	0	0	0	0	1
Deaths from other causes	0	0	0	0	0
Total deaths	0	0	0	0	1
(B) COSTS					
Acaricide @US$0.125/dipping	72	36	18	12	0
Veterinary services and drugs (US$)	19.5	23.6	18.5	20.5	31.2
Total costs (US$)	91.5	59.6	36.5	32.5	31.2
(C) REVENUE					
Total liveweight gains (kg)	1740	1650	1855	1970	1440
Value @$1.25/kg	2175	2062.5	2318.8	2462.5	1800
(D) PROFIT					
Profit (C - B)	2083.5	2002.9	2282.3	2430	1768.8
Profit per cattle	347.3	333.8	380.4[2]	405[2]	294.8

[1]Death due to *Theileria* spp. not confirmed as *T. parva*.
[2]Significantly higher than the control value ($P < 0.05$).

2.7 *RHIPICEPHALUS APPENDICULATUS* TICK PERFORMANCE IN RELATION TO TICK AGE AND HOST RESISTANCE

J. W. Chiera

This investigation was intended to establish whether or not specific tick performances are age-related. Unfed ticks are known to survive for a long time and whether their economic importance lasts that far or not was a question that needed to be answered. Another important question was whether or not the effect of host resistance on ticks is enhanced by tick age. Unfed ticks (larvae, nymphs and adults) were exposed at various time intervals and thereafter their feeding performance was tested at the same time as ticks of different age groups. The ticks were exposed in incubators in the laboratory at given temperatures and relative humidity conditions, and also in a Stevenson screen outdoors at Duduville.

The results obtained so far, indicate that the question of survival of ticks under captivity needs to be resolved. It has been reported earlier that ticks do not survive well under laboratory conditions. This investigation has revealed that ticks will survive much better if kept in smaller numbers than in larger ones. This is probably due to competition, but the question is still open for further investigation. The investigation was not originally planned to answer this question, nevertheless the results brought it out quite clearly. Differing numbers of caged ticks were exposed for different reasons and maintained under the same conditions. When the problem of poor survival was noticed in the largest groups, samples were taken and the differences quantified. Although this occurrence interfered with the investigation, it was considered an important finding with regard to tick maintenance under laboratory conditions.

Other results have also revealed that the feeding performance of old larvae and nymphs is severely affected by their reduced ability to attach on hosts. Host resistance, on the other hand, was found to reduce this ability even further. This happened even when their survival off the host was still good. For instance, 4-month old larvae that had been maintained outdoors showed an off-host survival of 70%, but completely failed to feed on both susceptible and resistant rabbits. Young, 2-week old larvae managed to feed successfully to levels of 71 and 46%, respectively, under the same conditions. This was remarkable in that the 4-month old larvae were apparently almost as active as the young ones. On the other hand, larvae that were maintained at 18°C and over 90% r.h. and tested after 4 months had a 44% feeding success on susceptible rabbits, while those tested after 8 months had only 21% feeding success compared to 72 and 78%, respectively, for young 1-month old larvae. On resistant rabbits, the reduction factor of feeding success of older larvae was more than twice that on susceptible rabbits.

The case for nymphs was similar to that of larvae, but the adults tested failed to show reduction in feeding success of older ticks. This was perhaps due to the fact that the adult ticks were tested when they were only 8 months old. The survival problem alluded to above made it impossible to wait much longer before testing them, although under ideal conditions these ticks can survive for upto 24 months.

These results show, first of all, that there is a need to establish what it is that affects tick survival in the laboratory and whether it is possible to improve tick survival under such conditions. The results also indicate that the presence of older ticks becomes less and less of a threat, particularly in the presence of resistant hosts.

2.8 USE OF *IN VITRO* FEEDING BIOASSAYS TO QUANTIFY HOST TICK-RESISTANCE

P. Losel[1]

The study of tick feeding behaviour *in vitro* allows processes controlling their feeding to be investigated in more detail than can readily be achieved on the host and may provide simple methods for assessing a host's resistance to ticks without subjecting it to test infestations, which may injure the host or alter its resistance status. In a 24-month collaborative project between the University of Neuchatel, Switzerland and ICIPE, funded by the Swiss government Directorate of Development Cooperation and Humanitarian Aid, two *in vitro* feeding methods for ticks, membrane feeding and capillary feeding, were considered. These were used to study *R. appendiculatus* feeding behaviour and how this was affected by test-sera from tick-resistant hosts.

In membrane feeding experiments, the tick pierces an artificial membrane with its mouthparts to reach a diet held underneath. In the capillary method, the diet is contained in fine glass tubes shaped at one end to fit over the mouthparts of ticks which are fixed, ventral side uppermost, on a glass microscope slide. Because of its simplicity and since most test sera were only available in very small quantities the capillary feeding method proved to be the more suitable.

As the weight gains achieved by previously unfed adults in periods under 3 days in length, both on the host and *in vitro*, were too small for accurate measurement, ticks were pre-fed on rabbits for up to 6 days. Females with weights of 35 to 70 mg, corresponding with the start of the rapid engorgement phase of their meal, were removed from the rabbit for use in experiments. Measurements of tick weight and length, distance moved by serum meniscus and change in optical density of the capillary contents provided simple indices of feeding performance. Weight gain, expressed as a percentage of the tick's starting weight, was the main parameter used. For more detailed studies of *R. appendiculatus* feeding behaviour, a "Feeding Electrogram" technique was employed. Five distinct electrogram pattern classes were identified (Figure 2.8). Simultaneous video-assisted observations of fluid movements in the vicinity of the tick's mouthparts and electrophysiological muscle recordings from regions of the tick's head, allowed these patterns to be correlated with aspects of its feeding behaviour. An orderly sequence of signals termed the "feeding complex" was associated with largest weight gains. This consisted of a 3–8Hz fast-sucking waveform

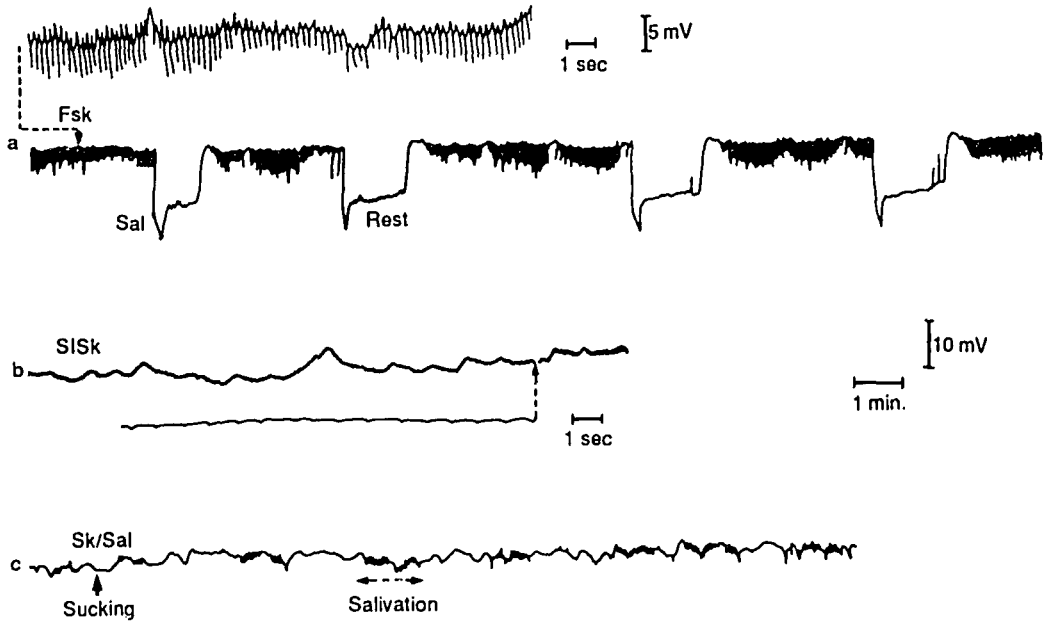

Figure 2.8 Feeding electrograms recorded from partially-fed *R. appendiculatus* females feeding *in vitro* consist of five types of signal correlated to different aspects of the tick's feeding behaviour: a, fast sucking (Fsk), burst-like release of saliva (Sal), rest; b, slow sucking (SISk); c, sucking and salivation (Sk/Sal).

typically lasting 4–5 minutes, a sharp drop in potential at salivation and a 1–2 minute period of apparent inactivity. Two further signals, the "slow sucking pattern" (small amplitude waveform at frequencies below 1Hz) and the "salivation-slow sucking pattern" (like the former but with sporadic, slow releases of saliva) were associated with smaller weight gains.

Resistant sera used in this study all came from animals in which resistance had been artificially induced by multiple infestation (naturally acquired immunity) or by inoculation with tick-antigen preparations. A sample of serum taken from the animal before the treatment generally served as a control for the *in vitro* feeding tests. Weight gain bioassays of pre-fed ticks (see above) over 18 hours (27°C, 95 + % r.h.) were used to identify resistant sera. Nine hour long feeding electrogram recordings were then used to investigate the response of individual ticks to a resistant serum and its control. Ticks were fed control serum for the first and last 3 hours of the experiment and resistant serum for the middle 3 hours. Weight changes were recorded at each change of serum and at the end of the experiment. This type of "bracketing" experiment was intended to show how rapidly the resistant serum altered feeding and if this effect was reversible.

Sera prepared from the blood of laboratory rabbits made resistant through successive artificial tick-infestations strongly inhibited feeding. Bracketing experiments showed that this inhibition was not permanent, suggesting that the tick is able to "sense" some antifeedant factor in the serum from resistant rabbits, perhaps detected peripherally by gustatory sensilla of the chelicerae. Serum of rabbits inoculated with tick-gut membrane solubilised protein (MSP) (donated by Dr. B. Rutti, Neuchatel), appeared to cause irreversible inhibition of feeding. No reliable cases of sera from cattle, which had been rendered resistant, influencing *in vitro* feeding performances of ticks were found. Resistant bovid sera tested include those from European strains, artifically infested with ticks, inoculated with anti-MSP and anti-20kDa (all donated by Dr. B. Rutti); African strains, artificially infested on two occasions seven times (donated by Dr. S. Essuman, ICIPE). Why there should be a humoral expression of resistance in rabbits but not in bovids is as yet unclear.

†*University of Neuchatel, Switzerland.*

2.9 STUDIES ON NATURALLY-ACQUIRED RESISTANCE IN BORAN CATTLE TO THE TICK *AMBLYOMMA VARIEGATUM* AFTER REPEATED INFESTATIONS

S. C. Dossa

Due to many drawbacks which arose with the use of chemical control, tick resistant animals have been found to be an alternative in tick control programme. This has

been shown to be effective in Australia where *Boophilus microplus* could be controlled with the use of cattle breed which have 75% zebu blood. In Africa reports indicate that the local breed *Bos indicus* acquires a more effective natural resistance to tick infestation than the exotic *Bos taurus* against *R. appendiculatus*, *R. e. evertsi*, *Amblyomma hebraeum* and *Hyalomma anatolicum anatolicum*. Resistance of rabbit against *A. variegatum* has been demonstrated but so far the resistance status in cattle has brought about many controversies. The objective of this study was to assess the cattle resistance dynamics against *A. variegatum* after repeated infestations using biological parameters and serology (Bailey's method). Twelve months old Boran cattle were used for this study.

Tick challenge was provided by 100 2-week old nymphs. All harvested nymphs from a particular animal were put together in a 7.5 x 2.5 cm flat bottomed glass tube and then incubated at 28° C. These samples were examined regularly to record the biological parameters. For adult feeding, 20 males were applied in the same manner as the nymphs.

Preliminary results show that the engorgement period in the second infestation was higher compared to that observed in the first infestation. Engorgement weights observed in the second infestation were higher compared to the first ones. These results were expected because of the one week starvation the animals had undergone while under challenge. When challenged with adults the engorgement period was higher with all the ticks on experimental animals compared to that observed on naive animals.

2.10 FURTHER PURIFICATION OF FRACTION F_2 PROTEINS POSSESSING ANTI-TICK VACCINE POTENTIAL

S. Essuman and P. Muteria

Fractionation of Triton X-100 solubilised gut-membrane bound proteins of *R. appendiculatus* on Sephacryl S-200 (Pharmacia) yielded three fractions, F_1, F_2 and F_3 (*ICIPE Annual Reports, 1986, 1987*). The fraction F_2 was found to induce a higher protective immunity in rabbits and cattle against subsequent tick infestations (*ICIPE Annual Reports, 1987, 1988*). Liquid chromatographic methods (e.g. Affinity and Ion-Exchange) have been employed to further purify the protein components of this fraction.

On a DEAE-Sephacel column, four polypeptides with very close relative mobilities (Figure 2.9,A) were eluted. Immune response induced by these proteins in cattle caused very slight reduction in engorgement weights of female ticks. There were no significant effects on the eggs laid and on the hatchability. The relatively low molecular weight proteins in Figure 2.9,B were also enriched on

Figure 2.9 Immunoblots of proteins eluted from anion exchange columns (DEAE-Sephacel, Pharmacia): A, four polypeptides with relatively close mobilities; B, enriched low molecular weight proteins.

Figure 2.10 Immunoblots of proteins eluted from lectin affinity columns: A, enriched protein; B, homogenate.

DEAE-Sephacel column under different elution conditions. This fraction has not yet been used in immunisation studies. Figure 2.10 shows proteins enriched on lectin affinity column. Further work is being done on these glycoproteins. A detergent with phase partition ability at a relatively low temperature (Triton X-114) is being employed to separate the membrane proteins into integral and peripheral molecules. This will narrow the possible vaccine candidates (integral molecules) and thereby facilitate their purification on FPLC.

2.11 CHARACTERISATION OF MEMBRANE-BOUND PROTEINS FROM THE MIDGUT OF *AMBLYOMMA VARIEGATUM* INDUCING HOST IMMUNITY TO TICKS

H. K. Kiara, S. Essuman and E. O. Osir

It was reported in an earlier study (*ICIPE 1990 Annual Report*) that integral midgut proteins from *A. variegatum* induced a significant level of protection against ticks in immunised rabbits. The same study also reported that there was cross-resistance to *R. appendiculatus*. This fraction consisted of about 20 major polypeptide bands and about ten of these were reacting strongly with sera from immune rabbits. We now report further attempts to purify and characterise this fraction and to identify the proteins responsible for inducing immunity to the rabbits.

Membrane bound proteins from midguts of partially-fed *A. variegatum* were prepared as reported earlier (*ICIPE 1990 Annual Report*). A 1 mg sample of the material in 1 ml PBS (pH 7.0) containing 0.02% sodium azide was applied to a 2 x 120 cm column of G-75 Sephadex (Pharmacia Chemical, New Jersey, USA) at 4°C. The column had previously been equilibrated with the same buffer. Fractions were collected every 10 min using fraction collector, Frac-100 (Pharmarcia) at a flow rate of 15 ml/hr. Samples from each of the peaks were pooled separately and concentrated. These were used to immunise two groups of rabbits which were later challenged with all instars of *A. variegatum* and *R. appendiculatus* respectively. Feeding and development parameters of ticks feeding on immunised and control rabbits were assessed. Integral membrane proteins eluted from a G-75 Sephadex column yielded four peaks as shown in Figure 2.11. Table 2.4 summarises the results of the immunisation of rabbits with the various fractions.

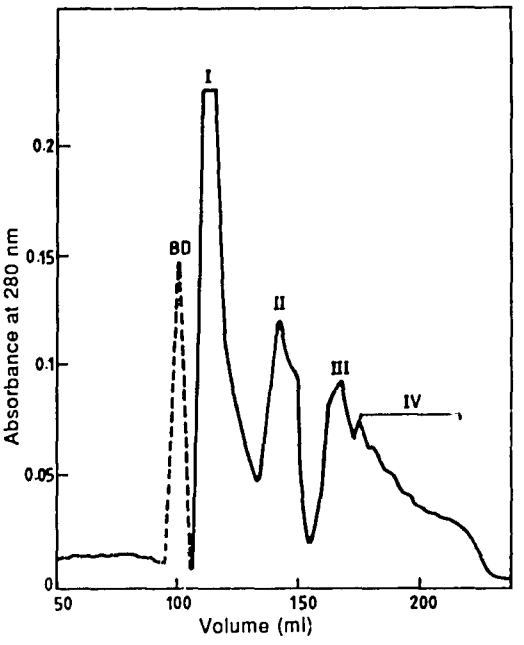

Figure 2.11 Gel filtration chromatography of membrane-bound proteins from the midgut of *Amblyomma variegatum* on Sephadex G-75. BD, blue dextran.

As shown in the table, the mean engorgement weight, the mean egg mass and the egg conversion efficiency of adult ticks feeding on rabbits immunised with F_1 antigens were reduced compared to the controls. The mean mortality of fed ticks was also significantly increased. Immature stages were also affected by F_1 antigens but to a lesser extent.

None of the parameters was affected in *R. appendiculatus*. The results tend to indicate that the protein(s) inducing resistance in rabbits have a molecular weight in upwards of 80,000 daltons because the inclusion range of G-75 Sephadex is 3000–80,000 daltons. This is supported by immunoblotting experiments which showed most of the reactive polypeptide bands being above 60,000 daltons.

Table 2.4 Feeding parameters of adult female *Amblyomma variegatum*

Parameter	Antigen F1	F2	F4	Control
Engorgement period (days)	13.5 ± 0.40[a]	13.9 ± 0.54[a]	12.8 ± 0.59[a]	14.0[a]
Engorgement weight (mg) (Mean ± S.E.)	1275.2 ± 142.22[a]	1408.6 ± 62.1[a]	1261.2 ± 166.1[a]	1369.0 ± 158.2[a]
Egg mass (mg) (Mean ± S.E.)	522.3 ± 69.3[a]	584.1 ± 99.1[a]	41.8 ± 2.1[b]	45.9 ± 2.4[b]
Egg conversion factor % (Egg mass/engorgement weight)	38.5 ± 2.3[a]	41.7 ± 2.6[ab]	41.8 ± 2.1[b]	45.9 ± 2.4[b]
Survival (%)	86.5 ± 3.6[b]	93.6 ± 3.1[ab]	100[a]	100[a]

Means with the same letter across the row are not significantly different at $P < 0.05$.

Compared to the proteins before fractionation by gel filtration the effect on ticks was reduced. This would be expected if more than one polypeptide plays a significant role in the induction of host resistance. Separation of these important polypeptides would tend to reduce their combined effect. The other reason for the reduced efficacy could be reduced concentration of the relevant protein in the fraction. Further purification of fractions 1 and 2 is currently underway.

2.12 CHARACTERISATION OF ANTIGENS FROM SALIVARY GLANDS, REPRODUCTIVE SYSTEM, GUT AND HAEMOLYMPH OF PARTIALLY- FED FEMALE TICKS, *RHIPICEPHALUS APPENDICULATUS*

A. O. Mongi, T. R. Odhiambo, I. G. Onyango, R. Chesang, J. G. Kabii and K. O. Ochung'

One possible approach suggested for tick control is the immunological method. The approach utilises acquired host resistance to tick infestations and/or by immunisation with tick-derived immunogens.Several workers have attempted to immunise laboratory animals and cattle with extracts derived from either unfed, partially-fed or fully-fed ticks with encouraging anti-tick effects obtained. Similar results have also been obtained by immunising with tissue extracts of either salivary glands, reproductive system, gut, haemolymph, cheliceral elements, fat body or the synganglion. Despite successes in the anti-tick effects attained through the above mentioned immunisation studies there is still the need to identify, isolate and characterise the target antigen(s) present in the crude extracts that are responsible for the protective response(s) attained against the feeding ticks.

In the present report, immune sera from rabbits immunised with solubilised extract of *Rhipicephalus appendiculatus* ticks were selected for the characterisation of antigens they recognised. The extracts were prepared from ticks fed on rabbits at different periods. The tissues included those of the salivary glands (SGA), reproductive system (RPS), gut (GUT) and the haemolymph (HAE). Anti-tick sera selected for the studies were collected from rabbits that adversely affected the feeding performance and reproductive potential of ticks fed on them.

Results of tick feeding on four rabbits immunised with solubilised whole tick extract are presented in Figure 2.12. The extracts were prepared from day 7 fed female ticks of *R. appendiculatus*. The immunisations adversely affected the feeding performance and reproductive potential of ticks fed on the rabbits as demonstrated by the reduction in tick engorgement weight of 155 ± 19 mg in the experimentals as opposed to 375 ± 17 mg in the controls. Reduction in egg mass of 67 ± 9 mg in the experimentals as compared to 198 ± 8 in the controls are shown in Figure 2.12. The decreased tick engorgement and egg weights were good indicators of tick resistance. The encouraging anti-tick effects formed the criterion for selecting anti-tick sera Nos.1 and 2 employed in the studies.

Immunoprecipitation results employing anti-tick rabbit

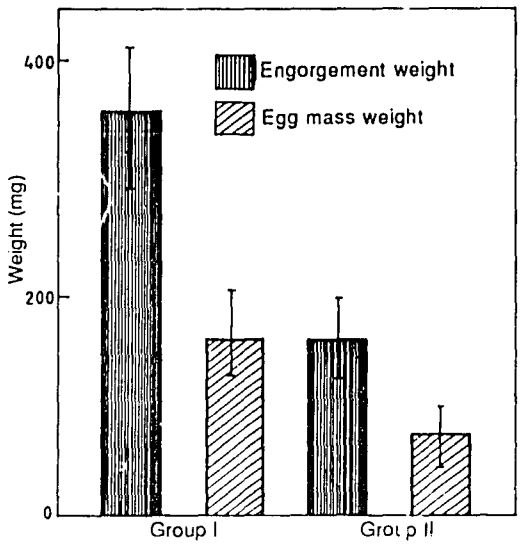

Figure 2.12 Histogram presentation of mean engorgement and egg mass weights of *R. appendiculatus* female ticks fed on control and experimental groups of rabbits. Group I contained the control rabbits immunised with normal saline in FCA. Group II are the experimental rabbits immunised with solubilised whole tick extract of day 7 fed *R. appendiculatus* in FCA.

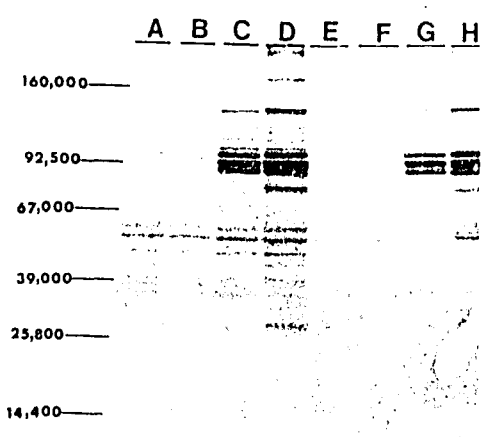

Figure 2.13 An autoradiograph of SDS-PAGE analysis of immune-precipitated radiolabelled polypeptide antigens in the presence of *S. aureus*. Lanes A, B and E, F contain the antigens detected by control (pre-immunisation) sera obtained from rabbits Nos. 1 and 2, respectively. Tick extracts under examination were obtained from day 5 and 6 of partially-fed female *R. appendiculatus*. Lanes C, D and G, H contain the antigens detected from the same extract preparation with experimental (pre-tick challenge) sera obtained from rabbits Nos. 1 and 2, respectively. The molecular weight marker proteins are indicated on the left.

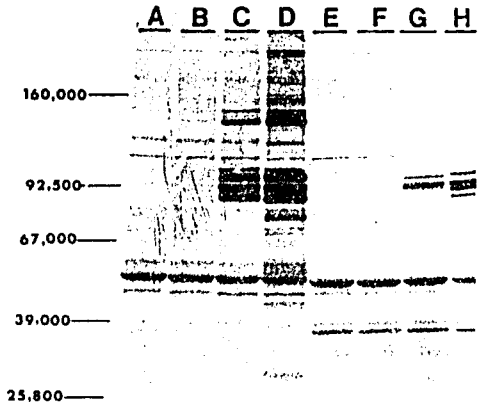

Figure 2.14 An autoradiograph of SDS-PAGE analysis of immune-precipitated radiolabelled polypeptide antigens in the presence of *S. aureus*. Lanes A, B and E, F contain the antigens detected by control (pre-immunisation) sera obtained from rabbits Nos. 1 and 2, respectively. Tick extracts under examination were obtained from day 7 and 8 on fully-fed female *R. appendiculatus*. Lanes C, D and G, H contain the antigens detected from the same extract preparation with experimental (pre-tick challenge) sera obtained from rabbits Nos. 1 and 2, respectively. The molecular weight marker proteins are indicated on the left.

serum No.1 in the presence of *Staphylococcus aureus* detected eight antigens in each of the various extracts prepared from ticks fed on rabbits on days 5, 6 and 7 respectively. The same rabbit serum detected four antigens from an extract prepared from ticks fed on rabbits for 8 days (Figures 2.13 and 2.14). At least 14 antigens were detected from the same extract preparation as that examined with anti-tick serum No.1 on days 5, 6 and 7 after probing the extracts with selected anti-tick rabbit serum No.2, while seven antigens were detected with this same serum from the day 8 tick extract preparation. Antigens detected with anti-tick serum No.1 had molecular weights ranging from 64,000–220,000 daltons while those detected with anti-tick serum No.2 had molecular weights ranging from 20,000–220,000 daltons.

Comparative analysis of antigens detected from various tick tissue extracts of SGA, RPS, GUT and HAE; prepared from female ticks of *R. appendiculatus* fed on rabbits for 6 days are shown in Figure 2.15. At least 22 polypeptide antigens were detected from each of the tick tissues. The detected antigens ranged in molecular weights from 20,000–280,000 daltons. There were no major differences in the number of detected antigens in each tissue. However, minor differences included the degree of radioactive labelling in some of the antigens as was the case with SGA which showed reduced amount of radioactive label than in the other tissues. In spite of the morphological and physiological differences between the tissues, the findings suggest a high degree of identity in the number of some of the detected antigens (Figure 2.15). Since the tissues are in close association and are constantly being

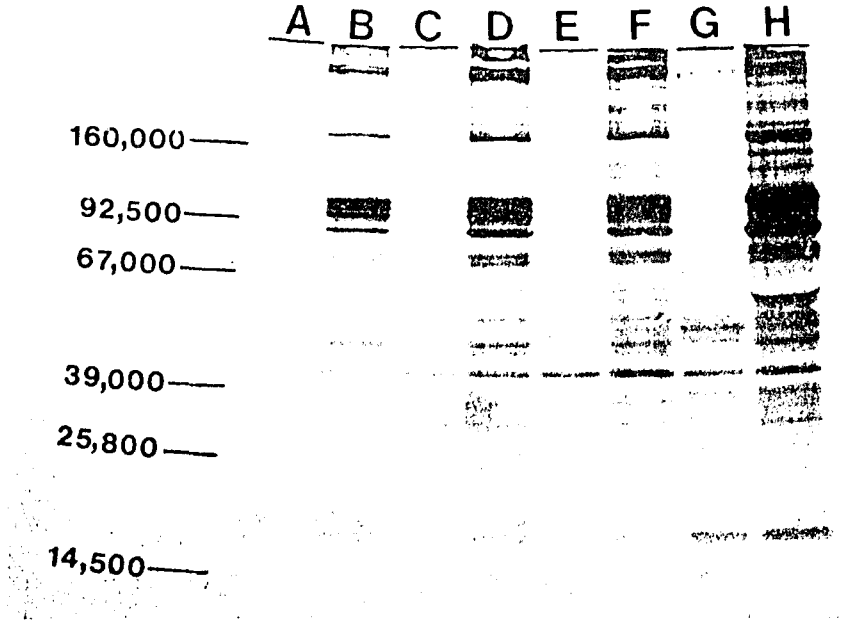

Figure 2.15 An autoradiograph of SDS-PAGE analysis of immune-precipitated radiolabelled antigens in the presence of *S. aureus* from solubilised antigen extracts prepared from SGA, RPS, GUT and HAE of day 6 fed female *R. appendiculatus*. Lanes A, C and E, G contain the antigens detected from the various tick tissues: SGA, RPS, GUT and HAE, respectively with selected control (pre-immunisation) rabbit sera No. 2. Lanes B, D, F and H contain the antigens detected with the selected (pre-tick challenge) sera also obtained from rabbit No. 2. Immune rabbit serum No. 2 was initially raised against tick extract prepared from day 7 fully-fed female *R. appendiculatus*. Molecular weight marker proteins are indicated on the left.

bathed with the haemolymph, contamination by some of the haemolymph proteins during their dissection may have occurred. Haemolymph proteins may also have been contaminated by the flufting off process of tick gut protein components into it.

Results of the present report suggest that there are differences in the number of antigenic components that were detected by individual animals serum. There was also no single tick tissue that could be ascribed as being responsible for the production of target antigens. Detection of extra bands in some of the tick tissues as opposed to those detected in the whole tick extract is probably as a result of better solubilisation process of the tissues than was the case with whole tick that might have been hindered with the presence of the ticks' cuticle. The detected antigens contain both irrelevant and relevant antigens responsible for the protective immune response(s) against the feeding ticks. Attempts are now being made to isolate some of these antigens for a number of immunochemical studies. This is in addition to fully characterising the exact tick tissue responsible for production of the target antigens for inclusion in an anti-tick vaccine design.

2.13 MOLECULAR VACCINES AND DIAGNOSTIC REAGENTS

M. Limo, E. Essuman and A. O. Mongi

Attempts to develop vaccines against ticks and tick-borne diseases has generally been unproductive. Difficulties have been encountered in identifying antigens which induce significant protective immune responses and in obtaining sufficient quantities of antigens for vaccine trials and diagnostic tests. Use of recombinant DNA techniques and advances in both immunology and biochemistry provide the necessary tools to overcome these problems.

Previous work in our laboratory has demonstrated the protective abilities of natural tick proteins when used as immunogens in laboratory animals and cattle. In addition, purification of a tick exposure field diagnosis antigen has been accomplished. To produce recombinant antigens from different tick tissues, a series of experiments will address the following: (a) Isolation and characterisation of genes coding for antigens from different tick tissues, (b) production of sufficient amounts of the recombinant, antigens for biochemical and immunological analysis, (c) determination of the protective role *in vivo* of the gene products.

Experiments were thus initiated to characterise polypeptides produced by clones in expression libraries constructed from tick tissues. As a first step, polyadenylated mRNA was isolated from salivary gland homogenates of partially-fed *R. appendiculatus* female ticks using the guanidinium caesium chloride procedure and chromatography over oligo (dT) cellulose. It was translated *in vitro* with a rabbit reticulocyte translation system. The *in vitro* synthesised proteins were labelled with 35 S-methionine, separated by sodium dodecyl sulfate polyacrylamide gel electrophoresis and identified by autoradiography. Several polypeptides were synthesised *in vitro* and identified by tick infestation sera. Double stranded cDNA was synthesised and an expression library constructed in gt11 vector. Screening of the *in vitro* synthesised proteins is being done with sera from animals vaccinated with diagnostic antigens and vaccine candidates. Purification and characterisation of the inserts from the potential clones will be done by restriction enzyme analysis. Our aim is to characterise the clones, sequence the genes, examine for open reading frames and study their gene products as potential anti-tick vaccines and diagnostic reagents.

2.14 EFFECT OF THE FUNGI *BEAUVERIA BASSIANA* AND *METARHIZIUM ANISOPLIAE* ON *RHIPICEPHALUS APPENDICULATUS*

E. N. Mwangi and G. P. Kaaya

Three strains of *B. bassiana* and two of *M. anisopliae* were tested against all stages of fed and unfed *R. appendiculatus* to investigate their suitability as biocontrol agents.

Ticks were dipped into a 10^9 spore/ml suspension of each pathogen strain and then incubated singly (except for unfed larvae and nymphs) at 28°C and 80% r.h. for 2 weeks and mortality recorded. For *B. bassiana*, tests were also repeated with doses of 10^8, 10^7, 10^6 and 10^5 spores/ml in order to establish the lowest active concentration of spores.

The Nairobi strain of *B. bassiana* was effective on all stages of unfed *R. appendiculatus*, killing 100% larvae, 82% nymphs and 70% adults in the laboratory but a UK strain of *B. bassiana* was not as effective (Table 2.5). The two *M. anisopliae* strains used, Mbita and a UK one killed only about 30% of each unfed instar.

Table 2.5 Effect of fungi on unfed *R. appendiculatus*

Pathogen	Strain	Mortality (%) Larvae	Nymphs	Adults
B. bassiana	Mbita	100	82	70
B. bassiana	UK	70	72	38
B. bassiana	Nairobi	19	22	70
M. anisopliae	Mbita	33	34	13
M. anisopliae	UK	30	22	19
Controls		1	4	3

Table 2.6 Effect of fungi on engorged larvae and nymphs of *R. appendiculatus*

Pathogen	Strain	Mortality (%) Larvae	Nymphs
B. bassiana	Mbita	94	66
B. bassiana	UK	71	73
B. bassiana	Nairobi	69	76
M. anisopliae	Mbita	71	37
M. anisopliae	UK	70	76
Controls		0	0

Table 2.7 Effect of fungi on feeding adult *R. appendiculatus* on rabbits†

Pathogen	Strain	Mortality before laying eggs (%)	Fecundity reduction (%)
B. bassiana	Mbita	33	90
B. bassiana	UK	33	69
B. bassiana	Nairobi	6	50
M. anisopliae	Mbita	3	18
M. anisopliae	UK	10	28
Controls		0	0

†N=30.

Table 2.8 Mortality caused by various concentrations of *B. bassiana* (Mbita strain) on unfed *R. appendiculatus*†

Concentration (spores/ml)	Mortality (%)
10^9	74.0
10^8	64.0
10^7	74.0
10^6	70.0
10^5	40.0
Controls	4.0

†N=50.

When engorged instars were exposed to the pathogens, the Mbita strain of *B. bassiana* was found to be the most effective killing 94% and 66% of larvae and nymphs respectively (Table 2.6). The Mbita strain of *B. bassiana* also killed engorged females (33%), and reduced egg production by 90% (Table 2.7). This fungal strain was observed to cause significant mortalities even at lower doses e.g. 10^6 spores/ml (Table 2.8).

2.15 INCIDENCE OF A TICK PARASITOID AT KUJA RIVER, SOUTH NYANZA, KENYA

E. N. Mwangi and G. P. Kaaya

A systematic survey was started at the Kuja river field site to investigate the presence and seasonal incidence of a tick parasitoid. Data collected for 8 months is presented in Table 2.9. Out of 200 fully-engorged *A. variegatum* collected, 68.5% were found to be infected with the parasitoid. Only nymphs of *A. variegatum* were found to be infected and no infections were recorded from *R. appendiculatus*. The parasitoid resembles another previously found in the Trans-Mara area, in its basic biology and morphology.

Table 2.9 Tick parasitoid in Kuja River

Month	No. of ticks collected	% with parasitoids
April 1991	10	100
May 1991	9	33.3
June 1991	7	57.1
July 1991	35	51.4
Aug. 1991	11	72.7
Sept. 1991	42	67.4
Oct. 1991	55	74.5
Nov. 1991	31	77.4
Dec. 1991	49	81.6
Total	249	71.0

2.16 NATURAL ANTI-TICK PRODUCTS

E. N. Mwangi, A. Hassanali and E. Nyandat

A purified oil of a local plant was tested for acaricidal and repellent effects on all stages of unfed *R. appendiculatus*, using an *in vitro*, and an *in vivo* test. Residual effect of the oil on rabbits was also investigated. For the *in vitro* test, the FAO adopted larval packet test was used. On rabbits, the oil, diluted with liquid paraffin, was sprayed on the ears using a cannister sprayer. A 0.2% concentration of the oil killed 100% larvae in the laboratory. In the *in vivo* test, a 10% solution killed 100% larvae, 100% nymphs, and 75% of adults. A single application of the 10% concentrated solution was found to protect rabbits from attaching larvae for 6 days and both nymphs and adults for 4 days.

2.17 INDIGENOUS PLANTS POSSESSING ACARICIDAL ACTIVITY

G. P. Kaaya and E. N. Mwangi

In 1991, two new indigenous plants were tested for acaricidal activity using both unfed and fed stages of *R. appendiculatus*. The plants were designated S1 and NE. Thick juicy leaves of S1 were crushed in a blender to produce undiluted juice (100% conc.) whereas leaves of NE which were non-juicy were similarly crushed in a blender and then boiled for 15 min (10 gm in 10 ml water) to prepare the 100% concentrated stock solution.

When tested on unengorged stages of *R. appendiculatus*, the 100% S1 extract killed 100% larvae, 42% nymphs and 11% adults (Table 2.10). Concentrations of 50–12.5% also caused a high mortality in larvae and to a lesser extent in nymphs but not in adults. The extract, however, caused very low mortality in engorged stages

Table 2.10 Effect of S1 extract on unengorged stages of *R. appendiculatus*†

Concentration (%)	Mortality (%) Larvae	Nymphs	Adults
100	100	42.3	10.95
50	96	44.3	1.15
25	93	38.6	3.15
12.5	85.6	25.0	3.15
6.25	72.7	24.7	1.05
0 (Control)	6.5	13.2	5.90

†Three replicates.

of *R. appendiculatus* (Table 2.11). Although 15–28% of the eggs produced by the treated gravid females were non-viable.

Table 2.11 Effect of S1 extract on engorged stages of *R. appendiculatus*†

Concentration (%)	Mortality (%) Larvae	Nymphs	Adults	Eggs of treated adults
100	11	6	0	26.7
50	2	2	0	28.4
25	6	2	0	20.0
12.5	4	4	0	20.7
6.25	0	2	0	18.8
0 (Control)	0	2	0	15.5

†Three replicates.

Unlike the S1, the NE extract was less active on unengorged stages of *R. appendiculatus* and was more active on the engorged stages. Mortality in unengorged stages caused by the 100% NE extract was 29% in larvae, 74% in nymphs and 25% in adults (Table 2.12). The NE extract, however, was found to be very active on engorged stages (except adults); at 100% concentration, it induced

Table 2.12 Effect of NE extract on unengorged stages of *R. appendiculatus*†

Concentration (%)	Mortality (%) Larvae	Nymphs	Adults
100	29.0	74.0	24.7
25	18.0	53.3	11.30
10	0.0	28.0	0.0
1	3.3	6.0	0.0
0 (Control)	0.0	6.0	0.0

†Three replicates.

Table 2.13 Effect of NE leaf extract on engorged states of *R. appendiculatus*†

Concentration (%)	Mortality (%) Larvae	Nymphs	Adults	Eggs of treated adults
100	93	48	0	69.8
50	83	46	0	52.4
25	81	44	0	52.5
12.5	24	33	0	51.8
6.25	19.5	27	0	21.0
0 (Control)	5	13	0	15.2

†Three replicates.

Table 2.14 Effect of S1 and NE extracts on eggs of *R. appendiculatus*†

Concentration (%)	Egg mortality (%) S1	NE
100	75.0	100
50	68.0	67.7
25	65.5	64.6
12.5	58.4	7.7
6.25	18.8	7.0
0 (Control)	11.6	1.0

†Three replicates.

mortalities of 93% in larvae and 48% in nymphs (Table 2.13) and lower concentrations 25–50% were also active against larvae and nymphs. Approximately 70% of eggs produced by the treated gravid females failed to hatch (Table 2.13).

Eggs of *R. appendiculatus* treated directly with the S1 and NE extracts also failed to hatch. The 100% extracts of S1 and NE killed 75 and 100% eggs respectively, while 50% concentrations killed 68% of the treated eggs (Table 2.14).

2.18 ANTI-TICK GRASSES

E. N. Mwangi

A study is underway to investigate the anti-tick properties of the molasses grass. Preliminary experiments were done to compare climbing behaviour of all instars of *R. appendiculatus* on the grass.

A stem of molasses grass (11 cm long) with 4 or 5 leaf blades was cut when the grass was green, and placed in a tube of ticks containing either larvae, nymphs or adults of *R. appendiculatus*. Control grass (Kikuyu grass) was also placed in the same tube as the experimental grass. Ticks (1000 larvae, 100 nymphs and 50 adults), were given 30 minutes to climb on the grass of their choice and numbers climbing on the stems and leaves of both grasses were counted. The experiment was done in three replicates.

Results show that instars of *R. appendiculatus* avoided climbing on the experimental grass whereas 758 larvae, 60 nymphs and 37 adults climbed the control grass (Kikuyu).

Research is underway to compare the climbing behaviour using various stages of grass maturation, extract and identify the anti-tick component(s) in the grass and investigate climbing behaviour of ticks in the field.

2.19 A NATURALLY-OCCURRING TICK REPELLENT PLANT

M. Malonza, D. K. Punyua and A. Hassanali

A plant commonly found in East Africa was identified

Table 2.15 Visual quantification of the number of ticks on the undersurface of leaves of the anti-tick plant and a control plant

	Tick stage	Visual quantification of ticks 2 hours	6 hours	9 hours	24 hours
Control plant	Larvae	+++	+++	+++	+++
	Nymphs	+++	+++	+++	+++
	Adults	+++	+++	+++	+++
Anti-tick plant	Larvae	++	+	+	+
	Nymphs	Nil	Nil	Nil	Nil
	Adults	+	+	++	++

Table 2.16 Percentage repellency by an anti-tick plant to the tick *R. appendiculatus*

Concentration	% Repellency
1.0	100
0.1	100
0.01	91
0.001	48
0.0001	41

with tick repellent activity. Ticks were observed to be absent in areas with high concentration of this plant in the field.

In the laboratory, larvae, nymphs and adults of *R. appendiculatus* were put in flat-bottomed glass tubes which were plugged tightly with fresh leaves of this plant and observed. The number of ticks on the undersurface of each plug was quantified by the number of ticks clustered on the plug after every 2, 6, 9 and 24 hours. An olfactometer was used in another set of experiments in the laboratory. The results (Table 2.15) show that ticks avoided coming into contact with the plant and in fact prolonged exposure caused high mortality. The degree of repellency by the oily extracts of the plant has been tested using a simple bioassay. The climbing ability of 30 adult *R. appendiculatus* (15 + 15) was determined using two vertical rods (one treated and the other untreated). The results from 14 replicates are shown in Table 2.16. More biochemical work is now in progress. Ecological studies are also in progress to determine its possible role in tick pasture management.

TSETSE RESEARCH PROGRAMME

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3 Tsetse Research Programme

Beyond outright hunger, many people in the third world lead lives trapped in subsistence agriculture or in urban poverty. With the world human population increasing by about 96 million additional people per year according to World Bank report (1991), during the decade of the 1990s it will take extraordinary efforts to feed this population or provide adequate health care. Africa's large increase in the projected population increase is the most dramatic. According to the same report (World Bank Report, 1991) Africa's share of the total world population will increase from 9% in 1950 to 19% in 2025. This has meant declining per capita food production. What this situation requires is the development of techniques that address specific needs. In particular the challenge facing farmers, is to increase food production while pursuing methods that are both economically and environmentally sustainable.

Tsetse is one of the major factors that continue to contribute to reduced food and agricultural production in Africa. Efforts made by the ICIPE Tsetse Research Programme over the years are beginning to have impact on the tsetse and trypanosomiasis problem. Research in this Programme has led to the development of a tsetse management system, which avoids the reliance on the application of chemical insecticides. In this report, attention has been focused on tsetse trapping as one component of IPM strategy, necessary for effective tsetse population suppression. There is evidence that effective suppression of tsetse population through trapping can lead to substantial decline in African trypanosomiasis incidence.

The major highlights of this report are the following:

- *Tsetse population genetics studies indicate that there may be some weak links within the genetic make-up of* G. pallidipes *in the wild which may be exploited in the design of tsetse control strategies in future.*
- *A new tsetse trap was designed and tested against* G. brevipalpis *and* G. pallidipes. *This trap proved to be the one single trap effective against both species.*
- *Placement of targets and monitoring traps inside continuous thickets improved their efficacy in suppressing population but the number of targets required per unit thicket area was too large to justify their usage for tsetse control in the Lambwe Valley situation.*

3.1 ISOENZYME MARKERS FOR STUDYING THE IMPACT OF TSETSE CONTROL TRAPS ON GENETIC VARIABILITY OF *GLOSSINA PALLIDIPES*

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

The experimental tsetse population suppression on the Olkeramatian Group Ranch using odour-baited NGU traps, which started some 4 years ago was continued. Throughout 1991 and in the past 3 years, the traps have maintained a reduction in the population of *G. pallidipes* ranging from about 92 to 99%. It appears that a new population equilibrium has been set and is being maintained at this very low level.

Due to current emphasis on the use of appropriate technology and environmentally friendly approaches to tsetse and trypanosomiasis control in Africa, traps have been recommended in conjunction with other IPM strategies as the most effective means of achieving suppression. There is evidence as indicated above that effective

suppression of tsetse populations by up to 99% of pre-suppression levels using traps and/or targets is possible in isolated areas and may effect a substantial decline in trypanosomiasis incidence. However it has become clear that tsetse cannot be eradicated in most cases due to suspected invasion from adjacent fly populations or as yet undefined mechanisms. Emerging residual populations which seem to sustain and assist recovery of tsetse fly population to pre-control levels have not been characterised due to technical difficulties in assessing flies which may be avoiding traps. It is not known, for example, whether residual fly populations are refractory to the traps due to physiological factors or natural selection. It is not known whether trap efficiency declines as fly densities fall below certain threshold levels.

Enzyme polymorphism provides metabolic flexibility in a changing environment and may therefore be a mechanism for adaptation by whole populations or individuals. The staggering amount of genetic variation in natural populations indicate that there is ample room for adaptation to extreme climatic changes or man-made pollution, or introduction of a predator, parasite, or competitor, or in this case, tsetse traps. If individual tsetse can be marked genetically by a specific isozyme variant (allele) then the changes in allele frequencies due to environmental factors can be determined and interpreted accordingly. Assessment of the deviation of observed allele frequencies from expected theoretical values as well as biochemical and physiological characteristics of individuals with such alleles may also provide a clue to the intrinsic factors militating against effective suppression of fly populations.

With this background in mind an investigation was commenced in June 1991 to monitor the changes taking place in the gene profile of the tsetse population on the Olkeramatian Group Ranch at Nguruman Kajiado district using isozyme markers and to study the characteristics of the residual population within the suppression zone following 3–4 years of trapping using odour-baited NGU traps with a view to understand some of the mechanisms by which residual fly populations are sustained. Similar investigations were commenced at ICIPE's Lambwe Valley project area for comparative purposes. In this work our goal was to determine: (a) Local genetic variation based on glucose-phosphate-isomerase (GPI) and phosphoglucomutase (PGM) isoenzyme polymorphism in flies from the Nguruman tsetse project area (stratification). (b) The seasonal changes in phenotype frequencies to ascertain the adaptive nature of such polymorphism in *G. pallidipes*. (c) The impact of trap deployment (since 1987) on isozyme profiles of flies in suppression and non-suppression zones of the project area. (d) The adaptive changes that may be occurring in the field as a means of identifying regions of weakness in the population that may be exploited for future control strategies against tsetse.

Tsetse (*G. pallidipes*) from various transects of the Nguruman project site were sampled on monthly basis from existing trap positions in the suppression zone and from monitoring traps within the non-suppression zone. Fly samples were frozen in liquid nitrogen and brought back to the laboratory where fly thoraces of individuals were homogenised and analysed by starch gel electrophoresis for phosphoglucomutase (PGM) and glucose-phosphate-isomerase (GPI) loci. Previous work

Figure 3.1 PGM isozyme banding patterns for male *Glossina pallidipes* (S = slow, F = fast).

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in the same laboratory indicated that *G. pallidipes* exhibited polymorphism at the two loci and that alleles at these loci were inherited in Mendelian fashion. Allele frequencies of offspring of adults caught in traps from various transects were also compared with their parents to assess changes in allele frequencies from generation to generation and from climate to climate through a seasonal cycle.

Preliminary results indicate that over 95% of all available isozyme variants (alleles) for both metabolic enzymes (PGM and GPI) were present in flies caught in traps from all localities. PGM isozyme bands for males were either fast or slow band whereas in females three phenotypes including the fast, slow and double band were observed. The lack of the heterozygous condition in males for PGM indicated that the gene coding for PGM was probably sex linked (Figure 3.1). GPI isozyme bands were expressed as triplets for heterozygous condition and a single band for the homozygous condition (Figure 3.2). Rare alleles at a frequency range of 0–3% found in non-suppression zones were absent or at negligible frequencies in the suppression zone. There were significant differences between allele frequencies of offspring of trap-caught females and their parents which indicated that certain categories survived better in the laboratory and poorly in the wild.

Tests for agreement with Hardy-Weinberg Equilibrium (HWE) indicated that allele frequencies differed significantly from the expected values in the suppression zone ($\chi^2 = 7.541$, $P < 0.01$). In the non-suppression zone the distribution of the phenotypes was not significantly out of the HWE ($\chi^2 = 1.009$, $P > 0.01$ (Table 3.1)). However these differences may have been due to the drastic reduction in fly numbers in the suppression zone which may have resulted in the elimination of some rare phenotypes within the suppression zone. Whether fly movement across the various transects examined affected phenotype frequencies in the suppression zone or not, needs further investigation. However it is expected that spatial differentiation in gene frequencies of *G. pallidipes* can be used to track the movement of flies between high and low density areas. The impact of the loss of such rare phenotypes on the gametic pool and the implications for future generations of flies is yet to be ascertained.

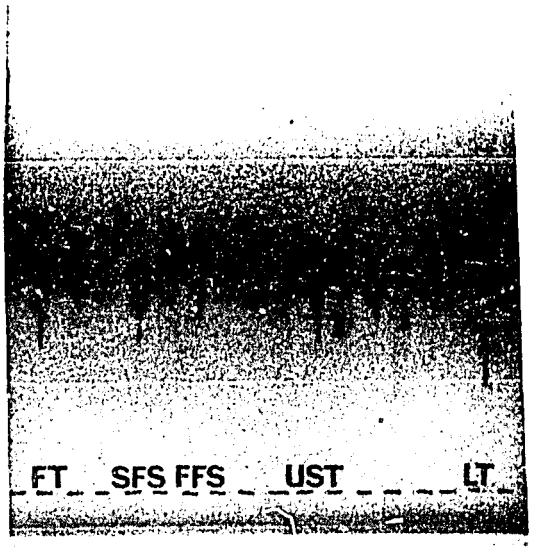

Figure 3.2 GPI isozyme banding patterns for male and female *Glossina pallidipes* (FT = fast triplet, SFS = slow fast single, FFS = fast fast single, UST = upper slow triplet, LT = large triplet).

Some expected interactions of PGM and GPI alleles located on the two loci examined were not found among

Table 3.1 Goodness of Fit test for PGM phenotypes in different transects at Nguruman

Transect†		Classes F	S/F	S	SUM	χ^2	D.F.	Sig. of P
1	OBS	40.00	26.95	33.05	100			
	EXP	49.99	16.67	33.34	100	7.541	1	**
4	OBS	47.20	25.60	27.20	100			
	EXP	49.99	16.67	33.34	100	5.322	1	ns
5	OBS	41.89	30.10	28.10	100			
	EXP	49.99	16.67	34.34	100	8.575	1	**
7	OBS	55.00	28.40	16.60	100			
	EXP	49.99	16.67	33.34	100	1.009	1	ns
8	OBS	40.90	50.00	9.10	100			
	EXP	49.99	16.67	33.34	100	12.307	1	***
9	OBS	35.70	33.40	30.90	100			
	EXP	49.99	16.67	33.34	100	15.118	1	***

†Transect 1 and 4, suppression zone; 5, semi-suppression zone; 7, non-suppression zone; 8, escarpment; 9, laboratory-reared offspring of transect 1 flies.

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Table 3.2 GPI and PGM locus interaction in *G. pallidipes* at Nguruman

GPI phenotypes[1]	PGM phenotypes			
	F	S	S/F	Total
FFS	34.0	18.6	47.4	100
FT	38.0	18.0	44.0	100
LFT	75.0	0.0	25.0	100
LSFS	33.3	33.3	33.4	100
LST	20.0	0.0	80.0	100
LT	40.0	10.0	50.0	100
SFS	37.3	18.6	44.1	100
SSS	0.0	50.0	50.0	100
ST	40.9	13.6	45.5	100
UFT	66.7	0.0	33.3	100
USFS	20.0	60.0	20.0	100
UST	28.6	14.3	57.1	100

[1]FFS, fast fast single; FT, fast triplet; LFT, lower fast triplet; LSFS, lower slow fast single; LST, lower slow triplet; LT, large triplet; SFS, slow fast single; SSS, slow slow single; ST, slow triplet; UFT, upper fast triplet; USFS, upper slow fast single; UST, upper slow triplet.

the 1500 or more flies examined (Table 3.2). Our suspicion was that such individuals were unavailable for trapping because they were unfit and probably died prematurely after emergence or were more amenable to predation. We are currently investigating physiological and behavioural aspects of flies with the various isozyme variants. Attempts are underway to study fly susceptibility to trypanosome infections, reproductive performance, mortality and mating behaviour of flies from the different categories. Similar studies of other tsetse populations undergoing suppression such as the Lambwe Valley project are in progress.

These results indicate that soft spots exist within the genetic makeup of *G. pallidipes* in the wild and if understood could be exploited in the design of control strategies in the future. Direct selection of specific isozyme variants of PGM or GPI and the development of "trap resistance" by residual populations may be more subtle than was observed over this study. A comparative study on the effect of fly movement and behaviour in high and low density zones on phenotype frequencies is required to make valid conclusions regarding the possibility of flies developing trap resistance.

3.2 TSETSE FEEDING BEHAVIOUR IN RELATION TO TRAPS

L. C. Madubunyi and D. F. Uvyu

Most methods of tsetse control are threatened by the residual population syndrome. With respect to odour-baited trapping, it has been suggested that the residual population consists of flies which are either intrinsically untrappable or have learned to avoid traps. Periodically, it may be boosted by seasonal immigrants, which at Nguruman mainly consist of females from the top of the escarpment.

Odour-baited traps arose from attempts to intercept tsetse presumed to be hungry and in search of a bloodmeal source hence they are easily attracted to host odour sources. However, no trap/odour bait system seems to catch all species of tsetse inhabiting a given ecosystem with equal effectiveness. The Nguruman experience is that, when employed for tsetse population suppression, the NGU trap-cow urine-acetone bait system exerts a more drastic impact on *G. pallidipes* than *G. longipennis*. This could be due to a difference in the olfactory response to cow urine and/or trap entry response of both tsetse species. The reported daily trapping mortality rate of 6.5 and 4.0% for male and female *G. pallidipes* respectively further suggests possible behavioural differences between the sexes with regard to response to odour-baited traps. Monitoring biconical traps baited also with cow urine and acetone reportedly catch virtually equal numbers of male and female *G. pallidipes* inside the suppression zone but 2.6 –1.4x more females in the barrier and outside the suppression zones respectively. This suggests further that the trap entry response of each sex differs with trap design and parts of the ecosystem.

Collectively, however, the foregoing suggestions in fact point to our fuzzy understanding of why tsetse approach and/or enter traps. Because of the general view that traps intercept mainly hungry tsetse in search of a bloodmeal, investigations were focused on aspects of blood feeding and reproduction of *G. pallidipes* and *G. longipennis* relevant to their trapability at Nguruman, namely, bloodmeal size, feeding frequency, interval between meals, feeding response of trap-caught flies and sex composition of offspring from individual wild females.

Flies caught with odour baited NGU traps at Nguruman were observed individually in the laboratory. They were fed on lop-eared rabbits daily. Females whose reproduction was irregular or abnormal were excluded from the results that follow.

Bloodmeals 0.5 to 1.0x and 1 to 2x the bodyweight were common[illegible]e for non-teneral males and females respectively of [illegible]h species. Nevertheless, *G. pallidipes* took smaller-sized bloodmeals (Table 3.3) and a greater proportion of their meals at short intervals (Table 3.4) than *G. longipennis*. However, males and females of each species took comparable number of bloodmeals per pregnancy cycle or 10-day unit of time. Interestingly, a few females of *G. longipennis* but not *G. pallidipes* successfully completed a pregnancy cycle on two bloodmeals.

Feeding response in reproductively normal female *G. longipennis* was highest on day 1 following larviposition but thereafter remained at the same level till the usual period of abstinence (2–3 days) preceding larviposition. The daily feeding rhythm of males, on the other hand, remained even throughout.

The surgical method of determining the interval between a bloodmeal and fly capture enables the identification of eight stages in the trophic cycle of both sexes of *G. pallidipes*. The distribution of laboratory-fed flies in the various trophic categories at known intervals after a bloodmeal revealed differences between individuals with respect to rate of digestion. Nevertheless, the distribution of trap-caught flies in the various trophic categories showed that most of them had fed between 2 and 3 days before capture (Tables 3.5 and 3.6). Males and females differed but slightly in this respect.

Table 3.3 Bloodmeal size of non-teneral tsetse

Species	Bloodmeal size, mg (mean + S.D.) Male	Female
G. longipennis	54.5 ± 42.8 (n = 220)	129.1 ± 48.4 (n = 205)
G. pallidipes	37.0 ± 16.3 (n = 125)	56.1 ± 29.1 (n = 116)

Table 3.4 Interval between bloodmeals of tsetse

Duration (days)	Proportion (%) of bloodmeals taken *G. longipennis* Male (n=185)	*G. longipennis* Female (n=194)	*G. pallidipes* Male (n=193)	*G. pallidipes* Female (n=315)
0	26.5	30.9	55.4	46.7
1	25.9	30.9	19.7	33.0
2	18.9	26.3	12.4	8.2
3	16.8	9.8	8.3	7.0
4	9.2	1.5	3.6	4.1
5	0.5	0.5	0.0	0.6
6	1.6	0.0	0.5	0.3
7	0.5	0.0	0.0	0.0

Table 3.5 Distribution of laboratory-fed and trap-caught male *G. pallidipes* in various trophic categories

Trophic category	Proportion (%) of flies/ trophic category: Hours after laboratory feeding 0	24	48	72	Trap-caught
0	0	0	0	0	4
1	100	20	0	0	0
2	0	77	5	0	0
3	0	3	17	2	8
4	0	0	23	5	14
5	0	0	36	21	15
6	0	0	14	16	34
7	0	0	4	37	21
8	0	0	0	19	4
n	20	31	77	63	104

Table 3.6 Distribution of laboratory-fed and trap-caught female *G. pallidipes* in various trophic categories

Trophic category	Proportion (%) of flies/ trophic category: Hours after laboratory feeding 0	24	48	72	Trap-caught
0	0	0	0	0	3
1	100	22	0	0	0
2	0	73	8	0	0
3	0	5	42	4	5
4	0	0	13	6	9
5	0	0	22	52	44
6	0	0	9	16	27
7	0	0	6	2	11
8	0	0	0	19	1
n	20	41	77	48	140

Most female *G. longipennis* produced equal numbers of male and female offspring. However a greater proportion produced more male offspring than those which produced more female offspring. Only females producing more than four offspring each were considered. It would seem therefore that the *G. longipennis* population at Nguruman produces more males than females.

The foregoing preliminary observations are being applied in on-going analysis of the feeding response of tsetse at Nguruman immediately after capture in, on and around traps and tethered animals in selected microhabitats of the ecosystem.

3.3 IMPROVEMENT OF TRAP EFFICIENCY FOR *GLOSSINA BREVIPALPIS* IN THE MUHAKA/SHIMBA HILLS AREA, KWALE DISTRICT

C. A. Kyorku

Trapping studies have been going on in the Muhaka/Shimba Hills area with the view to developing a cheap and effective trap/odour bait system that could be used for sampling *G. brevipalpis* and be deployed for any tsetse control campaign in the area.

In earlier studies we established that acetone was the most effective attractant for *G. brevipalpis*. Other substances including the popularly known bait, cow urine and 1-octen-3-ol did not significantly increase the catches of this species over acetone either on their own or in combination with acetone.

Subsequently, some other ketones(like acetone) were tested using the NG2B trap as the standard trap. These included 2-octanone, 4-heptanone, 2-butanone or methyl ethyl ketone (MEK). They were tested first on their own in comparison with acetone in relation to an unbaited trap then later on in combinations with acetone and cow urine. Acetone still proved to be superior to these other ketones as it was the only one that effected a significant increase in catch over an unbaited trap for *G. brevipalpis*. For *G. pallidipes* there was a 4x increase in catch with MEK as well as with acetone. When these ketones were dispensed together with cow urine and acetone there was no enhancement in attractancy of the latter pair of baits for either species.

Attention was also redirected at testing new trap designs. It was previously reported that the blue biconical trap baited with acetone alone was about 4x more effective than a similarly baited NG2B trap for *G. brevipalpis* but the reverse situation held for *G. pallidipes*. With the view to developing a single trap that could be effective for both species, several new trap designs were constructed and tested. Because the NG2B trap is cheaper and simpler to construct than the biconical trap efforts were directed at modifying the former for *G. brevipalpis* while maintaining the efficiency for *G. pallidipes*. Based on some observed behaviour of *G. brevipalpis* around traps a modification was made on the lop-sided NG2B(with an extra metre of blue cloth stretched on one side of the entrance) trap which turned out to be quite effective for both species. This was done by folding the extra metre of blue cloth backwards and constructing another NG2B trap to face the opposite direction. This twin trap called the "Siamese NG2B" trap was tested against the standard NG2B, the lop-sided, the biconical and two NG2B traps set close together but facing the same direction. The results obtained from three separate experiments showed that the "Siamese" trap and the biconical trap regularly caught 3–4x more *G. brevipalpis* than the other NGU traps. Furthermore the Siamese trap caught 2–3x more *G. pallidipes* than the biconical trap and was equal in performance to the NG2B traps for this species.

The "Siamese NG2B" trap is therefore the one single trap that is effective for both *G. pallidipes* and *G. brevipalpis*. Further modifications are underway to simplify it by reducing the double netting cones and two collecting cages to single ones.

3.4 POPULATION STUDIES ON *GLOSSINA AUSTENI* IN THE SOUTH COAST, KENYA

M. L. A. Owaga

In the last annual report it was indicated that the activities at the Kenya Coast were concentrated on the two relatively little studied species, namely *G. austeni* and *G. brevipalpis*. The report on *G. austeni* (see *ICIPE 1990 Annual Report*) was on the aspect of vectorial capacity and trypanosome infection in the wild population. This work was continued in 1991, and extended to other eco-behavioural aspects such as diel activity, responses to traps and population characteristics. Monthly monitoring of the population was carried out using three trap types, the biconical trap, the NG2B and the pyramidal traps. Trap sites were established in three selected habitats characterised by different vegetational associations, forest floor, ecotone and the area surrounding the forest, and near homesteads in the settled area between Shimba Hills and Muhaka forest in Kwale District, Coast Province, Kenya. The following aspects of *G. austeni* population characteristics were studied:

- Habitat preference
- Population fluctuations
- Relative density and dispersal.

In Muhaka, traps were set along the edges of the forest, on the forest floor, and on a cleared transect cut across a section of the forest. Climatic factors such as temperature, relative humidity and wind speed were monitored in the different habitat types. Traps were emptied every day during the week of the experiment. Mark-release-recapture was conducted to evaluate dispersal and density. Catches were analysed in terms of numbers captured per trap per day during the different months of the year. The monitoring traps in the settled areas were left in place throughout and emptied two times a week.

There was significant difference in mean trap catches between all the vegetation types. Catches in the settled area were too low for meaningful statistical analysis. *G. austeni* were very rarely captured. Occasional flies were captured in the isolated thickets, whereas *G. pallidipes* and sometimes *G. brevipalpis* were readily caught. In Muhaka there was clear significant preference for forest and dense thicket ($P < 0.01$, F test) with catches from the forest floor being greater than those from the edge of the forest throughout the year. Furthermore, catches from the cleared transect within the forest were not significantly different from those of traps set at the relatively open woodland surrounding the forest, indicating the effect of vegetation clearance on the distribution of *G. austeni* within its range.

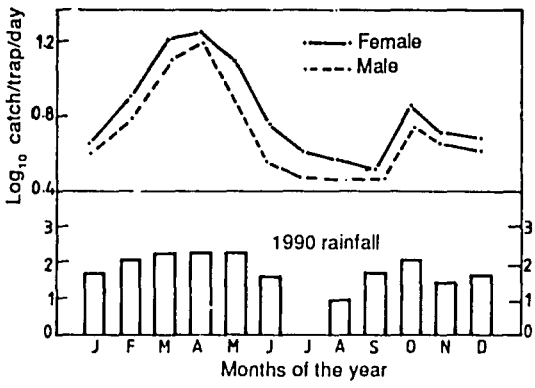

Figure 3.3 *Glossina austeni* monthly apparent density in Muhaka forest compared to monthly rainfall pattern.

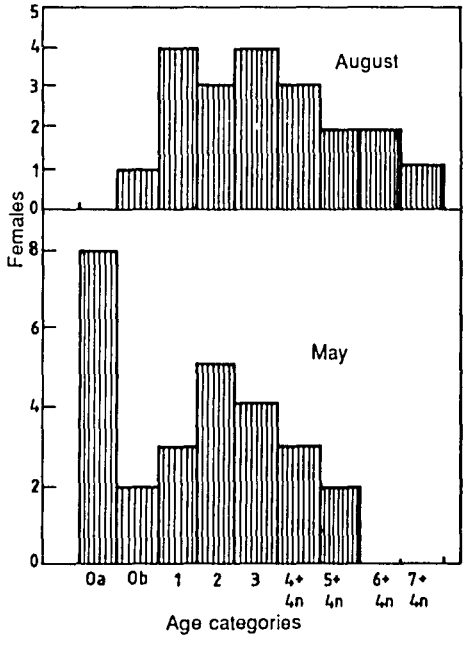

Figure 3.4 Age categories of mean samples of *Glossina austeni* captured in three trap types.

Seasonal fluctuation in apparent density is illustrated in Figure 3.3. Fluctuations in numbers occurred both within the forest floor and around the edges of the forest. The pattern of apparent density coincides with that of the rainfall. Highest apparent density was observed during high humidity periods. Analysis of age structure of females by the ovarian method showed an increase in the youngest age group (nulliparous) during the latter season (Figure 3.4) indicating either higher birth or survival rate. Fluctuations in the numbers of males and females ran parallel to each other (Figure 3.3). The minor differences observed were probably due to the shorter life span of the males.

The recovery of the marked flies was biased in favour of females. The exercise on mark-release will be continued to provide information not only on population size but also on survival rates, dispersal and true sex ratios as well. The data collected so far on female populations showed a parallel with that of apparent density. For example, the highest numbers were obtained in April to May and the lowest in January to February.

3.5 ATTRACTIVENESS OF AGEING COW URINE TO *GLOSSINA PALLIDIPES* AND *G. LONGIPENNIS* IN NGURUMAN

F. P. Oloo[†], *L. H. Otieno and P. A. Olet*[†]

In all our field studies cow urine is kept for 3 weeks to mature at room temperature before use. The dispensers in the field are topped monthly to compensate for evaporation, and replaced with new stock after 3 months. During this experiment, effectiveness of cow urine was studied for 1 year under different topping regimes.

A batch of cow urine was collected from the Maasai cattle in Nguruman. A portion of the urine was tested for attractiveness immediately after collection. The rest was divided into three batches each with four 2-litre cow urine dispensers. The dispensers had 2 x 4 cm opening in the middle of the top side through which the urine was evaporating at the rate of approximately 1000 mg/hr. The three batches were kept under high shade similar to the trapping sites in our study area. The cow urine dispensers were topped monthly to compensate for evaporation. One batch was topped with water, the second one with 50% cow urine (dilution being made from 3 week-old urine), and the third one with its own stock kept in the same site.

The fresh urine was tested in a 2 x 2 Latin Square design experiment with three replicates. It was dispensed together with acetone (150 mg/hour) and 1-octen-3-ol (20 mg/d). The acetone and 1-octen-3-ol were dispensed together as control.

On day 30, 60, 130, 175 and 355, a sample of the three types of urine was tested in combination with acetone and 1-octen-3-ol using 4 x 4 Latin Square experimental design replicated three times. Acetone and 1-octen-3-ol were used as control. Male and female tsetse were recorded and analysed separately. The analysis of variance was done after log $(x + 1)$ transformation.

The results show that dispensing cow urine with acetone and 1-octen-3-ol significantly increases the catches for both male and female *G. pallidipes*. The response was higher for females than males. The fresh cow urine in presence of acetone and 1-octen-3-ol increased the male and female catches 1.53 and 1.98x respectively. Upto day 175, there was no significant difference between the catches by the three topping regimes. On average, the topping regime using 50% cow urine had higher catches followed by undiluted one. The batch topped with water had the lowest increase. Apart from the batch which recorded the highest potency in day 60, the ones topped with 50% cow urine and undiluted had the highest

potency in day 175, with upto 3.74x for females. After 265 days, the cow urine increased catch significantly for females only. Average daily evaporation rates for the batch topped with water and 50% cow urine was 15.26 ± 4.45 (n = 14). The highest daily evaporation rate was recorded during the dry months of December and January. It was lowest (8.78 ml) during the wet month of April.

G. longipennis responded best to topping regime using 50% cow urine. The one topped with water was the least attractive. Fresh cow urine did not increase the catches significantly. On days 30 and 60, there was significant increase by the three topping regimes. From day 130, there was no significant influence executed by the three topping regimes. Both sexes behaved similarly to the cow urine.

The results show that for *G. pallidipes* the urine dispensers need to be replenished either with fresh or 3 week old urine every few months. For *G. longipennis*, cow urine appears to be less effective as an attractant when compared with *G. pallidipes*.

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3.6 TSETSE VECTORIAL CAPACITY

S. Mihok, N. Darji, E. Munyoki, J. K. Stiles and L. H. Otieno

Studies in the early 1980s have shown that tsetse flies are not passive vectors of trypanosomiasis; they have their own special set of "immune" factors that can prevent infection (e.g. lectins, lysins, agglutinins, etc.). Recent studies with DNA probes have also shown that tsetse harbour a bewildering variety of parasite types, some of which may not be of relevance to disease in man and his livestock. These new studies have suggested the possibility that immune mechanisms within the vector can be exploited to break the transmission cycle. Hence, we have begun to investigate the physiological mechanisms that lead to the blocking of infection in the fly.

In a preliminary experiment, *Trypanosoma brucei* parasites representative of three isoenzyme systems that appear to be markers of natural transmission cycles were cloned to investigate their behaviour in three economically-important vectors (*G. morsitans morsitans*, *G. m. centralis* and *G. pallidipes*). Three clones were tested for their reactions to an as yet uncharacterised tsetse midgut lectin(s) that can be inhibited by an amino sugar, (D(+)-glucosamine). Results indicated that this presumed midgut lectin was in fact responsible for much of the variation observed in infection rates between various tsetse species and trypanosome types.

Following up on this preliminary work, we completed a large, complex experiment on the transmission of various isolates of *T. brucei*, *T. congolense* and *T. simiae* to *G. m. morsitans* and *G. m. centralis*. This work investigated the relationship between trypanosome type and host type (buffalo, waterbuck, eland, oryx, cow, goat, pig), as well as the effects of blocking midgut lectin. Surprisingly, we found that host blood factors are important in determining the fate of the infection. Now that we have completed this overall survey, we plan to dissect out the biochemical and physiological processes responsible for facilitating infection in the fly. Successful elucidation of these processes may lead to a practical method of manipulating parasite transmission to tsetse, with possible implications for vaccine-like strategies in livestock.

3.7 EPIZOOTIOLOGY OF TRYPANOSOMIASIS

S. Mihok and E. Munyoki

Collaborative studies with the Kenya Wildlife Service (KWS), Kenya Agricultural Research Institute (KARI), Kenya Trypanosomiasis Research Institute (KETRI) and International Laboratory for Research on Animal Diseases (ILRAD) on the nature of trypanosomes found at Ngulia, a conservation area within Tsavo West National Park, continued. The area was chosen for study as it is one of the few places in East Africa that has had no contact between cattle and wildlife. It is also an area similar to Nguruman, where tsetse have been controlled by ICIPE since 1987, and where cattle live in close contact with wildlife populations. To date, we have completed a survey of the parasites found in *G. pallidipes* at Ngulia and have characterised these isolates to species and subtype using existing DNA probes. Unlike areas with a history of wildlife-livestock contact, the epizootiology of Ngulia appears to be quite simple, with little parasite diversity. However, through culture techniques, we have isolated a new kind of *Nannomonas* parasite infective to suids. The parasites from this area are currently being characterised with molecular techniques and are being used for many of our basic laboratory studies. Our intention is to continue with these studies in different areas in Kenya, and with different vector species. These studies will address the vectorial importance of different tsetse species in different ecological settings in disease transmission to livestock.

3.8 ODOUR BAITS FOR TSETSE FROM WILDLIFE

S. Mihok, E. Munyoki and A. Hassanali

Odour baits and traps for *fusca* group tsetse are at present relatively ineffective. In trapping programmes run by ICIPE, these species have remained as residual components of the tsetse community after the savanna species have been controlled successfully (e.g. *G. longipennis* at Nguruman, *G. brevipalpis* at Rwanda). Hence, we have begun to collect waste products from wildlife for testing as novel odour baits for tsetse. Initial results have suggested that rhino dung has attractive properties (phenols) similar to those found in the urine of bovids. Further work will concentrate on confirming these preliminary experiments both in the field and in the laboratory with waste products

Table 3. 7 Estimated rate of change (*r*) of *G. pallidipes* according to vegetation types in Ruma National Park, Lambwe Valley from January 1990 to February 1991

Site	Sex	Equation of the line	C.L. of slope (B)	Correlat. coef. (R)	Student-*t* value	Rate of change (*r*)
Outer	Male	$Y = 0.4729 - 0.1394X$	± 0.1141	-0.6094	2.662*	-0.1394
Edge	"	$Y = 2.6637 - 0.1615X$	± 0.0562	-0.8751	6.264***	-0.1615
Inner	"	$Y = 3.4873 - 0.0353X$	± 0.0661	-0.3204	1.172ns	-0.0353
Pooled	"	$Y = 2.4369 - 0.1066X$	± 0.0585	-0.7538	3.974*	-0.1066
Outer	Female	$Y = 1.0310 - 0.1789X$	± 0.1379	-0.6324	2.828*	-0.1789
Edge	"	$Y = 3.0779 - 0.1702X$	± 0.0524	-0.8982	7.079***	-0.1702
Inner	"	$Y = 3.8818 - 0.0450X$	± 0.0568	-0.5642	1.744ns	-0.0450
Pooled	"	$Y = 2.9123 - 0.1316X$	± 0.0532	-0.8405	5.374*	-0.1316

*Slope significantly different from 0 at $P < 0.05$; *** $P < 0.0001$; ns, slope not significantly different from 0, $P > 0.1$.

from unusual hosts such as rhinoceros, elephant and hippo in different areas with *fusca* group tsetse in Kenya.

3.9 ECOLOGY AND CONTROL OF *GLOSSINA PALLIDIPES* IN THE LAMBWE VALLEY

M. M. Mohamed-Ahmed, L. H. Otieno and J. Muchiri

The Lambwe Valley *G. pallidipes* belt is unique in several aspects. First, this belt has been known to contain the highest density of tsetse ever recorded for any *Glossina* species in Africa. Second, *G. pallidipes* in the Lambwe Valley has always defied control attempts including bush clearing and partial game eviction in the past and intensive insecticide applications at intervals, over the last 20 years. Third, flies have been known to recover to their pre-control level within a short time of cessation of every control attempt, though over 99.9% of population suppression might have been attained. The latest attempt has been the mass-deployment of the odour-baited targets in Ruma National Park, to suppress and eventually eliminate *G. pallidipes* from the area. By the end of 1990 (*c.* after 3 years of continuous target operation) regular monitoring showed that hundreds of thousands of flies still existed in the Park (*ICIPE 1990 Annual Report*).

Analyses of data from January to February 1991 according to trap catches whether inside continuous thickets, at the edge of these thickets or thicket clumps outside the Park revealed distinct subpopulations (substructures) of *G. pallidipes* in these vegetation types. The subpopulation in the continuous thicket had consistently the highest density of males and females ($P < 0.001$) and the lowest corrected female mortality rates estimated from monthly age grading data compared with those at the edge of thickets inside or thicket clumps outside the Park. Clearly, *G. pallidipes* in the continuous thicket was relatively less vulnerable (resilient) to control by targets placed at the edge of thicket as evidenced by its defiance to change with the progress of the control operation (Table 3.7).

Although the persistence of flies in Ruma Park could be explained in part by technical and operational shortcomings in target deployment and maintenance, these could not be considered in isolation of the substructuring of tsetse in the continuous thickets with which flies had evaded targets; and which must be viewed in the context of the favourability of the environment for tsetse survival and adaptation of flies to this mode of control. Substructuring of *G. pallidipes* as such not only has affected the level of tsetse reduction by targets in the Lambwe, but also the assessment of the efficiency of these devices and possibly that of the previous control methods in the area. Thus monitoring traps installed at the thicket edge to detect the level of suppression of tsetse do not exactly reflect the situation of flies inside the thicket and may completely miss it. This, in turn may lead to overestimation of the efficiency of the control technique and consequently the inflated figures of tsetse reduction. For all these reasons, we proposed that, probably, more effective control and better assessment of the tsetse situation could have been attained by deployment of targets and placement of monitoring traps inside the continuous thickets.

By March 1991 targets were placed at *c.* 90 targets/km² in narrow tracks in the continuous thickets in the original study area A (Figure 3.5). In consequence, the population of both male and female *G. pallidipes* collapsed precipitously by April to become less than 0.1% in June, and no fly has been caught since July 1991. Conversely, in other parts, as in site B (Figure 3.5), where targets were still placed conventionally at the edge and poorly serviced, the tsetse population was increasing (Figure 3.6a). On the other hand, at the third site C Figure 3.5 (*c.* 10 targets/linear km in vehicle transects across the

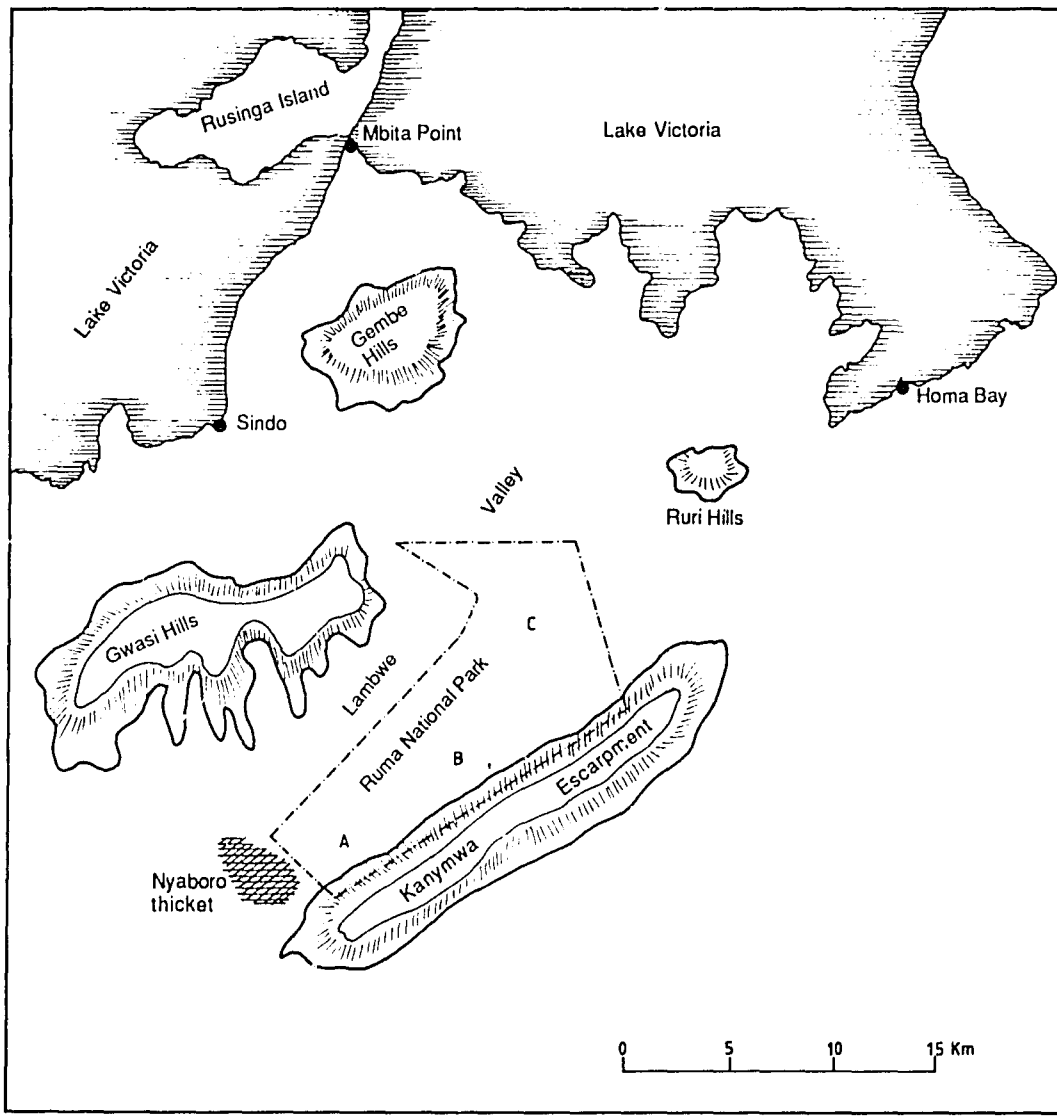

Figure 3.5 Study sites A, B and C in Ruma National Park, Lambwe Valley.

continuous thicket), the level of the local tsetse population was intermediate between sites A and B (Figure 3.6a, b, c). Mortality rates corrected for the rate of change (increase or decrease), *r* for each local population in the three sites showed that during the period from March to July 1991, flies at A were dying at about 10%/day, while those at B and C were increasing at about 4.5 and 4%/day, respectively.

The above results indicate that placement of targets and monitoring traps inside the continuous thickets have made significant improvements towards better control and assessment of the tsetse situation in the Lambwe, though the optimum economical number of targets/unit thicket area remain to be determined. It has also to be noted that in site A the local tsetse population collapsed to virtual extinction only after a high density of targets had been used (*c.* 90 targets/km^2). Considering that the continuous thicket subvegetation in the Lambwe Valley comprises about 80 km^2 and assuming an optimum target density of 90/km^2, approximately 7200 targets would be needed to achieve such a high level of control. The question is, can resources (local and/or external) be mobilised and maintained to see such a project through to completion and a tsetse-free Lambwe at the end?

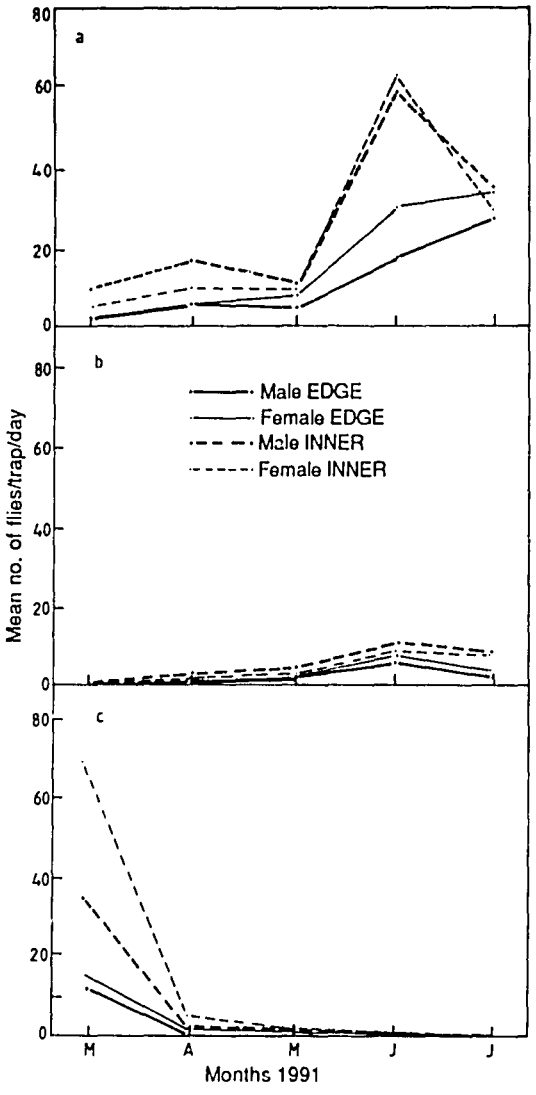

Figure 3.6 Response of *G. pallidipes* in Ruma National Park to the odour-baited insecticide-coated targets: a, targets placed at the edge of thicket in site B; b, targets in vehicle transect across the continuous thicket in site C; c, targets inside the continuous thicket in site A.

3.10 PREDICTION OF THE TEMPERTURE EXPERIENCE OF THE PUPA OF *GLOSSINA PALLIDIPES* FROM THE SIZE OF THE FIRST EGG FOLLICLE

M. M. Mohamed-Ahmed, L. H. Otieno, S. Mihok and J. Muchiri

Newly-deposited pupae of *G. pallidipes* were incubated until emergence at 20.5 ± 1°C, 22.5 ± 0.5°C, 25.0°C, 27.5 ± 1°C, 29.5 ± 0.5°C and in the insectary at ambient conditions. Egg follicles of the newly-emerged females were dissected and the oocyte length measured. Also, the length of the cutting edge of the hatchet cell of right and left wings was measured. Three-group canonical analysis of discriminance and linear discriminant function analysis of data showed the best classification according to temperature for the mean length of egg follicle A. Subsequent linear regression analysis showed a highly significant inverse correlation between temperature and mean egg follicle A length. The regression equation obtained allowed the prediction of the unknown temperature experience from the means of follicle A length of 17 monthly samples of newly-emerged *G. pallidipes* from the insectary. Predicted temperatures were well within the range and very close to the actual mean of the respective months (Figure 3.7). It was concluded that the mean size of egg follicle A of the newly-emerged *G. pallidipes* could be a simple reliable predictor for the temperature experience of pupae of this species in the field.

3.11 THE ROLE OF HORMONES IN THE PREGNANCY CYCLE OF *GLOSSINA*

J. A. Davies-Cole

Reproduction in tsetse requires the coordination of a number of cyclical events in the mated female, terminating in the production of a fully grown third instar larvae every 9 or 10 days at 25°C. Cyclical growth and involution of the highly modified accessory gland of the female is coordinated to provide nourishment for the developing larva *in utero*. The endocrine control of these events is generally unclear.

A role for juvenile hormone in the regulation in *G. austeni* was proposed some 15 years ago when it was reported that allatectomy during the first 2 hours of adult life led to cessation of oocyte development and follicles failing to become vitellogenic. Allatectomy also inhibited accessory gland function such that larval growth was retarded and interlarval periods were extended.

It was also reported that ablation of the median neurosecretory cells almost always inhibited ovulation and interfered with larval development and larviposition but did not appreciably influence blood feeding, digestion and egg maturation. Other reports however indicate that JH is not involved in regulating the gonotrophic cycle. Thus the situation remains confusing. The objective of this study is to examine the role of neuroendocrine systems in maintaining the pregnancy cycle with special emphasis on the role of hormones in the synthesis of milk and larval nutrition relating to successful reproduction in *G. m. centralis*, *G. pallidipes* and *G. longipennis*.

In order to re-examine this question females of *G. m. centralis* were allatectomized after emergence (0–24 hours). In another experiment, mated females were held until they produced their first larvae. They were then allatectomized. The length of the interlarval period and pupal weight were subsequently determined. In the first series of experiments the reproductive performance was observed until the third cycle. Another group of flies were injected in a separate experiment with homogenised

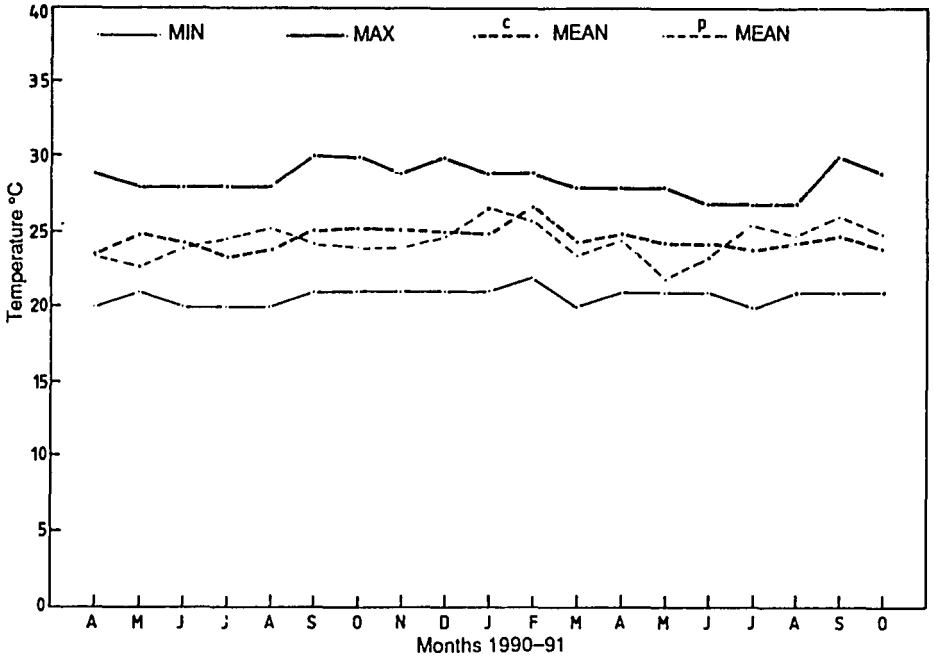

Figure 3.7 Monthly absolute minimum (MIN), absolute maximum (MAX) and mean ambient (c MEAN) temperatures (°C) and those predicted (p MEAN) from egg follicle A mean length each month.

brains from females in their second reproductive cycle. The flies were injected when they were 2 days old (still virgins) and mated when 4 days old. The length of the gestation cycle and pupal weight were determined.

It was found that all flies operated on 0–24 hours after emergence readily mated on the 4th day as did control flies. The interlarval period was slightly longer in all three reproductive cycles. (First cycle mean = 20.1 ± 0.6 S.E. days for allatectomised flies and 17.0 ± 0.6 S.E. days for controls). However, the pupal weights were more or less unaffected. In the second cycle, the mean length of the gestation cycle for allatectomised flies was 11.5 ± 0.95 S.E. days and for control was 9.8 ± 0.0 S.E. days.

The interlarval period was longer at the first cycle in females allatectomised after they had produced three larvae (mean = 12.5 days) compared to a shorter period for the controls (mean = 10.8 days). Development progressed normally and normal sized pupae were produced.

Various abnormalities were found in flies allatectomised 0–24 hours after emergence. Seven per cent aborted their first larvae with low pupae weight (mean = 24 mg). The normal average is about 30 mg. Seven per cent failed to larviposit even when they were inseminated. Egg retention in the ovaries was found to be the cause. These experiments show that alletectomy 0–24 hours after emergence has little effect on the pregnancy cycle. However, it is probable that hormones produced may be acting on the milk gland by depriving the larva of its nutrients, thus causing abortion and low birth weight and egg retention. This line of investigation (effect on milk glands) will be followed further in order to quantify milk portions produced after allatectomy as well as injection of brain extracts.

3.12 BIOLOGICAL CONTROL AGENTS FROM *GLOSSINA PALLIDIPES*

J. Davies-Cole, J. Stiles and L. H. Otieno

Laboratory colonisation of *G. pallidipes* has been accomplished on very few occasions and even then, with considerable difficulty. A once thriving colony of *G. pallidipes* at the ICIPE MPFS progressively declined (pupal production, adult emergence) from April 1991. The females continuously rejected mating attempts by males and it became difficult to get females inseminated even when they were kept with males for 1 week.

Earlier reports suggest that *G. pallidipes* is difficult to rear because of its susceptibility to virus-like infection. Rickettsia-like organisms have also been associated with *G. pallidipes* and *G. morsitans*. The objective of this study was to look more closely at the presence of microorganisms in *G. pallidipes* and their probable role in reproductive performance of the fly.

Tsetse flies (*G. pallidipes*) were obtained from the ICIPE Mbita Point Field Station colony. Male and female

flies were 1–4 months old with at least one mating experience. The flies were dissected and their reproductive system examined for any abnormalities. Guts were teased out and examined on a microscope slide using the high power magnification. Males were similarly treated, the testes and accessory glands were examined. Photographs were taken of the different organs. Electron micrographs of ovaries, testes and spermathecae were made. Batches of guts, spermathecae, testes and accessory glands were studied to identify any microbe present.

Examinations of these preparations revealed various reproductive abnormalities (retained egg follicles, egg resorption, ovarian degeneration, empty uterus and abortions), empty spermathecae and partially empty spermathecae. Eighty-eight per cent (n = 57) of females were inseminated and 91 per cent showed reproductive abnormalities. Forty-two per cent (n = 31) had enlarged salivary glands. Two *Bacillus* species, one gram negative and the other, gram positive grew on nutrient agar plates. Pathogenicity experiments to determine the role and mode of pathological effect is in progress. However, it is pertinent to note that the gram positive bacteria gave a positive reaction with gelatin.

These observations show that there is close association between these microorganisms and the reproductive abnormalities. Experiments are underway to establish the relationship between the bacterial infection and the virus-like infection since many bacteria-infected flies had also viral infection. The pathogenicity of the bacteria to the tsetse is being examined in more details to see if it could be a potential biological control agent.

3.13 ICIPE-ETHIOPIA COLLABORATIVE PROJECT

G. Tikubet and L. H. Otieno

ICIPE-Ethiopia collaborative project was established in September 1991. The operational base of the project is situated within the Institute of Pathobiology, Addis Ababa University. The project has got modest laboratory facilities and offices but these are being upgraded to meet basic standard requirements. Tsetse colony (*G. morsitans morsitans*) has been established. Automated walk-in breeding chamber is being prepared for the colonisation of *G. morsitans submorsitans* from south western Ethiopia. The project focuses on the evaluation of appropriate trapping technology for sustainable tsetse management in Ethiopia, consequently it was felt that it is essential to develop reliable tools for the assessment of trap designs and odour attractants. Standard electric screens are being modified, automated and solar powered with various power regulatory devices. Studies on the potential use of remote sensing for risk and challenge quantification have been started. Studies on tsetse challenge and trypanosomiasis risk in southwestern Ethiopia were correlated with NDVI values obtained for one specific area (i.e. the Ghibe river valley). It was found that there was a significant negative correlation with tsetse challenge ($r = -0.610$ and $P < 0.001$). In addition, it was also found that the relative fly density (*G. pallidipes*) was correlated with NDVI values ($r = -0.645$ and $P < 0.001$). Thus, it was possible to predict high tsetse challenge area in western, southern and south west parts of Ethiopia.

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4

Medical Vectors Research Programme

Medical Vectors Research Programme targets its activities in the rural arid and semi-arid areas of the tropics against disease vectors and reservoirs of malaria and leishmaniasis. These two diseases are the major cause of mortality and morbidity in these areas and furthermore they contribute to serious economic drawback as a result of loss of labour.

Among the Programme activities covered during 1991 were: (1) Continuing testing the efficacy of the "Mbu cloth" for the control of mosquitoes and sandflies in Marigat District, Baringo in Kenya; (2) Investigations into vector species, i.e., their identity, vector potential and vectorial capacity in three major endemic foci of leishmaniasis; (3) Vector-parasite-host interaction; (4) Plant-vector interaction; (5) Designing new trapping technologies; (6) Colour preference studies by mosquitoes and sandflies; (7) Biological control investigations and (8) Ecology of vectors.

Several significant findings emerged from these studies during the year which include:

- *The validation of the Mbu cloth among 2000 houses tested which showed that the technology is appropriate and effective for disease control in rural areas;*
- *The modification of the CDC trap for catching sandflies more efficiently which added to existing trapping methods, and*
- *The isolation of bacteria* (Bacillus *sp.) lethal to mosquito larvae; these are being characterised and tested.*

4.1 EPIDEMIOLOGY OF LEISHMANIASIS IN KITUI DISTRICT: STUDIES ON VECTORS AND RESERVOIRS OF LEISHMANIASIS

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

Kitui focus is the oldest focus of visceral leishmaniasis in Kenya where visceral leishmaniasis has persisted in man since the early 1950s. Several epidemics have occurred since that time resulting in loss of lives. Four sandfly vector species have been identified but it is necessary to carry out exhaustive studies using more sensitive trapping techniques for sandflies to ascertain that they are the only ones and to investigate their disease transmission pattern. This is necessary for the development of effective control measures.

Similarly the animal reservoir for kala-azar besides the domestic dog has not been identified. Hence the necessity to carry out further research which is currently in progress.

4.2 AN UPDRAFT TRAP FOR SANDFLIES

C. M. Mutero, M. J. Mutinga and F. A. Amimo

An updraft trap for sampling sandflies in the field was developed and tested in the Marigat area, Baringo District. The main components of the trap were a 12 cm long plastic drain pipe, a 9V DC electric motor, an aluminium fan and a perspex sandfly collection cage (Figure 4.1). The total cost of the trap was approximately US$ 21. An additional US$ 1.2 was spent on six dry cells required to operate the trap each night. Construction of the trap was carried out at the ICIPE workshop.

Comparisons of the performance of the updraft trap with a CDC light trap and a 1 x 1 m polythene sheet coated with castor oil (sticky trap) showed the former was more consistent than the other traps in sampling sandflies from animal burrows. The greater consistency could probably be explained by the general orientation of the various traps in relation to the opening of the animal burrows. In all cases, the sucking end of the updraft trap was closer and more directly positioned

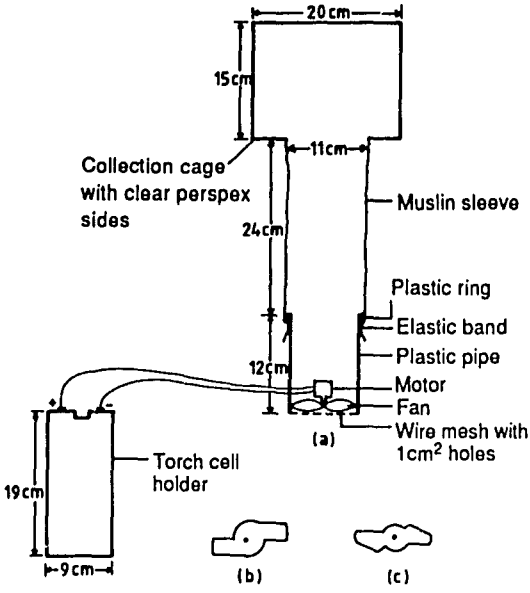

Figure 4.1 Diagram of an updraft trap a, complete trap; b, regular shaped fan; c, irregular shaped fan.

above the burrow opening than the other traps. Sandflies leaving or entering the burrow were therefore likely to have been captured before they could disperse in various directions. *Phlebotomus martini* and *P. duboscqi* the respective vectors of *Leishmania donovani* and *L. major* in Kenya were among sandflies commonly collected by updraft traps near animal burrows.

The low cost of constructing an updraft trap locally is an attractive alternative to importing light traps whose cost is approximately US$ 90 per unit. This is especially so, considering the availability of knowledgeable personnel and a well equipped workshop at the ICIPE where the traps were made.

4.2 THE IMPACT OF PERMETHRIN-IMPREGNATED CLOTH ON MOSQUITO POPULATIONS IN BARINGO DISTRICT, KENYA

M. J. Mutinga, C. M. Mutero and M. Basimike

Collection of mosquito data for assessing the impact of permethrin-impregnated wall cloth (Mbu cloth) on malaria vectors in Marigat area was started in 1989 and continued through 1990 and 1991. A statistically significant decline in the mosquito population was recorded by all the three sampling methods used, namely, hand catch, exit trap and CDC light trap methods. Results of the latter method are summarised in Table 4.1, and refer to four time phases corresponding to treatment of the cloth with permethrin as follows: pre-treatment phase, March–July 1989; first treatment, October 1989–January 1990; second treatment, March–August 1990; and third treatment, September 1990–February 1991.

Table 4.1 Monthly mean catches of mosquitoes collected by CDC light trap from various localities

Period	R9 indoor	R9 outdoor	Control indoor
Pre-treatment	127[a]	20.8[a]	43.4[a]
1st treatment	12.3[b]	46.8[b]	20.0[b]
	(90.3)	(125.0)+	(53.9)
2nd treatment	37.3[b]	60.5[b]	69.7[a]
	(70.6)	(190.9)+	(60.6)+
3rd treatment	26.2[b]	19.2[a]	45.8[ab]
	(79.4)	(8.3)	(5.5)+

Mean catches for each locality not followed by the same letter are significantly different ($P < 0.1$).
Decrease or increase (+) of a particular treatment mean relative to the pre-treatment mean is expressed as a percentage for each locality and shown in brackets.

Mosquitoes trapped indoors in the treated area within Perkerra irrigation scheme decreased during the post-treatment period by between 70 and 90%. In contrast, light trap catches in a control village, Ngambo, showed an initial significant decrease followed by an increase in mosquito numbers.

With regard to malaria vector species, a considerable reduction in numbers collected indoors was observed during the first and second treatments for *Anopheles gambiae*, and during the first and third treatments for *A. funestus* (Table 4.2). In contrast to the decline of *A. gambiae* in the treated area, a steady increase was observed in the control area with the numbers collected during the period corresponding to the third treatment being about 14 times those collected during the pre-treatment phase.

The monthly variation in light trap catches is further illustrated in Figure 4.2. As concerns the density of the general mosquito population, a single peak was observed during the pre-treatment phase in March 1989 followed by comparatively lower numbers with only a much smaller peak being recorded in March 1990. In contrast, two peaks obtained for mosquitoes from the control locality during the post-treatment period in June and November 1990 were higher than one recorded during the period corresponding to the pre-treatment phase in April 1989. Mosquito density in the irrigation scheme was much higher than in the control area prior to the introduction of the cloth, but a reversed situation was observed during the post-treatment phase.

We would like to indicate that the Mbu cloth was greatly appreciated by the Marigat community especially after the people's own observations of considerably reduced mosquito nuisance.

Table 4.2 Monthly mean catches of *A. gambiae* and *A. funestus* by CDC light traps from various localities

Species	Period	R9 indoor	R9 outdoor	Control indoor
A. gambiae	Pre-treatment	3.6	2.8	1.0
	1st treatment	1.0	1.3	5
		(72.2)	(53.6)	(50.0)+
	2nd treatment	2.5	0.2	4.7
		(30.6)	(92.9)	(370.0)+
	3rd treatment	5.5	0.5	14.2
		(52.8)+	(82.1)	(1320)+
A. funestus	Pre-treatment	1.4	8.8	0.4
	1st treatment	1.3	6.5	0.5
		(7.1)	(26.1)	(20.0)+
	2nd treatment	1.7	0.3	0.3
		(21.4)+	(96.6)	(25.0)
	3rd treatment	0.2	1.0	0.5
		(85.7)	(88.6)	(20.0)+

Decrease or increase (+) of a particular treatment mean is expressed as a percentage for each locality and shown in brackets.

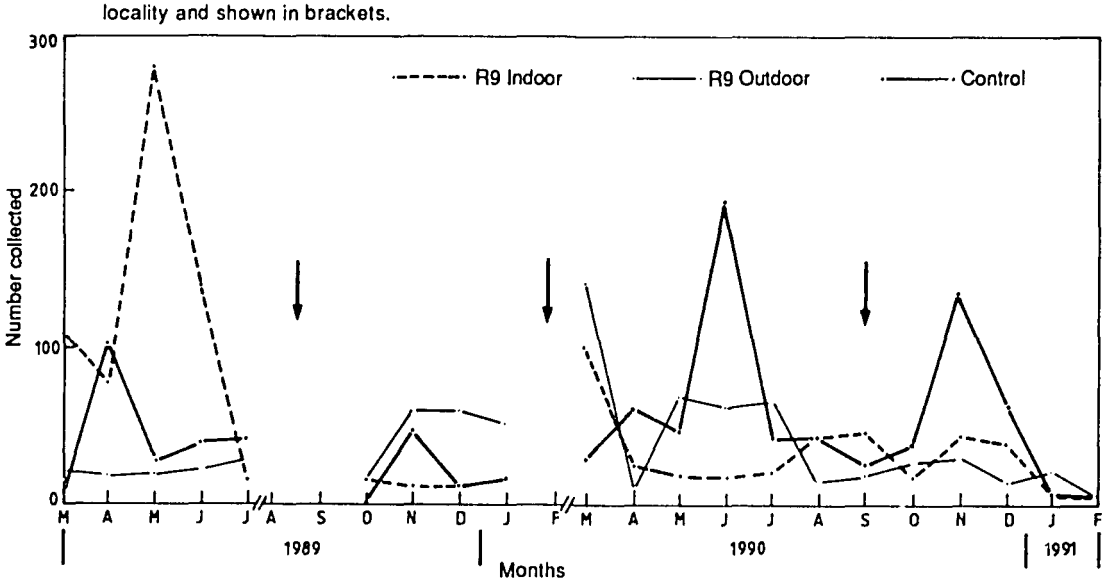

Figure 4.2 Monthly fluctuations of mosquitoes collected in light trap catches. Arrows indicate the months during which impregnation was undertaken.

4.4 THE EFFICACY OF "MBU" CLOTH AGAINST SANDFLIES

M. J. Mutinga, M. Basimike and C. M. Mutero

The evaluation of the impact of permethrin-treated wall fabrics ("Mbu" cloth) against phlebotomine sandflies in Marigat, Baringo District, Kenya, continued in 1991. Sandflies were sampled on a weekly basis from the experimental villages (Ngoswe, R5, R10, Muslim Camp, L1 and Turkana) and the control area (Ngambo 1 and Ngambo 2). Two thousand houses were fitted with Mbu cloth in the experimental villages. The control area did not have any fabrics. Six houses were randomnly selected in each village. Sticky traps made of polythene sheeting coated with castor oil were used for sampling sandflies from the selected houses. Eleven sandfly species had 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.*

A comparatively higher density of sandflies per house per trap night was collected in Marigat before the deployment of the wall fabrics (February 1989–July 1989), ranging between 2.5 to 14.5 sandflies per house per trap night. An overall mean density of 6.5 sandflies/

Table 4. 3 Average number of sandflies/house/trap and the sandfly reduction in the experimental villages

Village	Before treatment	Treatment 1st	2nd	3rd	4th	% Sandfly reduction
Ngoswe	9.4	3.8	4.2	2.5	1.8	81
R5	4.7	1.7	2.4	1.6	1.9	60
R10	2.9	1.2	1.4	1.3	0.9	69
Muslim Camp	4.8	3.2	2.7	2.3	1.7	65
L1	14.5	6.5	6.8	6.3	4.9	66
Turkana	2.5	1.2	1.0	0.8	0.2	92
Average	6.5	2.9	3.0	2.4	1.9	71

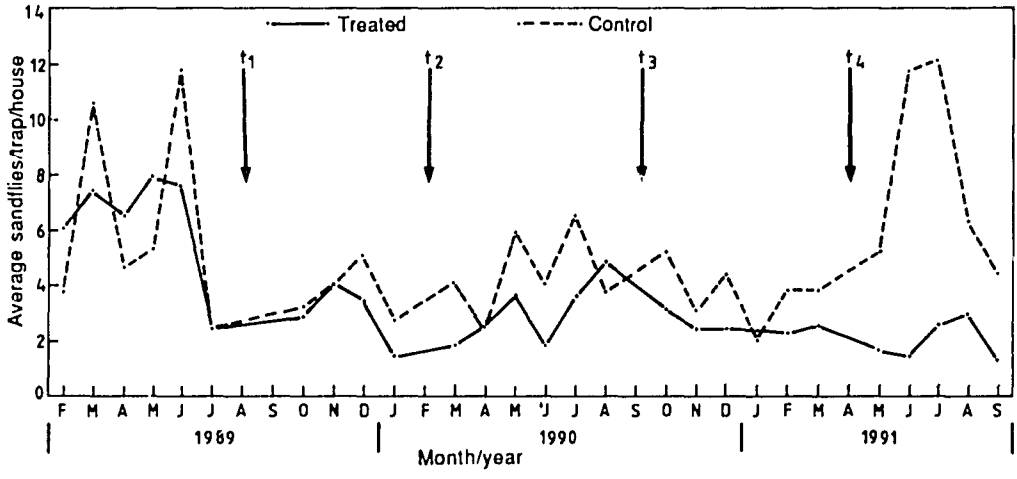

Figure 4.3 Relative abundance of sandflies in both treated and control villages: treated, . __ . ; control, ... ; t_1 – t_4, application of treatments.

house/trap night was observed. After the first treatment of the Mbu cloth (August 1989-January 1990), a reduction of sandflies ranging between 1.2 to 6.5 sandflies per house per trap night was observed in all experimental villages. An overall mean density of 2.9 sandflies per house per trap night was recorded. During the second treatment (March 1990-September 1990), all houses in the experimental villages continued to experience low sandfly relative abundance. The third and the fourth deployments of the Mbu cloth (October 1990–March 1991 and April-September 1991) continued to experience even lower sandfly population densities. An average of 2.4 and 1.9 sandflies per house per trap night was observed during both treatments, respectively. All the fabrics were re-impregnated with permethrin every 6 months.

The relative effectiveness of the Mbu cloth was determined by comparing the relative abundance of sandflies before deployment of the screens with that after treatments. After the 4th treatment, the sandfly population was reduced by 71%. The highest reduction was observed in Turkana (92%), while the lowest was seen in R5 (60%). Sandfly reduction of 81, 69, 66 and 65% were observed in Ngoswe, R10, L1 and Muslim camp, respectively (Table 4.3).

Sandflies collected in the control villages before treatment and during periods corresponding to treatment times (in experimental villages) did not present major significant changes.

The sandfly relative abundance remained low in treated villages. After the 4th treatment (April-September 1991), the sandfly population in control villages peaked up. No sandfly build up however was observed in treated areas (Figure 4.3). An important feature in the experimental area is that there has been no transmission of leishmaniasis to man since the operation started, a tremendous achievement.

4.5 BIOLOGICAL CONTROL OF VECTORS

B. Asimeng, M. J. Mutinga and M. Miti

Research activities were targeted towards the search for biocontrol agents with potential to control mosquitoes and sandflies, the vectors of malaria and leishmaniasis, respectively. The major studies, concentrated mainly at Mwea Rice Irrigation Settlement and Sagana Fish Culture Farm, covered two groups of biocontrol agents — entomopathogenic bacteria and larvivorous fish. In addition, studies continued on dynamics of larval mosquito populations at the Irrigation Scheme.

4.5.1 Entomopathogenic bacteria

Source materials for isolation (mosquito larvae, silt, soil, mud) were collected in sterile bags from mosquito breeding sites identified at the study area. The bulk of the materials collected consisted of soil and mud since larval cadavers initially proved difficult to find. By means of a plastic bottle (Figure 4.4), a technique was developed to overcome the problem of obtaining dead larvae. Bacteria were isolated from the source materials and screened for toxicity against mosquito larvae.

Three hundred samples of source materials comprising soil, 120 (40%); mud, 90 (30%); silt, 55 (18%); fish faeces, 30 (10%); and mosquito larvae, 5 (2%) were collected from numerous breeding sites of mosquito. Forty-two out of the total samples produced several types of bacteria but only five of these isolates were mosquito-toxic. The larval samples (all of which were used in the developed baiting technique) constituted just about 2% of the total source materials but accounted for 3 (60%) of the mosquito-active isolates. Each of the silt and fish faeces components represented 20%, while both soil and mud sources contained no pathogens. The LC_{50} computed for the various mosquito species/isolate combinations are presented in Table 4.4. Probit analysis regressions were significant at $P = 0.001$ in all cases and r^2 values were generally high. However, because of the few data points used in the analysis, the 95% confidence limits of LC_{50} were overlapping between almost all of

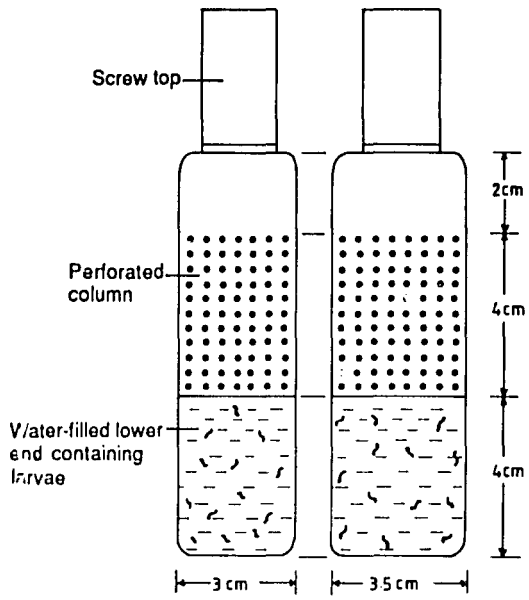

Figure 4.4 Diagram of the "baiting" apparatus for collecting mosquito larvae.

Table 4.4 LC_{50}s and regression slopes of isolates/mosquito species combinations

Isolate	Mosquito species	Regression slope ± S.E.	LC_{50} with 95% confidence limits mg/l
B42 (silt)	*Anopheles arabiensis*	2.41 ± 0.10	0.1(0.04 – 0.24)
	Aedes aegypti	2.02 ± 0.57	0.4(0.0 – 21.26)
	Culex quinquefasciatus	2.34 ± 0.43	0.3(0.0 – 23.3)
B51 (fish faeces)	*A. arabiensis*	2.34 ± 0.21	0.4(0.02 – 0.8)
	Ae. aegypti	2.16 ± 0.36	0.2(0.0 – 7.3)
	C. quinquefasciatus	3.72 ± 0.26	0.3(0.1 – 0.9)
B53 (larvae)	*A. arabiensis*	2.42 ± 0.06	0.8(0.05 – 0.13)
	Ae. aegypti	2.33 ± 0.44	0.3(0.0 – 27.8)
	C. quinquefasciatus	3.72 ± 0.34	0.3(0.0 – 0.13)
B54 (larvae)	*A. arabiensis*	2.32 ± 0.18	0.1(0.02– 0.6)
	Ae. aegypti	1.70 ± 0.42	0.1(0.0 – 55.3)
	C. quinquefasciatus	3.72 ± 0.28	0.3(0.1 – 0.97)
B55 (larvae)	*A. arabiensis*	2.33 ± 0.18	0.12(0.02 – 0.6)
	Ae. aegypti	3.72 ± 0.56	0.4(0.00 – 4.2)
	C. quinquefasciatus	3.72 ± 0.31	0.3(0.1 – 1.1)

Table 4.5 Analysis of variance of data obtained from feeding of *Tilapia zilli* and *Oreochromis niloticus* on *Aedes aegypti* larvae

Temp. (°C)	20	25	30	35
Mean[1]	13.96[b]	16.83[a]	14.89[b]	1.99[c]
pH	7.0	7.5	8.5	9.5
Mean	16.72[a]	14.08[b]	5.07[c]	0.707[d]
Species	*T. zilli*	*O. niloticus*		
Mean temp.	12.64[a]	11.19[b]		
Mean pH	9.34[a]	8.95[a]		

[1]Means with the same letter are not significantly different at $P < 0.05$.

the species/isolate combinations indicating no significant differences.

In comparison with the other materials, larval bodies were potentially more pathogen-concentrated and therefore productive source materials for isolating entomopathogenic bacteria. Demonstrating a success rate of 60%, the baiting technique developed in this study proved an efficient means of recovering bacteria from the breeding environment. Besides other advantages, the approach could also allow for the use of different species of mosquitoes for baiting purposes in order to enhance the possibility of recovering a wider range of host-specific pathogenic material.

The identity of the isolates has not been confirmed, although taxonomic evidence suggests that they are probably samples of *Bacillus thuringiensis*. Further studies are being carried out following this preliminary work. These studies, which include characterisation and comparative toxicity testing, will highlight the taxonomic identity as well as potential characteristics of the isolates which have demonstrated broad-spectrum larvicidal activity against *Anopheles*, *Culex* and *Aedes* mosquitoes.

4.5.2 *Larvivorous fish*

Several specimens of fish were collected from various bodies of water within Mwea Rice Irrigation Settlement. The collection covered a wide range of habitats which included rice paddies, irrigation canals, ponds and drains. The fish consisted of *Tilapia*, *Oreochromis*, *Clarias*, *Barbus*, and *Gambusia* species. The feeding habits of two of the species (*Oreochromis niloticus* and *Tilapia zilli*) in relation to quantitative feeding of mosquito larvae and the effect of temperature and pH was evaluated in the laboratory using the larvae of *Aedes aegypti*.

The two species of fish consumed large quantities of mosquito larvae; an average of 300 larvae were eaten by one fish in 15 min under optimum conditions of pH and temperature. Analysis of data on their affinity for larval diet showed a significant difference between the feeding performance of the two species ($P < 0.001$); *Tilapia* appeared to eat more larvae than *O. niloticus*. In general, their feeding capacity was markedly influenced by temperature ($P = 0.001$). As indicated in Table 4.5, more larvae were eaten at 25°C than at any other temperature but their feeding capacity did not differ at 20 and 30°C; the least number of larvae were eaten at 35°C.

In relation to pH, the capacity of the species did not differ ($P > 0.2055$); both *T. zilli* and *O. niloticus* had similar level of feeding capacity. However, the number of larvae consumed in general, varied with different values of pH ($P > 0.001$). They fed better at pH 7.0 but their feeding enthusiasm declined with increasing alkalinity (Table 4.5).

It is demonstrated in this study that Mwea Rice Irrigation System harbours a wide variety of fish some of which could offer great potential in making significant contribution to mosquito control programme. Maximum efficiency in larval predation could be encouraged by controlling weeds which prevent the fish from observing and seizing their prey. Another problem which adversely affects the predator population is the use of pesticide for controlling rice pests. There is enough evidence to show that the application of chemical insecticides against the pests kills the invertebrate predators and adversely affects the fish as well. As far as possible, the use of chemical insecticides should be discouraged. A combination of larvivorous fish, herbivorous fish and microbial insecticide against rice pests would provide an ecologically compatible environment inhibiting mosquito breeding as well as controlling weed and rice pests.

4.6 MOSQUITO VECTOR: IDENTIFICATION, ECOLOGY AND BEHAVIOURAL STUDIES

A. P. Mnzava, C. M. Mutero and P. M. Nyamori

Mosquitoes have been collected regularly since June 1991 from both indoors and outdoors in pits in two villages, Kapkuikui and Loboi in Marigat, Baringo District.

Cytotaxonomic identification of the *Anopheles arabiensis* complex have been carried out successfully. Four chromosomal inversion polymorphisms have been recorded in this species. The frequencies of the inversions will be compared for outdoor and indoor samples. Blood-fed mosquito samples from both indoor and outdoor are being processed to determine source of their blood meals. The results from this study are fundamental in understanding the epidemiology and control of malaria transmission.

4.7 EVALUATION OF SURVIVAL POTENTIAL AMONG DIFFERENT SIZE CLASSES OF BOTH LABORATORY-REARED AND FIELD-COLLECTED *ANOPHELES ARABIENSIS*

A. P. Mnzava, P. M. Nyamori and J. Ndambuki

The wing length of mosquitoes has been shown to be a good indicator of body size. Variation in body size is a regular feature of natural mosquito populations and may reflect their vectorial capacity. Experiments have been initiated to compare the survivorship of different size classes of female *An. arabiensis* reared under controlled conditions and relate those results to field observation on body size, survivors by parity and chromosomal inversion frequencies.

Preliminary results from the laboratory experiments show distinct differences. It will also be interesting if it can be shown from the field studies whether or not mosquitoes carrying a particular chromosomal inversion have any advantage and whether the advantage is related to vectorial capacity.

4.8 EVALUATION OF THE EFFECTS OF PERMETHRIN-TREATED CLOTH SCREENS ON THE PREVALENCE AND MORBIDITY OF MALARIA

A. P. Mnzava, R. Kimokoti, M. J. Mutinga, C. M. Mutero, M. Basimike and P. M. Nyamori

The permethrin-treated screens in Marigat area have been shown to be effective in reducing mosquito numbers. In order to assess the benefit of such a reduction to the human population, finger-prick thick blood films were taken from a sample of school children in 1991. Their temperatures were taken by an electronic thermometer and any reports of fever during the previous 2 days noted. Blood-spots from these children were also smeared on white filter papers for the detection of *Plasmodium falciparum* antibodies against the repeat part of the circumsporozoite protein (NANP)40.

The study has involved a total of nine schools (4000 children) from six villages in Marigat area. Three of the six villages have been issued with the treated cloth since October 1989.

The prevalence of both parasites and fever, and the parasite densities (number of parasites/200 white blood cells) will be compared between the treated and the control villages. The results of this study are still being analysed and similar surveys will be carried out in March and June 1992.

4.9 EFFECTS OF PLANT DIETS ON SELECTED ASPECTS OF BIOLOGY AND *LEISHMANIA* PARASITE INFECTIVITY IN PHLEBOTOMINE SANDFLIES

M. E. Muhinda

Objectives of the study are: (1) to determine the most efficient methods for raising a colony of phlebotomine sandflies under laboratory conditions, especially by trying to obtain satisfactory conditions for an optimal life cycle duration, and to acquire more expertise in monitoring biological parameters such as, fecundity, survival and longevity; (2) to assess the effects of selected plant species on selected aspects of sandfly biology; and (3) to assess the effects of the selected plant species to certain aspects of *Leishmania* parasite infectivity.

The main parameters used for monitoring fecundity were: number of sandflies fed; number of sandflies laying and the oviposition rate (%); number of eggs and the average per female; number of larvae and hatching rate (%); number of first instar larvae; number of fourth instar larvae; survivorship between the two instars; number of pupae and pupation rate (%); number of adults and sex ratio; reproductivity rate (%); developmental time (days); preoviposition; embryonation; larval development; pupal development; preimaginal stage and complete life cycle.

Teneral unfed flies 1–4 days old were exposed to plants, sucrose and water over a period in an incubator at specific temperature and humidity. For each exposure, 1–3 replicates were used. After each hourly interval flies were removed from the feeding chamber and feeding cage and kept 10–15 min in a deep freezer before the dissection. The unit/interval/replicate is 24 flies. Dissection of flies was carried out and specimens were placed in microliter plate containing anthrone solution and feeding performance assessed.

The results showed that the feeding peaks (rate and intensity) were variable during the exposure period in each sandfly species for either sucrose or plants. The feeding rates in female and male sandflies were quite the same in both species for the different diets. In the tested combinations, there was no significant interaction effect apart from one of the species which appeared to attain its feeding peaks in the second half of the 24-hour exposure period.

LOCUST RESEARCH PROGRAMME

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5 Locust Research Programme

The primary objective of the Locust Research Programme is to develop alternative biorational and sustainable locust management strategies. To attain this goal, research has been focused on two areas, namely, semiochemicals and biological control.

The objective of the semiochemicals approach is to develop technologies through which it would be possible to disrupt the processes vital for swarm formation. An array of semiochemicals appear to mediate these processes which influence gregarisation/solitarisation dynamics, sex attraction, synchronised maturation and oviposition, as well as host plant selection. During this year, good progress has been made in the various fronts of the research on semiochemicals.

The mediation of four semiochemicals systems have been demonstrated or confirmed in the desert locust. These include female-produced sex attractant(s) in the "solitary", a male-produced signal that synchronises and accelerates maturation in "gregarious" males and females, a signal that stimulates egg-laying within a confined area in "gregarious" females, and host plant derived attractants. Biochemical techniques to determine phase status are being developed. Field surveys of the locust recession and breeding areas along the Red Sea coast of Sudan were carried out and observations on gregarisation under field conditions were made. Interactions between hoppers of the desert and those of the African migratory locusts and between the complex of the two species and their host plants were also recorded.

The primary objective of the biological control approach is to develop virulent pathogenic organisms which could regulate field populations during recession times and prevent development of swarms. These pathogens should be adaptable to desert and semi-desert environments and should perpetuate in locust populations transovarially. Results so far indicate that Malamoeba locustae *has a promising potential. A strain of this protozoan has been isolated from field populations of solitary desert locusts and is being compared to another one isolated from a laboratory colony. An entomopox virus isolated from the nymphs of desert locust, is also being investigated.*

5.1 FACTORS INDUCING PHASE CHANGES IN THE DESERT LOCUST, *SCHISTOCERCA GREGARIA* AT RECESSION AND BREEDING HABITAT

S. El Bashir and H. E. Abdel Rahman

A survey of a confined desert locust winter breeding habitat along the western coast of the Red Sea, which was conducted during the second half of December 1991, suggested the possible role of *Locusta migratoria migratoriodes* and wild host plants in inducing phase changes in this insect. The surveyed area is within the flood plain of Khor Ashad, approximately 60 km to the south of Suakin town, with a total cultivated area of about 60 ha, mostly of millet. Three species of weed plants appeared to be dominant and attractive to locust; these were *Zygophillum simplex*, *Diptergium glaucum* and *Heliotropium* sp.

Both desert and African migratory locusts were encountered in the area but more so within and around the main water course where vegetation was greener and soil moisture was adequate for oviposition. The composition of the adult population was approximately one desert

locust to every ten African migratory locusts, and that of the hoppers was about 2:200.

All adults of the desert locusts were typically solitarious as indicated by their colour while only 1–2% of the African migratory locust adults showed the typical greenish colour of the solitary form of this species.

On the other hand, at the start of the survey, all *S. gregaria* hoppers were in the fourth and fifth instar stages and they were all green in colour; while those of *L. migratoria* were mostly of first and second instar stages and were mainly dark brown and black in colour. Hence *S. gregaria* hoppers were either solitary or *transient segregating* while *L. migratoria* hoppers were either gregarious or *transient congregating*. About 7–10 days later, second and third instar hoppers of *S. gregaria* with green background body colour and distinct black markings were found among the increasing population of *L. migratoria* hoppers. At this time hoppers of the African migratory locusts started to form bands and march in cohesive groupings. Those of the desert locust were found scattered, either on the periphery of the dense mass of the marching *L. migratoria* hoppers or keeping to leaves of millet and other host plants without forming any groupings.

It appears, therefore, that the dense population of the African migratory locust hoppers induced morphological changes typical of the gregarious phase in hoppers of the desert locust.

Another interesting observation is that hoppers of both species, especially the early stages (first, second and third instars) were found to be very much attracted to a common weed plant, *Zygophillum simplex*. Up to 30 hoppers of the desert locust were recovered from one plant, some of these, which were in the first and second instar stages, were greenish in colour, but all the third instar hoppers were showing distinct black markings. This plant appears to attract hoppers, concentrate their number and provide a suitable environment for transformation from the "solitary" to the "gregarious" form. *D. glaucum* was the second most attractive wild host plant, followed by *Heliotropium* spp., while millet, which is a cultivated host plant, was the least attractive to young hoppers.

Unlike other food plants, *Z. simplex* provides good shelter against natural enemies, because of its dense canopy which spreads on soil surface, and also provides adequate humidity which is critical during the early stages of hopper development.

5.2 COLOUR PERCEPTION OF THE DESERT LOCUST, *SCHISTOCERCA GREGARIA*

C. Inayatullah, D. O. Ojwang, A. Hassanali and S. El Bashir

The short-term objective of these studies is to develop suitable field luring devices for the desert locust in order to facilitate behavioural studies in the field.

Tests conducted with hoppers of crowded and solitary-reared locusts indicated that orientation of hoppers in a circular plane was fairly random; no clumping of hoppers was observed towards any specific direction indicating lack of directional responses.

Single choice tests were conducted to evaluate colour perception in the fourth instar hoppers of crowdedly-reared locusts, by using coloured paper strips of different hues and intensities, namely, black, grey, blue series (cobalt blue, turquoise blue, prussian blue), yellow series (cadmium yellow, cadmium green, foliage green, green bice), orange and carmine. The reflectance spectra of these coloured papers and the spectral irradiance of the light source used in the tests were measured by Li-Cor Spectroradiometer (Figures 5.1 and 5.2). The results indicated that the maximum response was towards cobalt blue. The response to orange, cadmium yellow pale and cadmium yellow ranged from 38 to 48% whereas, the response towards the other colours ranged from 74 to 88%. When the same coloured paper strips were tested against a brown background, the response of hoppers declined considerably. The maximum response was towards cobalt blue and carmine. Response towards the other colours ranged from 22 to 48%. These tests indicate that hoppers can differentiate colour contrasts.

5.3 SEX ATTRACTION IN THE DESERT LOCUST, *SCHISTOCERCA GREGARIA*

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

The mating behaviour of solitary locusts was studied. It was observed that prior to mating both males and females vibrated their bodies and in some cases both sexes rubbed the tips of their forewings for a few seconds. Thereafter, a male would suddenly jump over the female and grasp its body with the fore and middle legs. In response to this behaviour, a female would kick off the male by vigorous movements of its hind legs, but eventually it would submit (usually after 2–3 minutes) and mating would start. At the same time quick movements of the labial and maxillary palpi of the male were also observed. Thus active movements, vibration of the body and rubbing of the tips of the forewings and palpi are the signs of the mating behaviour in males. These response parameters were used in wind tunnel experiments.

In the wind tunnel, a female was held in a screen cage which was covered with black muslin cloth to hide it from a male that was released at the down-wind side and observed for 30 minutes. In the control treatment no female was provided. In nine out of eleven cases the males jumped near the female cage in 8 minutes or less. The males were observed to actively make peering movements, an evidence that males were perceiving signals from the female which they cannot see. These could be chemical or acoustic communication signals. In the control most of the males (11 out of 15 cases) remained near the release point without any peering or searching activities. These preliminary studies indicate the presence of sex related communication signals in solitary reared locusts.

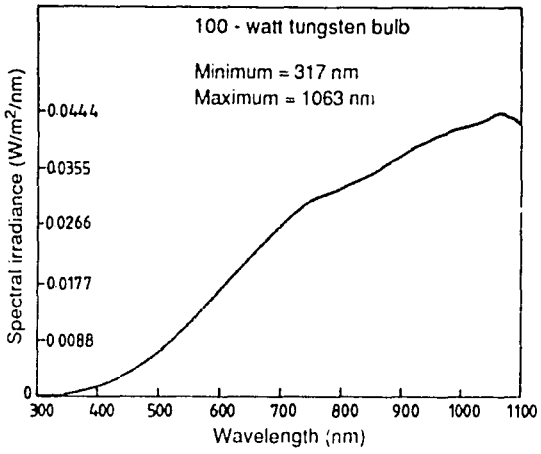


Figure 5.1 Spectral irradiance of 100-watt tungsten bulb.

immature adult locusts as monitored by the development of the yellow colour. We have continued to examine this process in detail with the objectives of establishing the nature of the pheromone system(s) involved and identifying more convenient criteria for monitoring the process. The following activities were undertaken or initiated:

(a) determination of the minimum exposure time required to induce accelerated maturation (yellowing) of immature to mature males;

(b) evaluation of solvent extracts of immature males for maturation (yellowing) acceleration effects, to confirm the mediation of a pheromone;

(c) development of a two-chamber bioassay to determine if the pheromone operates by contact or by olfaction;

(d) comparisons of gas chromatographic patterns of volatile emissions (trapped in suitable adsorbents such as glass wool and reverse phase silica), of mature and immature locusts with the objective of identifying components specific for mature locusts;

(e) isolation and purification of maturation specific proteins for possible use in the development of immunoassays for monitoring the maturation process; and

(f) examination of the morphological features of the accessory glands of the males to identify and characterise features specific for maturation.

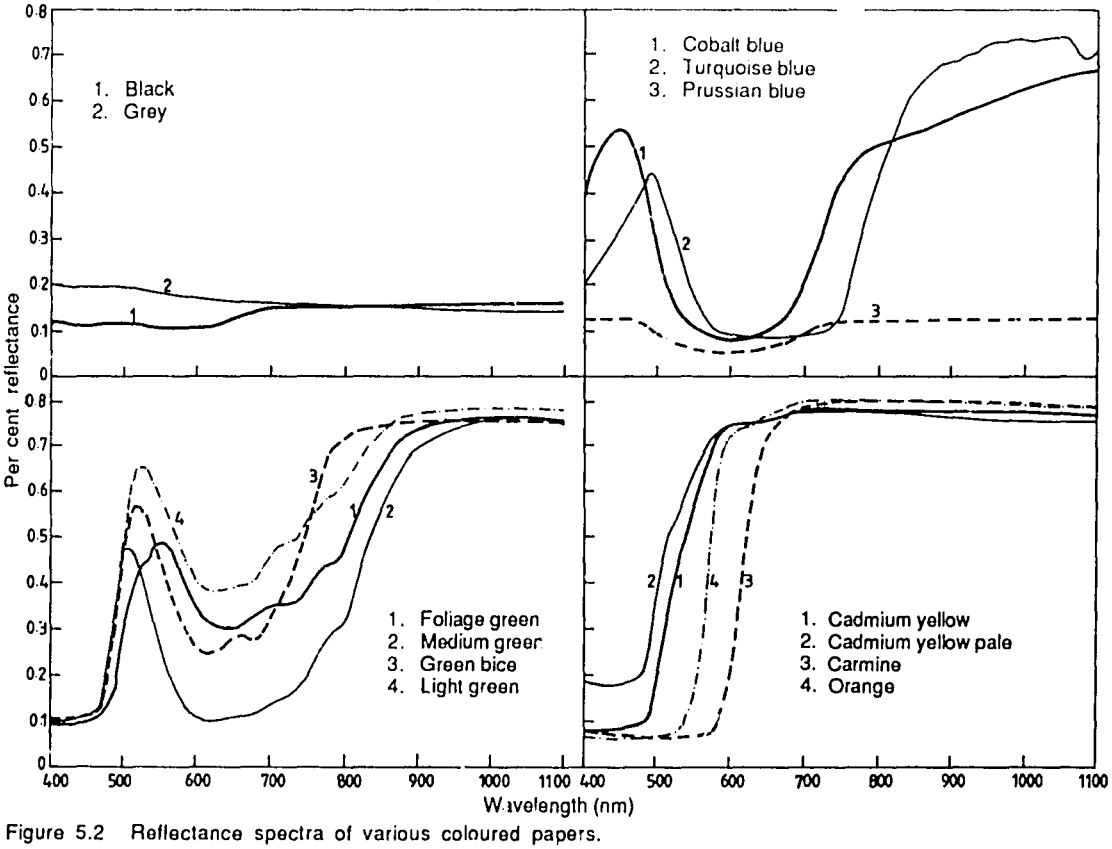


Figure 5.2 Reflectance spectra of various coloured papers.

5.4 STUDIES ON THE MATURATION OF *SCHISTOCERCA GREGARIA*

H. Ma'amat, A. Hassanali, E. O. Osir, M. F. B. Chaudhury, H. Odongo, J. R. Wawiye and S. El Bashir

Last year we summarised evidence which confirmed earlier observations that the presence of mature males had accelerating effect on the maturation of gregarious

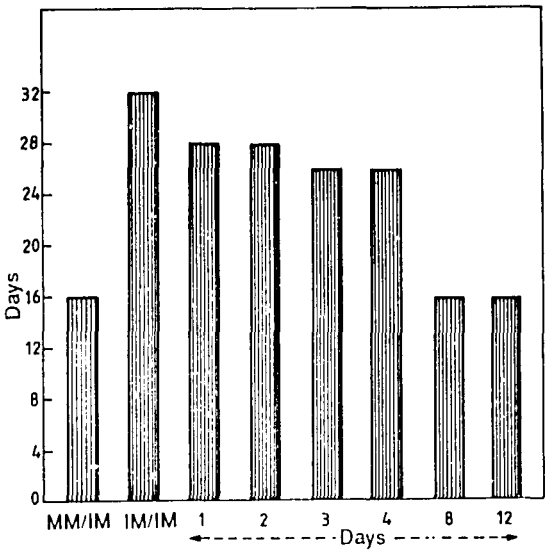
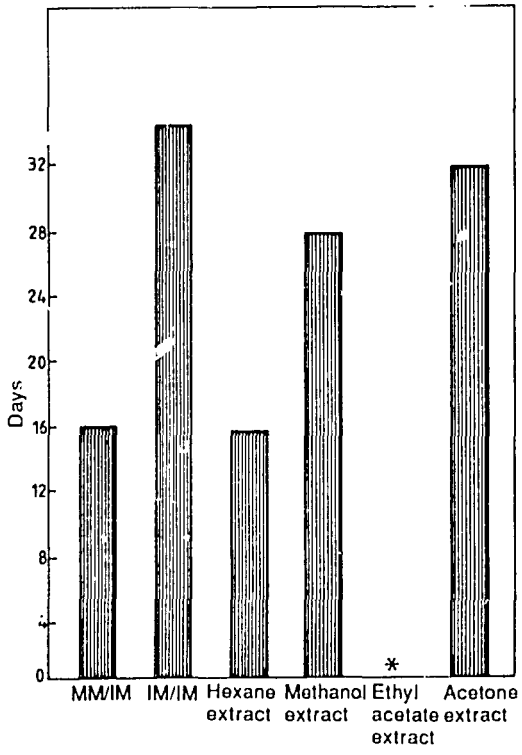


Figure 5.3 Effect of exposure time on immature locust, *Schistocerca gregaria* to mature males. IM/IM, immature male exposed to immature male; MM/IM, immature male exposed to mature male. The mature male was removed after the indicated days of exposure.



* Locusts exposed to this extract died of unknown reasons

Figure 5.4 Effect of mature male abdominal extracts on maturation of immature male locusts. MM/IM, immature male exposed to mature male; IM/IM, immature male exposed to immature male.

Figure 5.3 summarises the periods required for different groups of immature males exposed for different periods to mature males. Thus an exposure period of 8–12 days appears to be sufficient to induce accelerated maturation.

Maturation-accelerating effects of hexane, ethyl acetate, acetone and methanol extracts dispensed on filter papers were compared. Figure 5.4 shows that the hexane extract has an effect comparable to that of mature males.

A set of two chamber devices was constructed from glass bottles and metal covers to see if volatile emissions from one chamber containing mature males carried by air flow to the adjoining one containing immature locusts would accelerate the maturation of the latter. Unfortunately, the high mortality of the immature insects in the set-up has not allowed us to obtain conclusive results todate. The system is now being redesigned to allow natural ventilation and natural diffusion of the volatiles from one chamber to the other.

Gas chromatographic comparisons of isolates from mature and immature locusts have shown some components that appear to be specific to mature males. Identification of these, which we are treating as candidate maturation pheromone components, is in progress.

Bioassay based on the development of yellow colour has two distinct faults: it is somewhat subjective and it is slow, taking a minimum of 2 weeks. We have been examining haemolymph components by PAGE and HPLC and comparing these with body colour changes measured by reflectance spectrophotometer and with morphological changes in the male accessory glands. A number of candidate molecular markers have been selected and are now being examined in more detail to see if their appearance could provide a means of detecting, relatively early, the onset of pheromone-mediated, accelerated maturation.

5.5 MOLECULAR MARKERS FOR AUGMENTING MORPHOMETRIC CHARACTERISATION OF THE PHASE STATUS OF DESERT LOCUST

H. Mahamat, A. Hassanali, E. O. Osir, D. Ogoyi, H. Odongo and S. El Bashir

The objectives of this study are: (a) to carry out detailed comparisons of cuticular components of gregarious and solitary locusts in order to identify quantitative features which are phase specific; (b) to similarly identify and purify phase specific haemolymph proteins; and (c) to integrate these chromatographic markers with morphometrics and to develop a comprehensive set of criteria to characterise precisely the phase status of locust individuals.

Last year, we reported apparent differences in the more volatile cuticular components of laboratory-reared solitarised and crowded locusts originating from DLCO-EA, Addis Ababa. However, examination of a large number of individuals including those from a collection originating from the Red Sea area in Sudan, showed too large a variation in the composition of this region of the chromatogrammes. During this year we focused on the

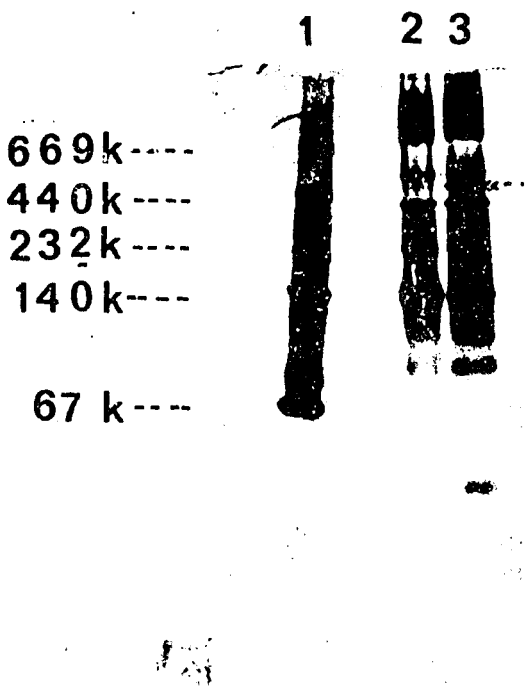


Figure 5.5 Electrophoresis of *Schistocerca gregaria* haemolymph-protein samples by gradient non-denaturating PAGE (4–20%). 1, high molecular weight standards; 2, gregarious male; 3, solitary male.

less volatile region of the chromatogrammes. Solitarised locusts from the two sources appear to show only minor quantitative differences. However, crowded locusts from the two sources demonstrate a richer set of peaks in this region. Currently we are comparing the effect, if any, of different diets, on different developmental stages of locust to see if consistent differences exist between the two phases.

Haemolymph samples of most solitarised locusts used during this study were found to be green in colour, whereas those of the crowded ones were yellow. Density gradient centrifugation of the haemolymph of the locusts from the two phases gave two fractions (A and B) each. The subphase (fraction B) of haemolymph of the crowded locusts showed a yellow coloration and that of the solitarised locusts showed a blue coloration. SDS and non-denaturating PAGE of the two subphases showed specific differences (Figure 5.5). Some of the bands were isolated and antisera to them are being raised for the development of immunoassay procedures for their quantification.

5.6 OVIPOSITION-AGGREGATING PHEROMONE OF THE DESERT LOCUST, *SCHISTOCERCA GREGARIA*

R. K. Saini, M. Rai, A. Hassanali, H. Odongo, J. A. Andoke and P. Ahuya

Behavioural studies undertaken so far confirm the presence of an oviposition pheromone which stimulates aggregation of pregnant females. Initial experiments in standard rearing cages, in which gravid females were given a choice between egg laying cups containing sterilised sand and sand in which eggs had been laid previously, indicated a preference (10% more) for the latter. However, these standard rearing cages were found to be inappropriate for egg laying and hence new oviposition chambers containing centrally placed larger egg-laying cups, with better ventilation and uniform heating were designed. Experiments undertaken in these new chambers indicated that gravid females lay 2–3 times more eggs in sand in which eggs had been previously laid as compared to control (cups containing sterilised sand), clearly indicating the presence of a chemical factor resulting in aggregation of gravid females. Behavioural and electrophysiological experiments to determine the origin of the pheromone and its chemical nature are in progress.

5.7 HOST PLANT KAIROMONES OF THE DESERT LOCUST, *SCHISTOCERCA GREGARIA*

P. G. N. Njagi

Y-olfactometer tests were carried out with air-borne volatiles of *Sorghum bicolor* and wheat (*Triticum* sp.) seedlings and Kikuyu grass (*Pennisetum clandestinum*) shoots to investigate their potency in eliciting orientation of early fifth instar nymphs of crowded and solitary-reared *S. gregaria* to the source.

Results show that, when tested individually or in a choice situation; volatiles from artificially damaged host plants attracted a higher proportion of the crowded nymphs of the desert locust to the source than either the control (air) or volatiles from intact plants (Tables 5.1 and 5.2). Another interesting aspect of the results is that, air-borne volatiles of the host plant that had been used for rearing the nymphs were more attractive than those of the other host plants. Nymphs reared on *S. bicolor* seedlings responded more to volatiles from sorghum seedlings whose leaves had been artificially damaged than to those from damaged wheat seedlings and Kikuyu grass shoots (Table 5.1). Similarly, crowded nymphs reared on Kikuyu grass were more responsive to volatiles from artificially damaged Kikuyu grass shoots than to the control and volatiles from intact and artificially damaged sorghum seedlings (Table 5.2). However, for both these grasses, presence of volatiles from a second plant in choice tests depressed the attractiveness of the volatiles from the rearing host plant (Tables 5.1 and 5.2).

These results indicate the possibility of a learning process in the host finding behaviour of *S. gregaria* with regard to host plants encountered over a certain period in a given locality during their life cycle. However, the polyphagous nature of the desert locust suggests some flexibility in the CNS that enables utilisation of airborne volatiles from a broad range of host plants.

A limited number of similar tests were also carried out with individual solitary nymphs of *S. gregaria* and their total response pooled. Up to 75% of the nymphs reared on sorghum responded to volatiles from artificially damaged sorghum seedlings whereas only about 25%

Table 5.1 Per cent of gregarious early fifth instar nymphs of *S. gregaria* reared on sorghum seedlings responding to airborne volatiles from intact (WS) and artificially damaged (BS) sorghum seedlings; intact (KG) and damaged (DKG) Kikuyu grass shoots; and intact (WH) and damaged (DWH) wheat seedlings

	Per cent responders (Mean ± S.D.)					
AIR	WS	BS	KG	DKG	WH	DWH
18.0 ± 14.75(5)[1]	22.0 ± 16.19(5)					
16.0 ± 15.78(5)		55.0 ± 26.77(5)				
	15.0 ± 14.34(5)	42.0 ± 17.5(5)				
12.5 ± 7.66(5)			37.5 ± 9.88(5)			
11 25 ± 10.27(5)				32.75 ± 14.91(5)		
	25.0 ± 11.86(6)		22.92 ± 10.95(6)			
		28.13 ± 11.46(6)		23.96 ± 8.31(6)		
15.63 ± 11.69(6)					34.52 ± 14.93(6)	
14.44 ± 14.88(6)						38.24 ± 14.52(6)
	19.64 ± 13.71(7)				18.75 ± 12.5(7)	
		14.29 ± 10.65(7)				25.21 ± 11.24(7)

[1]Numbers in parentheses indicate numbers of trials. For each test, test materials were interchanged in the specimen jars o the olfactometer arms.

Table 5.2 Per cent of gregarious early fifth instar nymphs of *S. gregaria* reared on Kikuyu grass responding to airborne volatiles from intact (WS) and artificially damaged (BS) sorghum seedlings; and intact (KG) and artificially damaged (DKG) Kikuyu grass shoots

	Per cent responders (Mean ± S.D.)			
AIR	WS	BS	KG	DKG
18.50 ± 15.06	33.0 ± 14.1(5)[1]			
7.50 ± 6.85		33.9 ± 10.9(5)		
12.75 ± 10.09			48.0 ± 25.96(5)	
12.25 ± 7.93				69.5 ± 11.75(5)
	32.81 ± 28.58(4)		42.41 ± 11.07(4)	
		20.31 ± 3.13 (4)		45.31 ± 12.89(4)

[1]Numbers in parentheses indicate numbers of trials. For each test, the test materials were interchanged in the specimen jars of the olfactometer.

or less responded to the control (air) and volatiles from intact sorghum seedlings.

Steam distillates of 2 and 4 week old sorghum seedlings were also tested in the Y-olfactometer at concentrations within the range 5–50 µg impregnated on filter paper discs. Crowded nymphs of the desert locust showed very low random responses or none.

More tests will be carried out with passively trapped volatiles and their components from the above host plants as well as from wild desert host plants of *S. gregaria*.

5.8 TRANSOVARIAL TRANSMISSION OF THE PROTOZOAN, *MALAMOEBA LOCUSTAE* IN THE DESERT LOCUST, *SCHISTOCERCA GREGARIA*

A. S. Mohmed, S. K. Raina and S. El Bashir

Batches of 150 third instar nymphs each, were orally administered various dosages (2×10^7, 2×10^8 and 2×20^9 per ml) of *M. locustae* cysts using sorghum leaves Different degrees of mortality were observed with time (Figure 5.6). About 10 to 20% survivors carried over the pathogen and mated. The females laid eggs which were less in number (35–50%) as compared to controls. Histological observations of the ovary and the embryo of infected groups revealed the presence of vegetative stages (primary and secondary trophozoites) and few cysts in both oocytes and germinal tissue of the embryo. This indicated that the pathogen was transmitted through the ovary into the embryo. This was further confirmed by observing the mortality in emerging F_1 nymphs where 70 to 80% of the nymphs were infected and 25 to 57% died during the different nymphal instars before reaching the adult stage. The highest rate of mortality occurred in third (57%) and fifth (37%) instars. However, about 80% of the F_1 adult survivors succumbed to transmitted infection before reaching maturity. In subsequent generations (F_1 – F_4), the mortality range remained at 60 to 70% in adults but decreased to 20 to 30% in

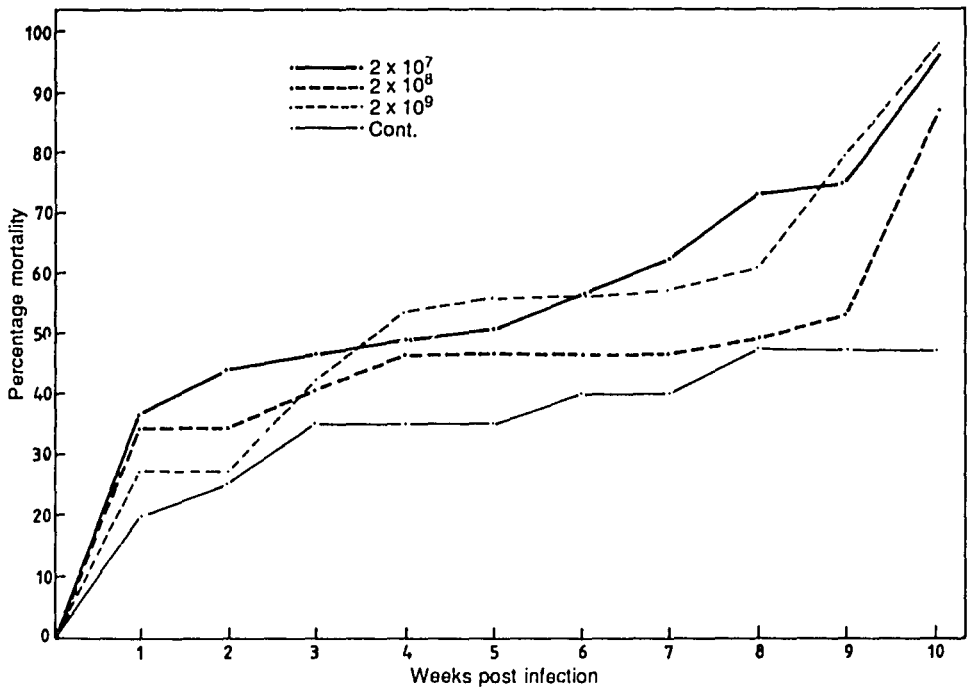


Figure 5.6 Dose-mortality-time relationships in *Schistocerca gregaria* nymphs treated with protozoan *Malamoeba locustae*.

nymphs. Figure 5.7 explains the process of transovarial transmission from F_1 to F_4 generations in the desert locust.

Further confirmation of the process is being done by crossing infected with non-infected individuals. Our findings with *M. locustae* suggest that a suitable protozoan strain might constitute an effective tool in regulating endemic populations of the desert locust.

5.9 IDENTIFICATION OF SOME HUMORAL FACTORS IN DESERT LOCUST INFECTED WITH *MALAMOEBA LOCUSTAE*

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

When the fourth instar nymphs of locusts were fed with the protozoan *Malamoeba locustae* at the concentration of 1 x 10^9 per ml, 75–90% mortality was obtained. The survivors, however, carried the infection and lived beyond the maturity age. SDS polyacrylamide gel electrophoresis technique was used to identify the haemolymph protein factors responsible for developing resistance in the surviving population. Figure 5.8 demonstrates the different protein banding patterns in the infected and control groups.

Further investigation was carried out using agglutination tests. Locust gut homogenate and the haemolymph were incubated with various parasites (*M. locustae, Leishmania major* and *Trypanosoma brucei*) at 37°C from 1 to 24 hours.

Positive reactions were observed with *L. major* (agglutination) and *T. brucei* (lysis) but not with *M. locustae* cysts (Figure 5.9). This indicates the presence of some agglutinin-like factor(s) in the gut and the haemolymph which might be playing a role in developing resistance against foreign bodies. However, the negative agglutination reaction with *M. locustae* could be due to a surface protein coat of this parasite. Isolation of the humoral factors using FPLC and SDS PAGE is in progress.

5.10 POTENTIAL OF DESERT LOCUST FOR PRODUCTION OF *MALAMOEBA LOCUSTAE*

S. K. Raina, M. A. Mbeke and S. El Bashir

The chronic and debilitating nature of the disease caused by the protozoa, *M. locustae* in the desert locust, *Schistocerca gregaria* was reported last year. The pathogenicity, loss of fecundity by this pathogen in the locust and its transmission through ovaries into the next generations have also been reported. *M. locustae* requires to be cultured in the living cells of its host. Hence the present study has been undertaken to evaluate the potential of the adults of desert locust for mass production of *M. locustae*. It has been observed that adults of both sexes succumbed to the infection of *M. locustae* just before maturation, which is about 10–12 days after the last moult.

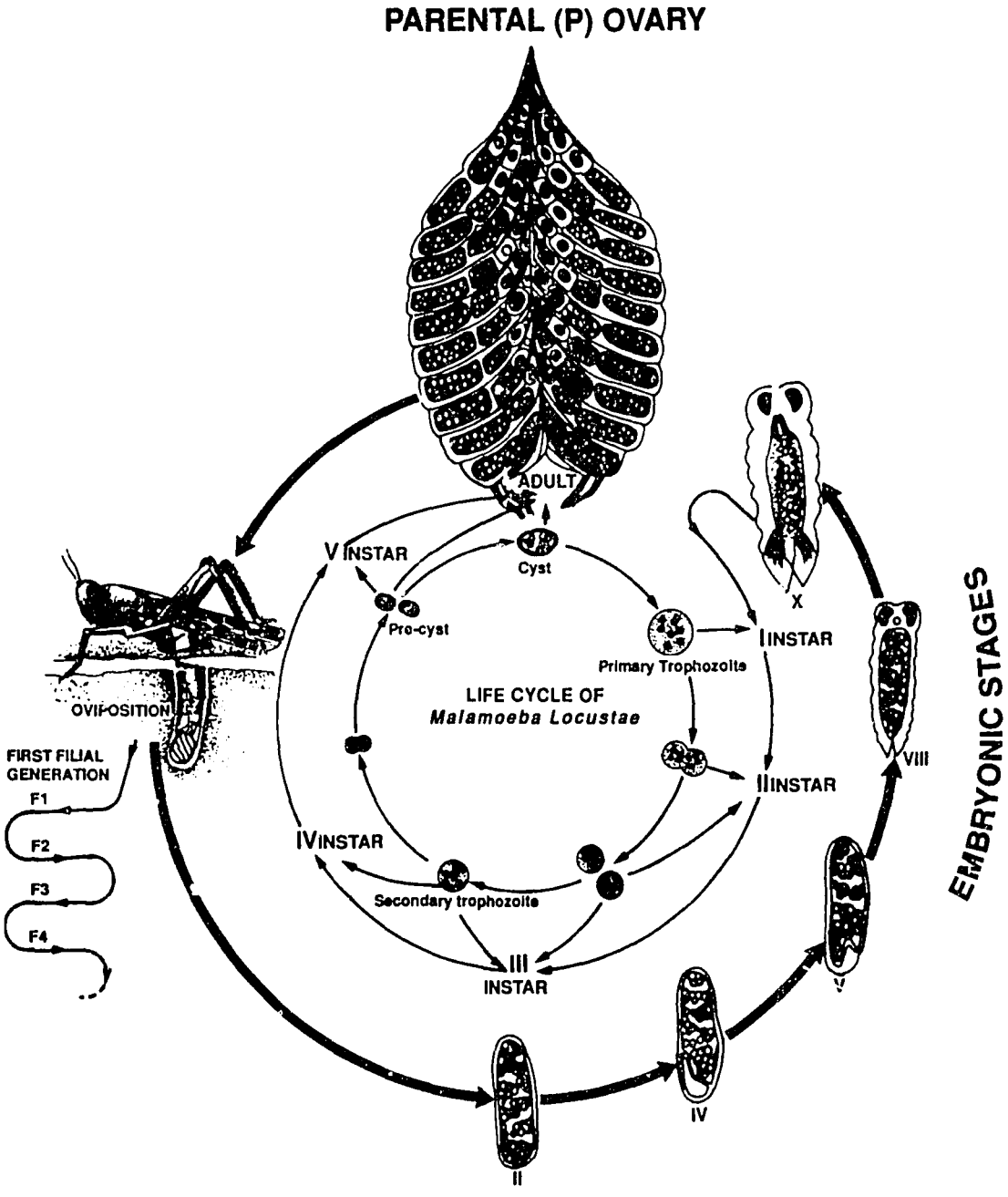


Figure 5.7 Mechanism of transovarial transmission of *Malamoeba locustae* in generations of the locust *Schistocerca gregaria*.

A group of adult locusts of both sexes, which died as a result of infection with *M. locustae*, was collected. Each locust was crushed separately and homogenised in a mortar and filtered through a cheese-cloth. The homogenate was centrifuged at 10,000rpm for 1 hour. Two layers were obtained, the lower containing *M. locustae* cysts and the upper bacteria. Cotton wool swab was used to clear the bacterial layer. The layer containing *M. locustae* was diluted with 5 ml of distilled water and the number of protozoa was counted by means of a haemocytometer.

The pattern of cyst production indicates that a male can produce an average of 2.61×10^9 cysts and a female 1.50×10^{10} cysts. Although the females produced more

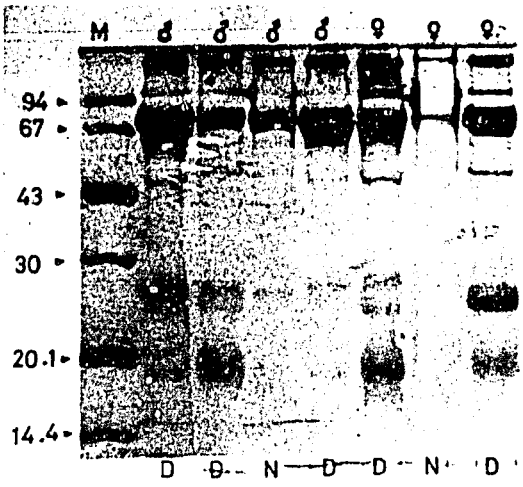


Figure 5.8 SDS-polyacrylamide gel electrophoresis of haemolymph proteins from *Malamoeba locustae* infected and control male and female *Schistocerca gregaria*: D, infected; N, normal.

cysts per insect than the males it would be economical to produce *M. locustae* from males because the females are used for egg production which is necessary for maintenance of the locust colony. A mass production prototype will be developed after an appropriate strain is selected.

5.11 INCIDENCE OF *MALAMOEBA LOCUSTAE* IN THE FIELD POPULATION OF DESERT LOCUST IN THE RED SEA COAST OF SUDAN

S. K. Raina, S. El Bashir and C. Inayatullah

A field survey was conducted in December 1990 and January 1992 for monitoring the incidence of the protozoa *M. locustae* in populations of the desert locust at the Red Sea coastal area of Sudan.

In December 1990 the population of the desert locust was very low (1–2 individuals per hectare) and the percentage of the diseased individuals was also very low (1.6%). This may be due to the low density of the desert locust population. However, in early January 1992, due to favourable conditions at the Red Sea coast, the population density was high (600–700 locusts per h). The locust population appeared in pre-gregarious forms with some third instar hoppers showing black markings. This high density appeared to have raised the incidence of biotic factors among the population of the desert locust since about 13.02% individuals were found infected with *M. locustae*. These locusts were recognised in the field by a characteristic irregular blackening of the sternum and its joints.

Figure 5.9a Agglutination reaction of locust gut homogenate with *Leishmania major*, control.

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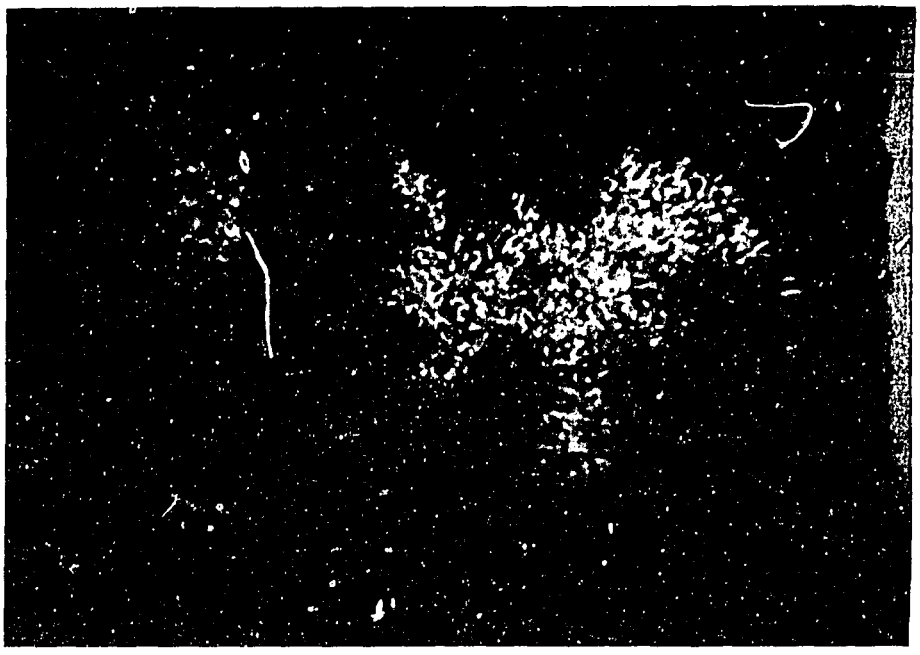

Figure 5.9b Agglutination reaction of locust gut homogenate with *Leishmania major*, agglutination reaction.

Several batches of desert locusts were examined for *M. locustae* infection in both sexes. The percentage of diseased female individuals was significantly higher (8.33%) than that of the males (4.69%) which indicates that the females, as carriers, might be regulating the transmission of this endemic disease more than the males in the field.

This field strain of *M. locustae* is being improved in the laboratory by selection procedures so as to make it more virulent and yet persistent under field conditions.

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CHEMISTRY AND BIOCHEMISTRY RESEARCH UNIT

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6 Chemistry and Biochemistry Research Unit

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

- *Ecological chemistry and biochemistry of the ICIPE's target disease vectors and plant pests currently focused on tsetse flies (in collaboration with TRP and SPRU), and the crop borers* Chilo partellus, Maruca testulalis, Busseola fusca *and* Cosmopolites sordidus *(with SPRU and CPRP).*
- *Protein and nucleic acid biochemistry focused on (a) the endotoxins of different strains of* Bacillus thuringiensis, *their mode of action and characterisation of the genes that code for the toxins; and (b), on the factors involved in trypanosome transformation in tsetse gut (with LRP).*
- *Exploratory studies on selected anti-arthropod natural products (particularly tick repellents and stored products protectants).*

In addition, the Unit is playing a major role in the Locust Research Programme's project on the chemical ecology of the desert locust, and in the elucidation of the semiochemical bases of the phase dynamics of the insect.

6.1 SYNOPSIS OF MAIN ACTIVITIES AND ACCOMPLISHMENTS

A. Hassanali

6.1.1 Crop pests related studies

Work on the semiochemicals of *C. partellus* is focused on feeding and oviposition allelochemics and on the sex pheromone system. Studies on the allelochemical basis of feeding preference of three maize cultivars (resistant, tolerant and susceptible) by larval *C. partellus* has shown that non-preference is associated with the amount of anti-feedants present in the cultivars relative to feeding stimulants. Identification of these allomones is in progress. These allomones may also account for antibiosis effect observed when larvae are fed on the resistant cultivar.

Sex pheromone studies are now based on the assumption that the failure of synthetic blends to give trap catches comparable to those obtained from traps baited with virgin females may be due to the presence of inhibitory compounds in synthetic samples and/or inappropriate rates of release from dispensers. A candidate inhibitor, (Z)-11-hexadecenoic acid, now has been confirmed in screen house experiments to depress male catches. Quantification of release rates from virgin females and from dispensers has started. Future field evaluation of pheromone blends will ensure that the blends are scrupulously free of the acid and released at appropriate rates.

Last year we initiated an analysis of cowpea flowers with the understanding that rearing of *M. testulalis* had been hampered by the dependence on a diet made up of a large proportion of cowpea flowers. As part of this initiative, the effect of missing cowpea flowers in the artificial diet was studied at IABU (MPFS) and shown to have no significant effect on the performance of the insect. Accordingly, the project has been suspended pending further observations on the insects that feed on flower-free diet. The related project on the identification of allelochemics in older host plants that contribute to the induction of diapause in *B. fusca* has been adversely affected by the low availability of the insects for experimental work. However, recent improvement in the insect colony is expected to increase the pace of this project.

Studies on banana weevil semiochemicals focused on volatile host kairomones and aggregation pheromone. In addition, an ARPPIS student is examining the feeding allelochemics for the weevil. A comparison of attraction of the weevil to volatiles of a susceptible and resistant cultivar ("Githumo" and "Wangae", respectively) showed no significant difference, suggesting that preference of a cultivar may be controlled at the oviposition or feeding stage. Identification of the attractant components is in progress. The mediation of a male-produced aggregation

pheromone has been confirmed and its identification is also in progress.

6.1.2 *Tsetse related research*

Work on tsetse continued on two main fronts: survival and differentiation of trypanosomes in the fly's midgut and short-range kairomones from host body. In addition, the Unit was involved in the setting up of a cDNA library from milk gland and the fat body, and in preliminary examination of larviposition pheromone and of potential allomonal compounds.

Last year it was shown that the transformation of trypanosomes in tsetse midgut was associated with trypsin activity. Interestingly, it has now been found that intact parasites and, particularly, crude membrane proteins derived from them, inhibit trypsin activity in a competitive manner. This may represent an important way in which trypanosomes survive the hostile midgut environment.

The identification of the gene coding for the major protein of milk gland secretions (*ICIPE 1990 Annual Report*) is at an advanced stage and will be reported next year.

The complexity of body washings of host animals and the fact that different components act synergistically or additively has made the pace of identification of the active kairomonal compounds very slow. However, the project has made some notable progress and breakthroughs are expected in the coming year.

The two new initiatives on tsetse oviposition pheromones and potential allomonal compounds got off to a good start. The source of the pheromones has been traced to the larval exudates produced prior to pupation and identification of the active components has started. As part of an attempt to understand tsetse's indifference to certain animals, the urine of water buck was examined and found to have large amounts of (the parent) phenol relative to two most active kairomonal compounds, 4-cresol and 3-*n*-propylphenol. The possibility that phenol may modify the attractancy of the phenolic blend is now being explored.

6.1.3 *Tick related research*

The Unit has continued to contribute intellectually to the anti-tick vaccine project in LTRP. In addition, exploratory studies on the chemical basis of some anti-tick plants and on potential semiochemicals that may mediate certain behavioural traits of *R. appendiculatus* have been undertaken. Essential oils of some plants have shown potent repellent properties and their potential in protecting cattle against tick infestation is being investigated. Assay of cattle ear washings and volatile collections from ticks, off-the-host and on-host, have implicated the mediation of a number of semiochemicals. The results of this continuing exploratory work will be reported next year.

6.1.4 *Locust related research*

The Unit has been involved intimately on all aspects of the semiochemical research of *S. gregaria* as reported in LRP report. Noteworthy accomplishments include the identification of molecular markers for characterising the phase and maturation status of the insect, the demonstration of the mediation of a sex pheromone in solitaria, the demonstration of the existence of two sets (polar and non-polar) of oviposition pheromones and the development of a gregarisation behavioural bioassay. Identification of the various semiochemicals is underway.

6.2 INVOLVEMENT OF TSETSE MIDGUT TRYPSIN IN DIFFERENTIATION OF TRYPANOSOMES

M. O. Imbuga, E. O. Osir and V. Labongo

Differentiation of bloodstream *Trypanosoma brucei brucei* into procyclic forms is crucial for the establishment of

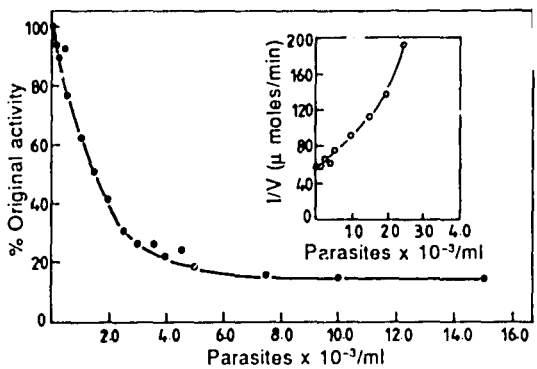


Figure 6.1 Inhibition of midgut trypsin activity by isolated trypanosomes. Trypsin activity in crude homogenates of *G.m. morsitans* was assayed under standard conditions in the presence of increasing concentrations of isolated trypanosomes. Data (•) are the average of three determinations. Inset: Dixon plot of the reciprocal of initial velocity (v) versus parasite concentration of the data above (o).

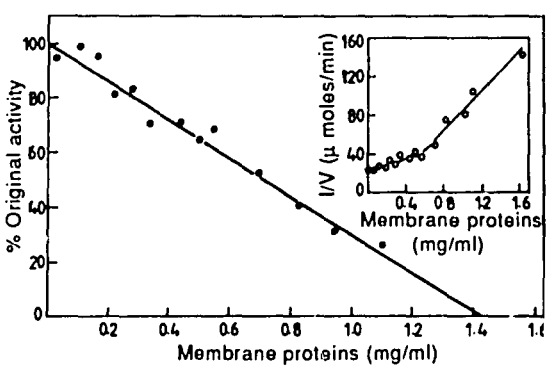


Figure 6.2 Inhibition of trypsin activity by trypanosome membrane proteins. Trypsin activity in crude midgut homogenates was assayed under standard conditions in the presence of increasing concentrations of crude trypanosome membrane proteins. Data (•) are the averages of three determinations. Inset: Dixon plot of the reciprocal of initial velocity (v) versus increasing concentrations of membrane proteins (o).

infection in tsetse fly vector as reported previously (*ICIPE 1990 Annual Report*). A correlation was established between the transformation activity of the midgut homogenates and trypsin activity. Factors such as the presence of whole blood and protease inhibitors, and temperature affected trypsin activity and also inhibited the transformation process. Optimal concentrations of trypsin were crucial since high concentrations resulted in the lysis of the parasites.

The ability of intact parasites, or crude preparations of the trypanosome membrane proteins, to inhibit tsetse midgut trypsin was assessed. It was established that increasing concentrations of either intact parasites (Figure 6.1), or crude membrane proteins (Figure 6.2), caused a progressive reduction of enzyme activity. The dose-activity profiles obtained suggest that membrane proteins bind tightly and stoichiometrically to the enzyme unlike intact parasites that appear to have a loose: association with the enzyme. Further experiments suggest that, the inhibition is partially competitive. These results indicate that one of the ways by which trypanosomes may overcome the hostile tsetse midgut barrier is by inhibition of trypsin activity.

6.3 TSETSE KAIROMONES STUDIES

W. P. Ouma, E. Nyandat, A. Hassanali, R. K. Saini and L. Madubunyi

During the year, research focused on HPLC fractionation of active fractions of host body washings (see *ICIPE 1990 Annual Report* and SPRU report), examination of crude extracts active as oviposition pheromone and potential tsetse allomones.

Considerable progress has been made in the location of active components in the neutral fraction of the body-wash from the cow. However, the complexity of the mixture and the fact that the different components act additively or synergistically has made the pace of identification of the compounds slow (See Sensory Physiology Research Unit report).

Larval exudates formed before pupation have been shown to be sources of oviposition pheromones for *G. m. centralis* and *G. m. morsitans*. These exudates have been examined by gas chromatography and found to have different compositions. Identification of the active compounds by behavioural assays, GC-EAG and GC-MS is in progress.

The basis of tsetse's indifference to water bucks has been a subject of speculation in the literature. We have considered the possibility that this may be partly due either to unusual composition of the kairomonal components which renders the animal unattractive or to the presence of allomonal (repellent) compounds on the animal. In view of the potential of such semiochemical blends in tsetse management, particularly, in the protection of cattle in cleared areas, we have initiated some exploratory studies on the odours of water buck and on the analogues of 2-methoxyphenol, a repellent constituent of the phenolic fraction of buffalo and cattle urine. We examined an extract of the urine of water buck by gas chromatography and found that its phenolic composition is different from those of buffalo or cattle. The implication of this is being explored.

Of the analogues of 2-methoxyphenol, one has been tested todate in the wind tunnel and has shown significant repellent activity. A detailed structure-activity study is now planned both in the laboratory (wind tunnel experiments) as well as in the field.

6.4 SEMIOCHEMICAL STUDIES ON BANANA WEEVIL

I. O. Ndiege, W. J. Budenberg, F. W. Karago, D. O. Otieno, B. Hanson and A. Hassanali

The objective of this project is to identify the semiochemicals which mediate the different elements of behaviour of the banana weevil and to utilise these in integrated control of the pest. The following activities were undertaken during the year:

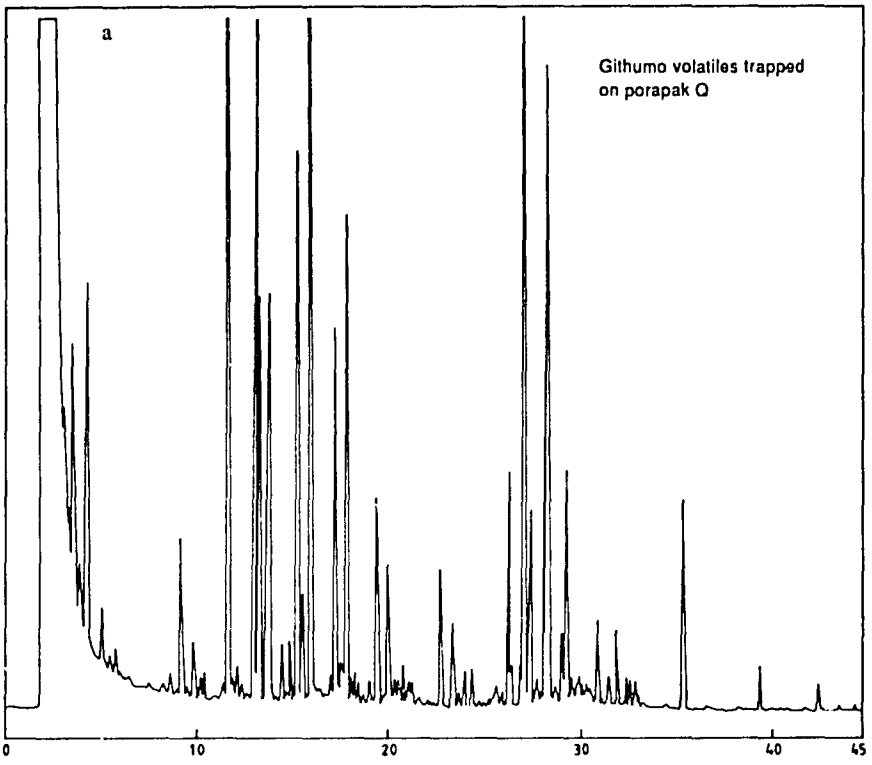
(a) Continued studies of the semiochemistry of volatiles of different cultivars of banana with varying level of susceptibility to the weevil; identification of the active components and comparison of attractancy of volatiles of different cultivars.
(b) Development of a suitable microanalytical technique for trapping volatiles from small pieces of pseudostem for chemo-taxonomic studies.
(c) Search for intraspecific chemical signals in the weevil.
(d) Search for an effective adsorbent for volatiles that is free of leachable impurities which interfere with the identification of bioactive volatile compounds.

Progress made in each area is summarised below.

The composition of air-borne volatiles of the pseudostem of three varieties of banana of different susceptibility to the weevil is summarised in Table 6.1.

Table 6.1 Summary of the air-borne volatile composition from three banana cultivars

Compound	Githumo	Wangai	Mitahato
Tricyclene	–	+	–
α-Pinene	+	+	+
Sabinene	–	+	–
β-Pinene	+	+	+
Myrecene	+	+	+
Limonene	+	+	+
p-cymene	–	+	–
trans-Ocimene	–	+	+
Unidentified	+	–	–
α-Cubebene	+	–	–
α-Copaene	+	–	+
α-Cedrene	+	–	+
α-Caryophyllene	+	–	+
α-Humulene	+	–	–



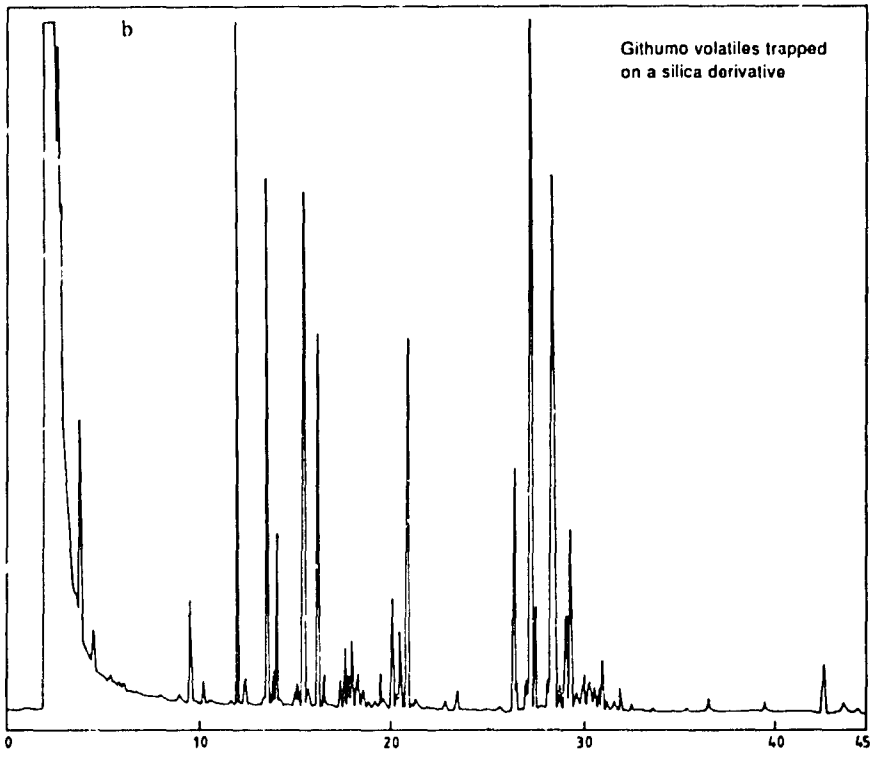


Figure 6.3 Gas chromatograms of hexane eluent of banana volatiles (from "Githumo" variety) trapped on porapak Q (a) and a silica derivative (b).

Although the weevil can locate the source of the host odour, comparative studies of "Githumo" (susceptible) and "Wangae" (resistant) show no preference for one set of volatiles over the other. This suggests that preference of a cultivar may be controlled at the oviposition or feeding stage currently under study. Gas chromatography linked to electroantennogram detector (GC-EAD) of trapped volatiles has shown that the antenna consistently responds weakly to only one compound in the blend. One chiral form of this, however, does not elicit any discernible behavioural response in the weevil. In addition, blends reconstituted from identified components also failed to attract the weevil showing clearly that critical components in the natural blends, probably present in small amounts, remain unidentified. This is now being addressed.

Airborne volatiles from four banana cultivars examined todate show different compositions suggesting that these may be useful in varietal taxonomy of banana. We have now demonstrated that a sufficient amount of volatiles from small pieces of pseudostems can be collected in a microtrapping device to give prominent gas chromatographic profiles at normal attenuations. The full potential of the technique in banana chemotaxonomy will be explored in the coming year.

Behavioural assays and electroantennogram measurements have now confirmed the presence of a male-produced aggregation pheromone system that is attractive to both males and females. Identification of the active components in airborne volatiles of male weevils is in progress.

Since successful identification of bioactive components in airborne volatiles depends upon trapping and desorption techniques that introduce minimum impurities into the isolated material, we have examined a number of candidate alternatives to conventional adsorbents such as porapak which contain a lot of leachable impurities. We now have found a silica derivative which is an effective adsorbent for a range of C_2–C_{15} alkanes, alkanols, alkanals, alkanones and esters. The adsorbent contains much lower levels of impurities (Figure 6.3) and the trapped volatiles are readily eluted by organic solvents. The adsorbent has now been adopted as one of the materials of choice for all air-borne volatiles work in CBRU.

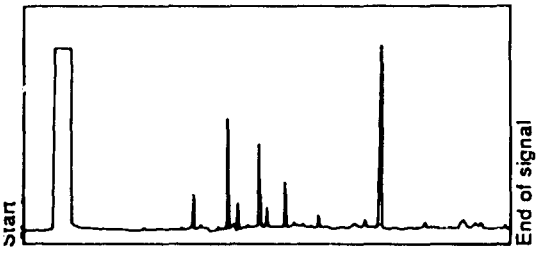


Figure 6.4 Capillary gas chromatogram of *Maruca testulalis* pheromone gland extract.

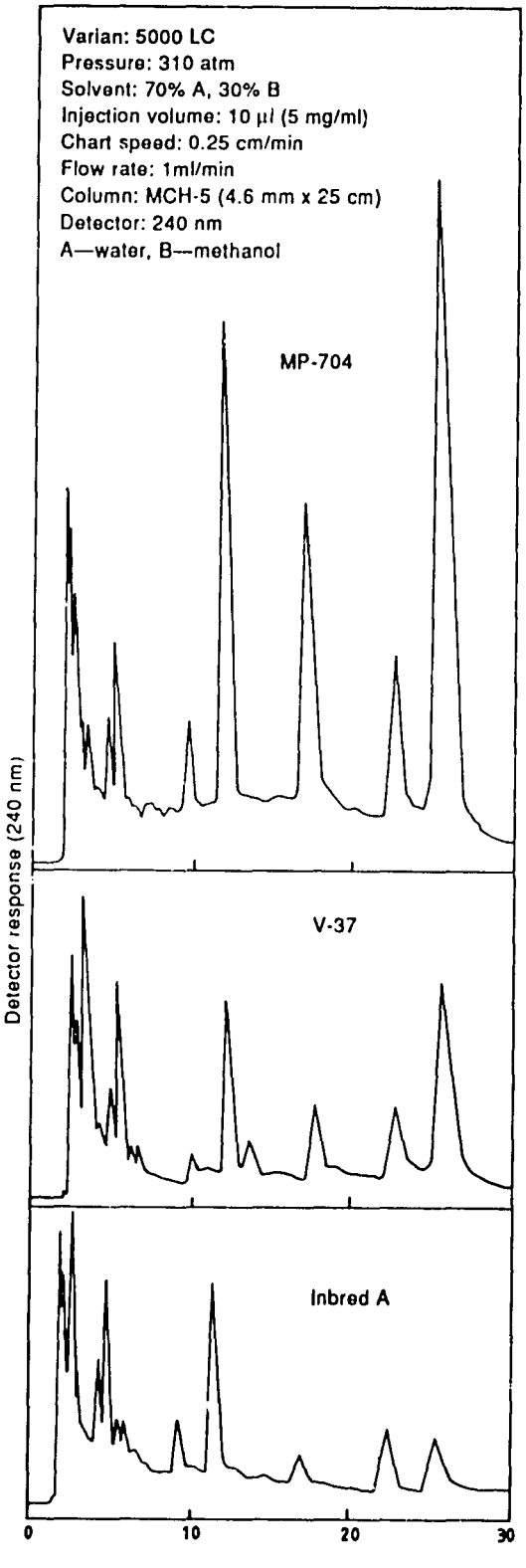


Figure 6.5 HPLC profiles of ethyl acetate extracts of MP-704, V-37 and Inbred A maize cultivars.

6.5 ANALYSIS OF THE FEMALE SEX PHEROMONE OF *MARUCA TESTULALIS*

W. Lwande, S. M. Waladde, S. A. Ochieng, G. Achieng and H. Amiani

Studies on the identification of the female sex pheromone of the legume pod borer, *Maruca testulalis*, a serious pest of cowpea (*Vigna unguiculata*) and other legumes, were initiated. The pheromone was extracted from female sex pheromone glands dissected from abdominal tips of *M. testulalis* and also collected from airborne volatiles during their calling period. Figure 6.4 shows a gas chromatogram of *M. testulalis* gland extract. Identification of the pheromone compounds in the extract by a combination of techniques such as gas chromatography, gas chromatography linked mass spectrometry and gas chromatography linked electrophysiology is in progress.

6.6 ALLELOCHEMICAL BASIS OF FEEDING BY *CHILO PARTELLUS* LARVAE ON MAIZE VARIETIES

D. Nyarango, A. Hassanali, K. N. Saxena and W. Lwande

Studies have shown that the feeding behaviour of third instar larvae of *Chilo partellus* (Swinhoe) on maize is influenced by several categories of chemicals present in the whorls of maize. As part of a study to elucidate the allelochemical basis of feeding, the surface chemicals from maize varieties Inbred A (susceptible), V-37 (tolerant) and MP-704 (resistant) have been sequentially extracted into petroleum ether (15 min), ethyl acetate (15 min) and methanol (24 hours).

Chromatographic examination of extracts of the three varieties shows both quantitative and qualitative differences. Feeding bioassays in no choice situation on cellulose acetate discs impregnated with crude extracts show that the methanolic extracts were most stimulatory followed by the ethyl acetate extracts and lastly is the petroleum ether extracts. Extracts derived from susceptible cultivars were more stimulating than those derived from less susceptible cultivars.

Comparison of the HPLC profiles of ethyl acetate extracts of the three cultivars suggest that relative resistance is directly related to the amounts of allomones present (Figure 6.5). Identification of these compounds is in progress.

6.7 STUDIES ON *BACILLUS THURINGIENSIS* ENDOTOXINS

E. O. Osir, G. Magoma and F. Wamunyokoli

Bacillus thuringiensis (*B.t.*) is a group of gram-positive soil bacteria that synthesise parasporal crystalline inclusions during sporulation. These inclusions consist

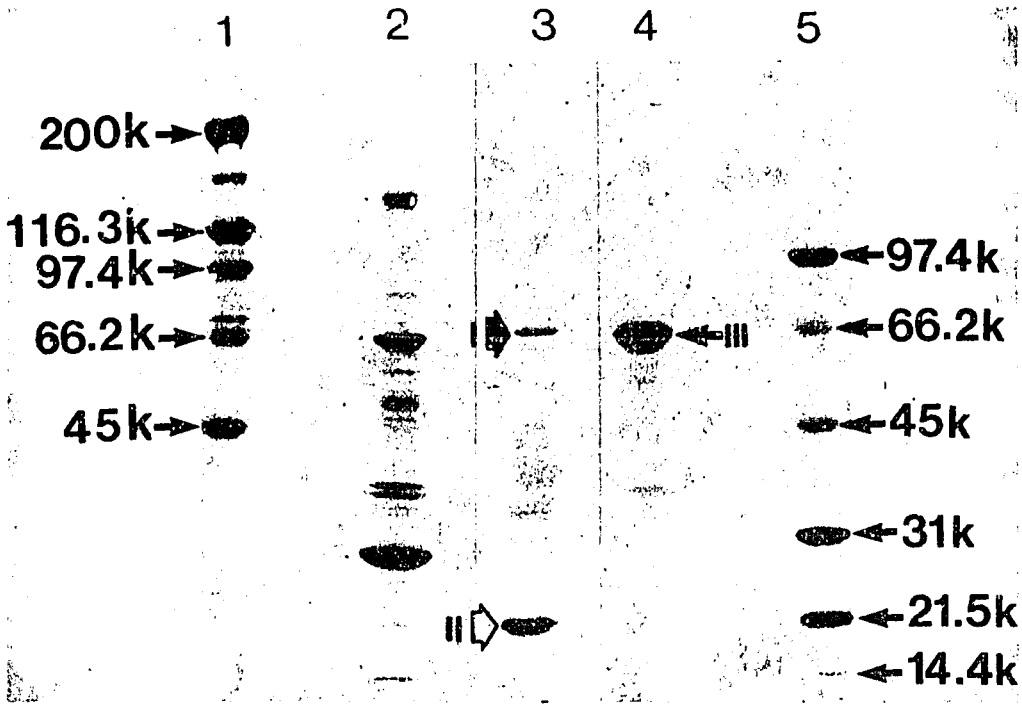


Figure 6.6 SDS-polyacrylamide gel electrophoresis (4–15%) of *Aedes aegypti* specific *Bacillus thuringiensis* δ endotoxin: 1, high molecular weight marker; 2, crystal; 3, trypsin digested solubilised protoxin (sub-unit I, 66 kD; sub unit II, 21 kD); 4, trypsin digested insoluble protoxin (sub-unit III, 66 kD); 5, low molecular weight marker.

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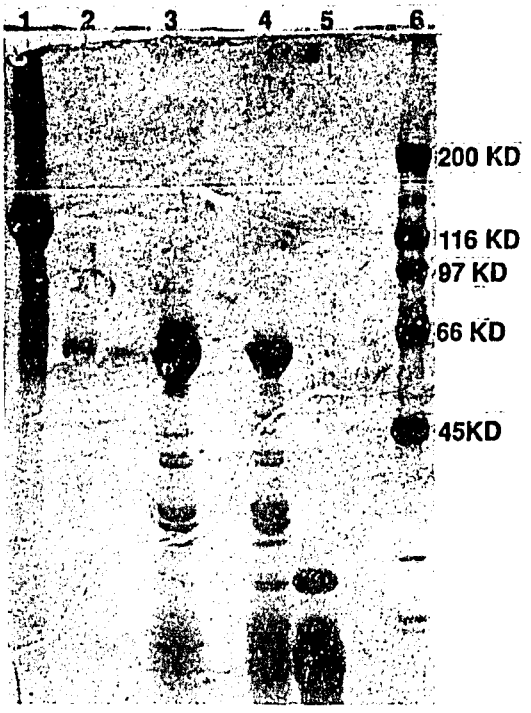

igure 6.7 SDS-polyacrylamide gel electrophoresis l–15%) of *Spodoptera/Chilo* specific *Bacillus thuringiensis* ·endotoxin. 1, purified crystal; 2, insoluble crystal; 3, ɔluble crystal; 4, trypsin treated soluble crystal; 5, trypsin; high molecular weight standard.

proteins collectively known as delta-endotoxins or secticidal crystal proteins (ICPs). The insecticidal ·operties of ICPs make *B.t.* attractive biological control ;ents.

We have recently initiated a new project to study the biochemistry of *B.t.* endotoxins as well as the molecular biology of the endotoxin genes. Since a given *B.t.* strain exhibits a limited host range, a major thrust of the project is to elucidate the molecular basis for its selective toxicity. Initially, this project is focused on two locally isolated strains active against *Chilo partellus* or *Spodoptera exempta* and *Aedes aegypti*. In both cases, the strains were grown in a broth medium until sporulation and lysis. The endotoxin crystals were subsequently purified by centrifugation in sucrose gradients. The purified crystals were then solubilised under high pH and reducing conditions. Activation of the protoxins into the active toxins was carried out using bovine pancreas trypsin. The mosquito-specific *B.t.* crystals solubilised into a pellet band (Mr (66,000) and a supernant band (Mr 21,000) when analysed by electrophoresis (Figure 6.6), both of which showed biological activity. On the other hand, the *Chilo/Spodoptera* specific strain yield only one major protein band (Mr 66,000) which was active to the larvae of both insects (Figure 6.7).

6.8 ACTIVATION OF A DIPTERAN-SPECIFIC *BACILLUS THURINGIENSIS* δ-ENDOTOXIN

W. R. M. Vundla and E. O. Osir

The *Bacillus thuringiensis* δ-endotoxin is a proteinaceous crystal, composed of several distinct polypeptides making up the proendotoxin. Depending on the strain, the endotoxin has Mr 70–130 kDa and is proteolytically cleaved to yield active toxin subunits, following solubilisation of endotoxin in the insect midgut.

We have shown that the crystal of a dipteran-specific

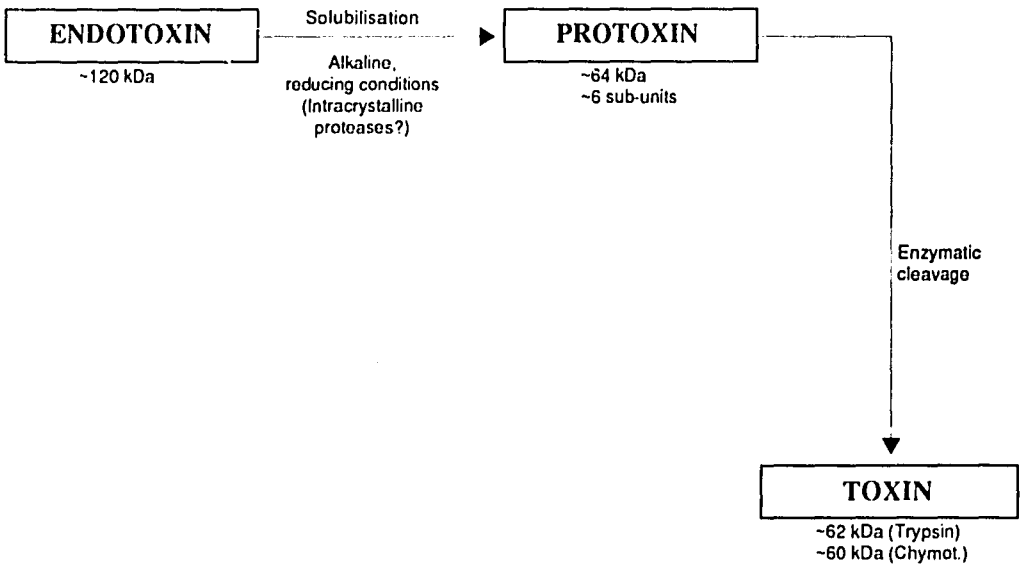

Figure 6.8 Activation of a Dipteran-specific *Bacillus thuringiensis* δ-endotoxin.

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Table 6.2 Repellency of *G. gynandra* and Labiatae oils and DEET to *R. appendiculatus* at different doses†

Dose (µl)	*G. gynandra* oil	Labiatae plant oil	DEET
10	100	99.5	–
1	100	98.6	–
0.1	90.9	100	96.2
0.01	48.0	98.6	95.2
0.001	41.1	99.2	90.5
0.0001	–	92.2	84.7
0.00001	–	–	54.2

†Calculated from the formula $[(C-T)/C+T)]\times100$ where C represents the number of ticks that arrived on top of the control rod and T represents the number that arrived on top of the rod containing paper strip treated with the test material.

B.t. strain has Mr 120 kDa. On solubilisation (30 h at pH 9.5 and 37°C in the presence of a reducing agent), the protoxin (Mr 64 kDa) is formed. When subjected to gel filtration on a Superose 12 column (FPLC), the protoxin resolves into 6 subunits, two of which show trypsin-like activity. The protoxin can be activated by incubation (37°C, 30 min) with commercial trypsin or chymotrypsin to yield active toxins of Mr 62 kDa (trypsin) or Mr 60 kDa (chymotrypsin) (Figure 6.8).

6.9 ESSENTIAL OILS OF SOME ANTI-TICK PLANTS

L. Moreka, E. Nyandat, A. Hassanali, D. Punyua, E. Mwangi, W. Lwande, M. M. Malonza and G. Achieng

As part of an attempt to understand the basis of allomonal effects of some plants on ticks, we have isolated and bioassayed the essential oils of two shrubs, *Gynandropsis gynandra* (Capparaceae) and a plant belonging to the family Labiatae. The bioassay exploited the climbing behaviour of adult *R. appendiculatus* ticks exposed to high humidities. It consisted of two 25 cm long metal rods covered with glass tubes, 7 cm apart, attached to a metal base placed in a tray containing water. Ticks climbing up the rods had to cross filter paper rings, 1 cm wide, placed 10 cm up the rod treated with either various doses of the test material or the solvent (hexane). Table 6.2 summarises the repellency data of the two essential oils. The results obtained for the commercial repellent, N,N-diethyltoluamide (DEET) are also given for comparison.

Both essential oils are repellent, the oil from the Labiatae plant having higher activity than DEET. Interestingly, *G. gynandra* is used by certain communities in Kenya to control domestic fowl mites (see LTRP section, *ICIPE 1990 Annual Report*), and the Labiatae plant is used as a general insect repellent. The possibility of using the oils in tick management is being explored in collaboration with LTRP.

CELL BIOLOGY RESEARCH UNIT

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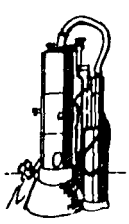

7 Cell Biology Research Unit

The primary role of the Cell Biology Research Unit is to assist and support the ICIPE Core Programmes and Units by carrying out morphological and functional studies on the target crop pests and disease vectors at the organic, cellular and molecular levels. During the year 1991 research activities in the Cell Biology Research Unit focused in the areas of cell and tissue cultures, molecular biology, ultrastructure, histology, immunobiochemistry and virology. These studies were conducted on Leishmania *parasites and on tsetse.*

Investigations on the epidemiology of leishmaniasis concentrated on human visceral leishmaniasis caused by Leishmania donovani *complex. During the year species specific DNA probes were developed for identification and characterisation of the parasite.*

Work leading to the establishment of in vitro *cultures of cells derived from* Glossina *spp. has been initiated. This will facilitate the study of DNA virus of tsetse for biocontrol purposes.*

Work on the role of male accessory reproductive gland (ARG) proteins on tsetse reproduction continued during the year, mainly on the identification and isolation of ARG and spermatophore common proteins and the assay for their immunological effects on tsetse reproduction. Also, histopathological effects of virus infection in the ARG of tsetse were investigated. Additional research on DNA virus of tsetse focused on the mating behaviour of male tsetse infected with the DNA virus and the determination of infectivity and virulence to Balb/c mice, of Trypanosoma brucei *metacyclics from tsetse salivary glands infected with the DNA virus.*

Studies on insect neuropeptides aiming at identifying neurosecretory substances involved in the stimulation/modulation of parturition (larviposition) and ovulation in tsetse, were initiated.

Ultrastructural and histological studies on the ARG and the abdominal glandular epidermis of the desert locust have been initiated to determine the possible role of ARG in sexual maturation of the desert locust.

Following the acquisition of a new scanning electron microscope (JSM-T330A) from Japan, a technician from the Unit attended a course at the Jeol Datum Ltd. Training Centre in Tokyo, Japan to acquaint herself with the operation of the new machine and to learn new techniques in scanning electron microscopy.

7.1 IDENTIFICATION AND CHARACTERISATION OF *LEISHMANIA* PARASITES

N. N. Massamba and R. K. Rotich

7.1.1 Leishmania donovani: *Development of species specific DNA probes*

Visceral and cutaneous leishmaniasis is widespread in East Africa especially in Ethiopia, Kenya and Sudan. Human visceral leishmaniasis (kala-azar) is caused by protozoan parasite *L. donovani* complex including *L. donovani* which infects adults in Asia and Africa, *L. infantum* which infects mainly children in the Mediterranean region and *L. chagasi* which infects infants in South America.

In Kenya, visceral leishmaniasis or kala-azar is endemic in Baringo District. *Phlebotomus martini* is believed to be the main vector of visceral leishmaniasis

although two other species of the subgenus *Symphlebotomus*, *Phlebotomus vansomerenae* and *P. celiae* are found in the country (Kitui and Machakos Districts). To investigate reservoirs of visceral and cutaneous leishmaniasis due to *L. donovani* we have developed species specific DNA probes for identification and characterisation of *Leishmania* from a wide range of clinical types, animal reservoirs and sandfly vectors from Kenya.

Kinetoplast DNA (kDNA) sequences from World Health Organisation *Leishmania* reference strains of *L. donovani* (IC-245; NLB-065 and NLB-061) were isolated by preparative gel electrophoresis on 0.6% agarose gel after digestion with restriction endonuclease BamHI (Figure 7.1). DNA was then ligated and cloned into the BamHI site of plasmid pUC-19, which was transformed and propagated into *E. coli* strain JM 83.

Recombinants were selected on LB indicator plates containing 50 µg ampicillin and 30 µg X-Gal per ml. Recombinant colonies were grown in LB-broth medium and plasmid DNA was extracted using alkaline lysis method. After BamHI digestion, the DNA was electrophoresed, Southern-transferred to nitrocellulose filter and sequentially hybridised to ^{32}P labelled homologous and heterologous total DNA of *Leishmania* reference strains.

The recombinant plasmids purified from positive clones were used as probes. Work is in progress using the cloned kDNA sequences, to screen by hybridisation genomic DNAs isolated from various *Leishmania* stocks.

7.1.2 Leishmania major *IC-235: Isolation of a small characteristic chromosomal DNA fragment*

In our previous work using isoenzyme analysis by cellulose acetate electrophoresis and DNA analysis with restriction endonucleases, we showed that the two World Health Organisation *Leishmania* reference strains, *L. major* IC 235 and *L. major* IC-236, were genetically different although they were identified as *L. major* by other authors.

In view of these conflicting results we decided to carry out molecular karyotyping analysis of the two

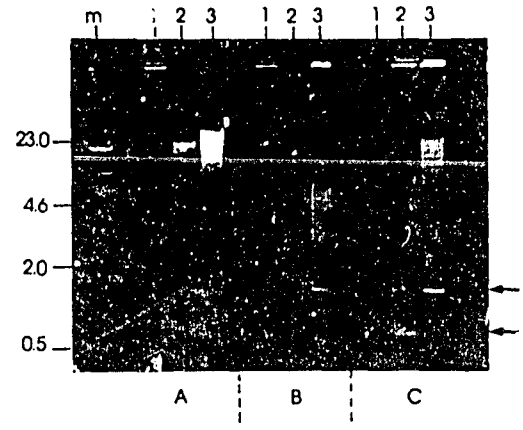

Figure 7.1 Gel electrophoretic analysis of restriction digests of genomic DNAs from *Leishmania* reference strains: (1) *L. donovani* NLB-061; (2) *L. donovani* NLB 065 and (3) *L. donovani* IC-245; (m) molecular weight markers provided by Hind III-digests of lambda DNA. Total DNAs were digested with EcoRI (A) Hind III (B) and PstI(C). Photograph of ethidium bromide-stained gel showing prominent characteristic bands (I and II)

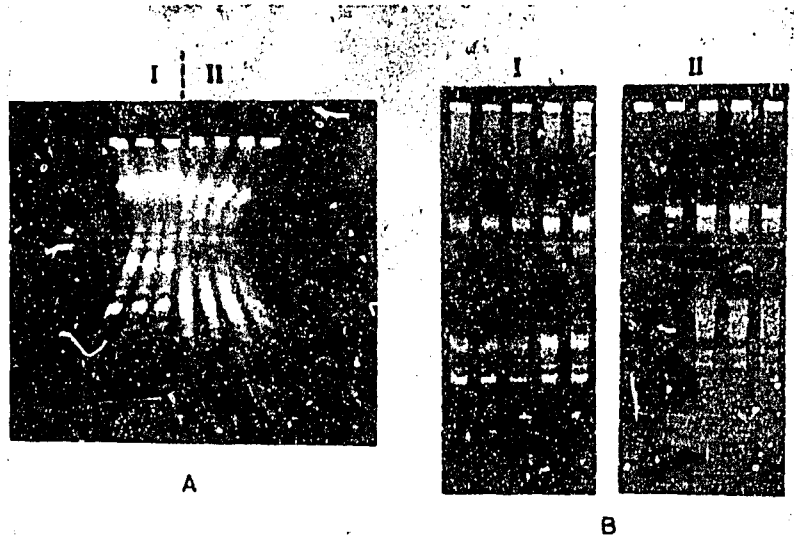

Figure 7.2 Molecular karyotypes of *Leishmania* reference strains (A) derived by OFAGE (B) derived by TAFE. Ethidium bromide stained gels of cloned promastigotes of (I) *L. major* IC-235 and (II) *L. major* IC-236. Note the presence of small chromosome in *L. major* IC-235.

strains applying the orthogonal field alternation gel electrophoresis (OFAGE) and transverse alternating field electrophoresis (TAFE) techniques. The analysis was carried out on cloned materials from *L. major* IC-235 and *L. major* IC-236 reference strains. When OFAGE and TAFE gels were carried out, the reference strains of *L. major* IC-235 and *L. major* IC-236 exhibited different molecular karyotypes. *Leishmania major* IC-235 showed a characteristic karyotype revealed by the presence of small chromosome-sized DNA molecules (Figure 7.2). This small chromosomal DNA fragment was excised from ethidium bromide-stained OFAGE and TAFE gels, isolated and purified by electro-elution and phenol extraction then recovered by ethanol precipitation. Cloning of the fragment into an appropriate vector and its restriction mapping are in progress. The potential of the cloned fragment in distinguishing between *L. major* strains will be assessed.

7.2 *IN VITRO* CULTURES OF *GLOSSINA* LARVAL AND PUPAL CELLS

V. Lutje and N. N. Massamba

The aim of this project was to establish *in vitro* cultures of cells derived from *Glossina* spp., to be eventually used for the study of the DNA virus of tsetse flies.

In vitro cultures of tsetse fly organs and tissues have been attempted by several workers over the past 25 years, with varying results and no continuous cell line from *Glossina* spp. has been obtained and none is in existence. Primary cultures were initiated with cells obtained from third-instar larvae and from 1 day to 3 days-old pupae of *Glossina morsitans morsitans* and of *G.m. centralis*. Studies on the capability of these cultures to support the *in vitro* growth of trypanosomes were also carried out.

7.2.1 *Cell cultures from third instar larvae*

When larval masses of *Glossina* spp. are placed in culture, cells tend to adhere to the plastic and to assume an epithelial-like shape. Regardless of the number of larvae which are used to initiate a culture, a confluent monolayer is not usually obtained, and cells remain isolated or form patches of different sizes. Common observations in these cultures are the budding of hollow or multicellular viscles from the cut ends of larval fragments, and the presence of large fragments of intestinal tissue which keep on pulsating rhythmically for extended periods of time. However, larval cells maintained *in vitro* start degenerating after a few weeks, and assume a "granular" appearance before progressing to death. It has not been possible so far to maintain a larval culture for more than 2 months.

Several factors such as mechanical manipulations, choice of medium and medium supplements, and frequency of changes of medium, seem to affect larval cell cultures, and will be considered in the next set of experiments.

7.2.2 *Cell cultures from 1 to 3 days-old pupae*

In cultures derived from young tsetse pupae, cells display a round shape and remain in suspension, only occasionally loosely adhering to the plastic if left undisturbed for a period of time. However, this adherence is only temporary; cells do not modify their shape and they can be resuspended by gentle agitation of the flask. Pupal cells can maintain a healthy appearance for a long period of time; cultures have been maintained for 3 months or more, and several cultures are still in progress. However, no increase in cell number is usually observed. Pupal cells, unlike larval cells, show a good tolerance to mechanical treatments and to partial changes of medium.

Preliminary electron microscopic analysis of 1 week-old pupal culture has demonstrated the prevalence of muscle cells (Figure 7.3). The muscular fibres in these

Figure 7.3 Electron micrograph of cultured pupal cells of *G. m. morsitans* showing the presence of muscular fibres (F) and several degenerating mitochondria (M). Magnification, x20,650.

cells appear to be still assembling. Mitochondria show some degree of degeneration, with modified shape and enlarged cristae, which could indicate a maladaptation of the cells to culture conditions. No other cell types have been observed. No similar analysis has been attempted with cultures of larval cells.

7.2.3 In vitro *trypanosome cultivation*

The accidental contamination of a larval culture with trypanosomes prompted some studies on the use of *Glossina* cell cultures to support the *in vitro* growth of this protozoan. Tsetse explants of whole thoraxes, complete alimentary tracts, and heads with attached salivary glands, have been used by various workers to cultivate insect forms of different species of trypanosomes, to obtain complete cyclic development *in vitro* and to evaluate their infectivity to mammals. However, survival of these explants was usually quite limited. The use of *Glossina* cells lines in supporting the growth of trypanosomes might constitute

a useful system, to help elucidate mechanisms of trypanosome differentiation of other issues such as factors involved in tsetse susceptibility to infection by the parasite.

In our hands, larval cultures of *G. morsitans morsitans* supported the growth and multiplication of procyclic forms of trypanosomes (probably *T. brucei*) for over a month; the culture was eventually lost because of inadvertent overgrowth of trypanosomes and exhaustion of nutrients in the culture medium. Trypanosomes in culture were actively motile and often formed clumps, free in the medium or attached to tsetse cells. They were routinely examined by Giemsa stains and counted in a haemocytometer chamber. No forms other than procyclic were observed. More detailed studies will be needed to establish modalities of trypanosome infection of the cultures and the requirements for the switch to metacyclic forms.

7.3 VIRUS PARTICLES IN THE CELLS OF MALE ACCESSORY REPRODUCTIVE GLANDS OF TSETSE, *GLOSSINA MORSITANS MORSITANS*

E. Kokwaro and J. Murithi

Results of previous work on hypertrophied salivary glands of tsetse have shown that diverse microorganisms infect salivary glands of tsetse, and that one of the microorganisms, the DNA-virus is linked with sterility in tsetse population. In view of the lack of confirmatory information as to whether or not the male accessory glands (ARG) could be infected by virus particles, a study was undertaken to establish the extent of virus infection to the male ARG, the effect of the infection on the gland structure and the significance of the changes.

The infection of salivary glands of *Glossina morsitans morsitans* by virus particles extends to the male ARG cells and causes extensive cytopathological changes characterised by retraction and degeneration of the cytoplasm, vacuolation, elimination of some protein synthetic apparatus and detachment of the muscle layer from the basal plasma membrane (Figure 7.4). The epithelium of infected cells contains lysosomal-like bodies and lacks microvilli at apical surface. Some virus particles, degenerating but identifiable cytoplasmic components such as mitochondria, free ribosomes, small membrane-bound vesicles and vacuoles were discernible.

The nuclear changes in infected cells involved all nuclear components and consisted of scattered nuclear structures, clumping of chromatin material, invagination and, partly, disruption of the nuclear membrane. Virus particles were distributed in close association with chromatin aggregates and in clear parts of the nucleoplasm.

Abnormal degenerative changes could be seen in secretory components which consisted of margination of granules, appearance of clear areas around the secretion and fragmentation of the filamentous secretion. Viral

Figure 7.4 Electron micrograph of virus-infected ARG showing membrane-bound vesicles (Vs), vacuoles (V), mitochondria (M) and virus particles (Vp). Lumen (Lu) with secretion. Magnification, x25,000.

rods were frequently found scattered in the lumen among secretory granules.

In histochemical tests, the ARG secretions from infected individuals gave negative results for proteins and carbohydrates while those of uninfected ARG were intensely positive. These results suggest that the infected ARG is devoid of high concentrations of the carbohydrate - protein complexes.

The primary function of the tsetse ARG is to synthesise continuously ARG secretions, transport them to the apical cell surface and release them into the lumen. During mating the glands provide copious amounts of secretion to facilitate sperm transfer, thereby ensuring the reproductive success of the species. In the case of virus infected ARG, the cytoplasm is extensively vacuolated, the intracellular organelles are destroyed while sloughing of epithelia and damage to the nuclear inclusions are evident. These changes would inhibit or totally arrest progress of glandular synthesis which could eventually culminate in lack of transfer and replenishment of luminal secretion, required to transfer spermatozoa to the female. Elimination of major essential constituents of ARG secretion may also impair spermatophore formation. The severe degradation would eventually destroy the male accessory reproductive glands, and could partly account for the abnormal male sterility induced by the virus.

7.4 MATING BEHAVIOUR OF MALE *GLOSSINA MORSITANS MORSITANS* INFECTED WITH THE TSETSE DNA VIRUS

W. G. Z. O. Jura and J. A. O. Davies-Cole

It has been demonstrated that when the males of *Glossina pallidipes* and *G. m. morsitans* are infected by the DNA virus, the lesion in the testes of such males results in total arrest of spermatogenesis and severe degeneration, in turn resulting in complete sterility in the flies. Sterile males are extremely important in autocidal or genetic techniques for managing pest populations. The success of the release depends on the ratio of the released sterile males to fertile field males. If an excess of sterile males in the area is maintained by a continuous release of such insects, it may lead finally to the extinction of the population. In this case, it is assumed that a sterile (released) male has the same chance of mating with a wild female as does a fertile (wild) male.

The specific objective of this study was to assess, in the laboratory, whether and/or how infection of male *G. m. morsitans* with the DNA virus, which makes them sterile, affects their mating activities. For example, whether or not, or how soon, the sterile males locate sexually receptive females. Is their sexual appetitiveness (libido) affected? For how long do they mate and if they are able to inseminate, what is the degree of insemination of the mated females?

Virus-infected *G. m. morsitans* were produced by inoculating third-instar larvae with the virus suspension. The resultant pupae were maintained until emergence. Males were isolated and maintained at 25°C, 70% relative humidity until they were 3 weeks old when they were used in the mating experiments. Two groups of flies were used. In group 1, the 3-week old virus-infected males were mixed with an equal number of 3-day old normal females in PVC cages and allowed to mate freely. The second group, the controls, consisted of 3-week old normal *G. m. morsitans* males mixed with an equal number of 3-day old normal females. In both groups, the time of pairing of each mating couple was noted and each pair was isolated in a vial. Sexes were isolated immediately after pairs separated, in order to avoid re-mating. The time of, and behaviour at, separation were noted. The separated flies were kept individually in labelled vials until the following day when the females were dissected to determine the value of the degree of insemination (mean spermathecal value) and to examine the nature of spermathecal contents. Males were also dissected to confirm whether or not they were infected by the DNA virus by examining salivary gland and testicular lesions.

Both virus-infected and normal *G. m. morsitans* males located the females instantly and manifested a very high level of sexual appetitiveness (libido). They were both equally very aggressive (darted around, held and mounted females almost instantaneously). A comparison, by the Student's *t*-test, of the mean duration of copulation between the normal males (149.4 ± 17.6, n=17) and the sterile, virus-infected males (193.3 ± 20.3, n=17) revealed that there was no significant difference between the two groups ($P > 0.05$). All males in both groups experienced a "jerking phase" before separating. A similar analysis between females mated to the virus-infected males and those mated to the control males showed that the mean spermathecal value (MSV) for the females mated to the normal males (1.68 ± 0.10, n=15) was significantly greater ($P < 0.01$) than the MSV for those mated to the males infected with the DNA virus (0.31 ± 0.16, n=15). The observations on the MSV were in total agreement with those obtained from microscopy. While spermathecae of all the females mated to the control males showed a high degree of insemination as evidenced by the presence of sperm mass (Figure 7.5), the majority of spermathecae of females mated to virus-infected males were devoid of spermatozoa and only contained lightly stained secretory material (Figure 7.5B). Some contained debris of degenerative sperm and polyvalent epithelial cells (Fig. 7.5C).

We have demonstrated in this study that infection of male *G. m. morsitans* with the DNA virus is not deleterious to their libido; such infected flies are as highly sexually appetitive as the normal males are. Although their ability to inseminate is significantly reduced,

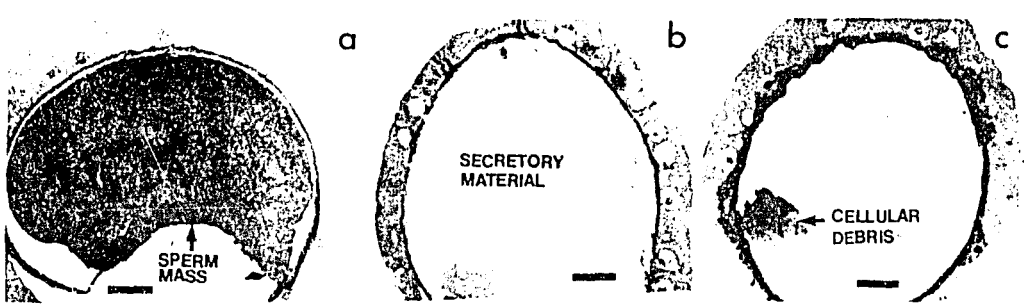

Figure 7.5 Sections of spermatheca of the tsetse fly, *Glossina morsitans morsitans*: A, female mated with normal male showing high degree of insemination; B, female mated with virus-infected male showing secretory material but no sperm; C, female mated with virus-infected male showing debris of degenerative sperm cells (arrow); bar=22μm.

they nevertheless locate females instantly, aggressively capture and mount them almost instantaneously and conclude copulation with a characteristic "jerking phase". Therefore, their mating behaviour is as normal as that of normal, healthy *G. m. morsitans* males.

7.5 SEXUAL RECEPTIVITY OF FEMALE *GLOSSINA MORSITANS MORSITANS* PRE-MATED WITH VIRUS-INFECTED STERILE MALES

W. G. Z. O. Jura

In a recent study, we demonstrated that *G. m. morsitans* males, even when infected by the sterilising DNA virus, were still highly sexually appetitive and located females instantly. Although such infected males were sexually aggressive and mounted females almost instantaneously, their ability to inseminate was seriously impaired. The spermathecae of the females they mated with were devoid of spermatozoa.

Several investigators have shown that after a female tsetse mates with a normal male, its willingness to re-mate diminishes rapidly. For example, between 1-24 hours, about 50% of previously mated flies lose their receptivity to subsequent matings. By 72 hours after mating, over 80% of the female *G. m. morsitans* have been shown to be refractory to re-mating. The loss of female sexual receptivity has been attributed to various factors by several investigators. One of such factors is the relative amount of semen in the spermathecae; another factor is mechanical stimulation, especially the jerking phase, which is believed to be the crucial element in the act of the mechanical stimulation.

If the DNA virus-infected tsetse males are to be used successfully in the sterile-male insect-release method for natural control of *Glossina* species, it would be of paramount importance to know whether or not they would induce refractoriness in female flies they mate with.

Consequently, the specific objective of this investigation was to study and determine how normal, healthy *G. m. morsitans* females previously mated to the DNA virus-infected males, would respond to mating advances of normal, sexually appetitive *G. m. morsitans* males 72 hours after the initial mating.

Two groups of flies were used in the study. In Group 1, virus-infected, sterile males were mixed with an equal number of 2-day old, normal, healthy females in PVC cages, allowed to mate and each pair isolated in a vial. Group 2 served as the control, where equal numbers of 3-week old, normal males and 2-day old females were mixed and handled exactly as Group 1. In both groups, sexes were isolated immediately the pairs separated to avoid re-mating. The behaviour of the males at separation was noted.

The females in both groups were maintained individually at 25°C, 70% relative humidity for 72 hours. Each female was then paired with a healthy, 7-day old, sexually appetitive *G. m. morsitans* male and the female behaviour to male advances noted. In the first matings, all the females in both groups displayed a very high level of sexual receptivity. As soon as a male was introduced into a vial with a female, it captured the female which immediately opened her wings and the mating started. For males of both groups, copulation terminated with a jerking phase.

Receptivity, in the second matings, of the females in the group previously mated to the virus-infected males and those pre-mated to the normal males was 15% and 20%, respectively. This shows that after 72 hours, more than 80% of the healthy *G. m. morsitans* females pre-mated to the virus-infected, sterile males acquired complete sexual refractoriness to subsequent mating advances. All such females reacted consistently to aggressive mating strikes by males. They refused to open their wings, rejected hypopygeal connection and struggled violently to push the males away. Every mating strike was warded off successfully.

In this study, it has been demonstrated clearly that although sterile, the virus-infected *G. m. morsitans* males are equally as able to induce complete sexual refractoriness in their female partners as do the normal males.

7.6 INFECTIVITY AND VIRULENCE OF *TRYPANOSOMA BRUCEI* METACYCLICS FROM *GLOSSINA MORSITANS MORSITANS* SALIVARY GLANDS INFECTED WITH THE TSETSE DNA VIRUS

W. G. Z. O. Jura and L. H. Otiene

The salivary glands of the tsetse, *Glossina pallidipes* and *G. m. morsitans* provide a suitable environment for the development of the infective forms of *Trypanosoma brucei* subspecies. It is there that the proventricular-form trypanosomes transform into epimastigotes and eventually into the metacyclic forms that are infective to mammals. Salivary gland infection by the DNA virus in *G. pallidipes* and *G. m. morsitans* has been shown to result in massive epithelial cell proliferation and vacuolation, sometimes accompanied by complete obliteration of the glandular lumen. In some of such structurally deformed salivary glands, *T. brucei* metacyclics have been found to co-exist with the virus particles. Whether or not such trypanosomes are able to invade, multiply and be maintained within the mammalian host and whether or not they possess the capacity to damage and cause the disease is not known.

The specific objective of this study was to determine, in BALB/c mice, the pathogenicity of *T. brucei* metacyclics from hypertrophied, DNA virus-infected salivary glands of *G. morsitans morsitans*.

To obtain flies whose salivary glands were infected with the DNA virus, larvae were inoculated with virus suspension immediately they were deposited. The control group of larvae was not inoculated. Pupae resulting from both groups were maintained at 25°C, 70% relative humidity until emergence. Teneral flies from both groups were fed on a rat, infected with C16 clone 1 of *T. brucei*,

with a parasitaemia of 100 trypanosomes per field of view on unstained wet blood films. The control group was allowed to feed first followed by the infected group.

When the flies were found to be positive for *T. brucei* infection through saliva examination, two groups of inbred BALB/c strain of mice were exposed to trypanosome infection by allowing each fly to take blood meal on a mouse. Mice fed on by the control flies were referred to as Group A while those fed on by the virus-infected flies as Group B. Parasitaemia due to *T. brucei* was monitored in both groups of mice until death.

Electron microscopic examination of the negatively stained copper grids, immersed in the supernatant of the homogenised and centrifuged hypertrophied *G. pallidipes* salivary glands showed that this preparation, which was used to inoculate one group of *G. m. morsitans*, contained numerous identical rods of the DNA virus (Figure 7.6). Examination of the *G. m. morsitans* salivary glands, retrieved after they transmitted *T. brucei* to the BALB/c mice, showed that while glands from both the control group (*T. brucei* only) and the test group (*T. brucei*/virus), harboured trypanosomes, those obtained from the latter group of flies, in addition, were markedly hypertrophied and contained hyperplastic epithelial cells, some of which were fragmented (Figure 7.7), changes characteristic of the DNA virus infection in tsetse salivary glands.

A comparison, by the unpaired Student's *t*-test, of the mean prepatent periods between the control mice (Group A; n=4), 4.75 ± 1.11 (mean ± S.E.) days, and the test group (Group B; n = 3), 2.33 ± 0.33 (mean ± S.E.) days, revealed that there was no significant difference ($P > 0.05$). A similar analysis also showed that the mean times to death in the control group, 13.25 ± 0.95 days, compared to that in the test group of mice, 11.00 ± 1.53 days, were not significantly different ($P > 0.05$). Daily mean parasitaemia levels for both groups of BALB/c mice are presented in Figure 7.8.

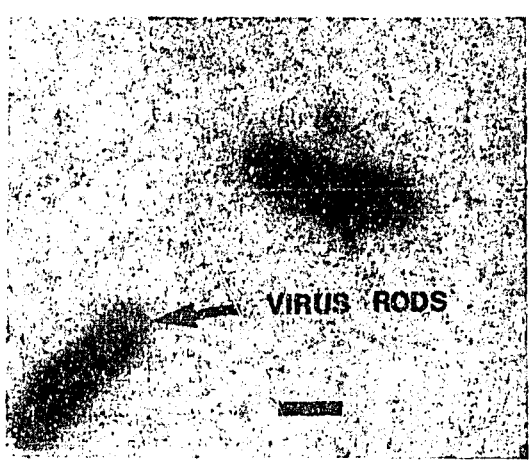

Figure 7.6 Unfixed, negatively stained preparation of the supernatant of the homogenised and centrifuged hypertrophied *G. pallidipes* salivary glands, used to inoculate *G. m. morsitans* larvae, showing identical rods of the DNA virus. Magnification, x 32,500; bar = 0.308μm.

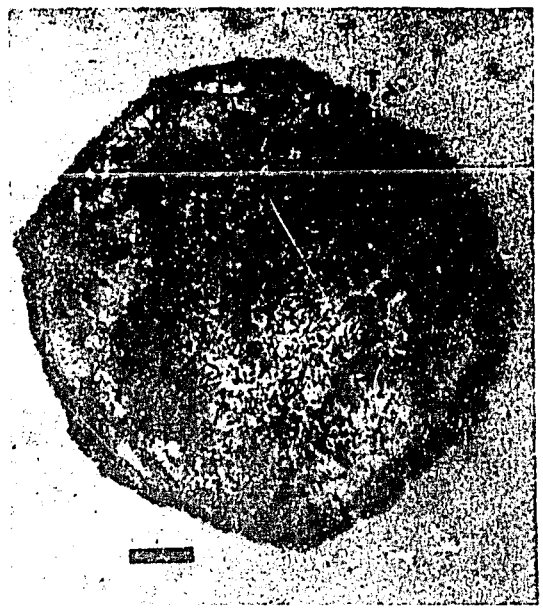

Figure 7.7 Photomicrograph of a hypertrophied salivary gland from *G.m. morsitans* infected with the DNA virus and then *T. brucei*. The specimen, retrieved after the flies transmitted the trypanosome metacyclics to the test group BALB/c mice, shows hyperplastic epithelial cells (HEC), some of which are fragmented (F), and numerous trypanosomes (T). Magnification, x403; bar = 25 μm.

Comparison between the two groups of mice by the *t*-test, each day, revealed that the mean values of parasitaemia in the test mice (Group B) rose to significantly higher levels ($P < 0.05$) than in the controls (group A) on days 4, 6 and 7 post transmission. On the other days, the mean levels of parasitaemia were essentially

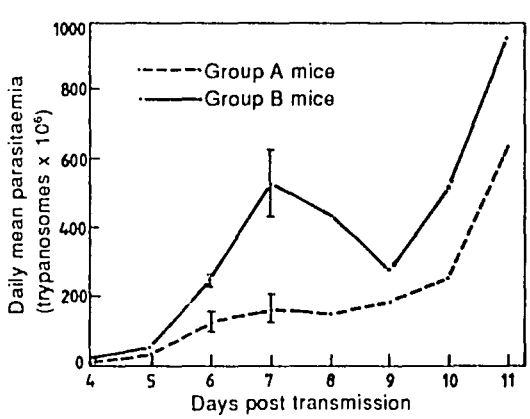

Figure 7.8 Daily mean parasitaemia in the control (A) and test (B) groups of BALB/c mice infected with *T. brucei* transmitted by *G. m. morsitans* whose salivary glands harboured *T. brucei* alone (• - - - - - •) or *T. brucei* together with the DNA virus (• —— •) respectively. Significant differences in parasitaemia between the control and the test mice are illustrated on days 4, 6 and 7; mean values ± S.E. are given at these points.

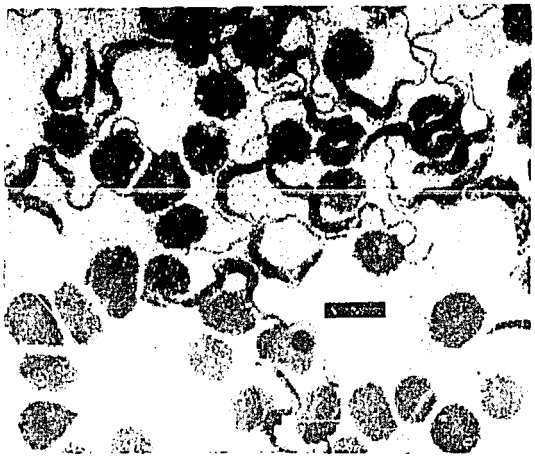

Figure 7.9 Photomicrograph of a representative blood smear made during the terminal stages of trypanosomiasis in the BALB/c mice, depicting high parasitaemia. Magnification, x202; bar = 5 µm.

similar between the two groups. All the mice in both groups developed high parasitaemia (Figure 7.9) and died of trypanosomiasis.

We have shown in this study that when *G. m. morsitans*, whose salivary glands are hypertrophied due to prior infection with the DNA virus, subsequently contract *T. brucei* infection as well, the trypanosomes nevertheless develop to the metacyclic stage. We have also demonstrated that despite the structural deformities of their salivary glands, the *G. m. morsitans* flies harbouring both the virus and *T. brucei* infections are able to transmit the trypanosome metacyclics to a mammalian host (BALB/c mice) as are the flies with trypanosomes only. This study further shows that such metacyclics have the ability to multiply and be maintained in the host and also possess the capacity to damage and cause fatal disease in the mice. Although simultaneous presence of both virus particles and trypanosomes in tsetse salivary glands has been reported before in wild *G. pallidipes*, it has not hitherto been possible to tell whether trypanosomes would develop within the salivary glands after the tissues have been invaded and structurally deformed by the virus. This study was possible because of the method we developed recently which allows the inoculation of third-instar larvae of *Glossina* species with the DNA virus so that at emergence the teneral flies have developed the virus-induced glandular hypertrophy and can then be superinfected with trypanosomes.

Conflicting information has emanated from previous literature regarding susceptibility of the virus-infected tsetse to trypanosome infection. Whereas one investigator suggested, without substantive evidence, that in *G. pallidipes*, flies with hypertrophied salivary glands were peculiarly suited to the development of trypanosomes, particularly *T. brucei*, another group of workers concluded that there was no evidence to indicate that viral infections predisposed flies to infections with trypanosomes. It is also noteworthy that there is no reliable technique available, so far, for accurate quantification of metacyclics within salivary glands. In our present study, analysis of data has revealed that the mean prepatent periods and the mean times to death in the control and the test groups of mice were similar.

These findings imply that the metacyclic trypanosomes transmitted by *G. m. morsitans* harbouring both DNA virus and *T. brucei* simultaneously in their salivary glands were as infective and as virulent as those transmitted by those flies with only *T. brucei*. Infectivity is defined as the ability of a parasite to multiply and be maintained in a given host, while virulence refers to the capacity of a parasite to damage and cause disease to its host. The initial rate of multiplication and the degree of pathogenicity of the two groups of *T. brucei* must have been similar, thus indicating that the lesions produced by the DNA virus in tsetse salivary glands were not deleterious to, and did not preclude the development of the trypanosomes. In addition, the changes in such salivary glands was not detrimental to the transmission of parasites.

7.7 INSECT NEUROPEPTIDES

W. G. Z. O. Jura

The identification of insect neuropeptides represents an important challenge for future scientific research. These peptides control fundamental physiological and metabolic processes (i.e. they are the master regulators of insect development, metabolism and homeostasis or molecular messengers that allow coordination of insect tissues).

Apart from the intrinsic, basic scientific value of identifying the substances, the neuropeptides have the potentials for application in the field of insect control. For example, (a) incorporating neuropeptide or "antineuropeptide" genes in the genome of insect specific viruses to enhance the pathology of infection by the over production of the gene product; (b) developing control agents that could block or overstimulate the secretion of a neuropeptide; (c) designing of peptide mimetics that can penetrate the insect cuticle or gut and block or overstimulate the peptide-mediated response at the target cell; (d) the use of receptor assays to screen rapidly for stable insecticidal materials in culture broths or plant extracts.

Our initial objective is to carry out studies aimed at identifying neurosecretory substances (myotropic factors) involved in the stimulation/modulation of parturition (larviposition) and ovulation in tsetse, *Glossina* species.

The specific objectives of this study were, (1) to identify and document the syndrome of behavioural characteristics associated with parturition and ovulation; (2) to monitor rhythmic pulses of muscular activity prior to and during parturition and ovulation in *G. m. morsitans*.

Female *G. m. morsitans* with final stage of pregnancy were identified, isolated into transparent vials and their behaviour observed and recorded. Muscular activity was

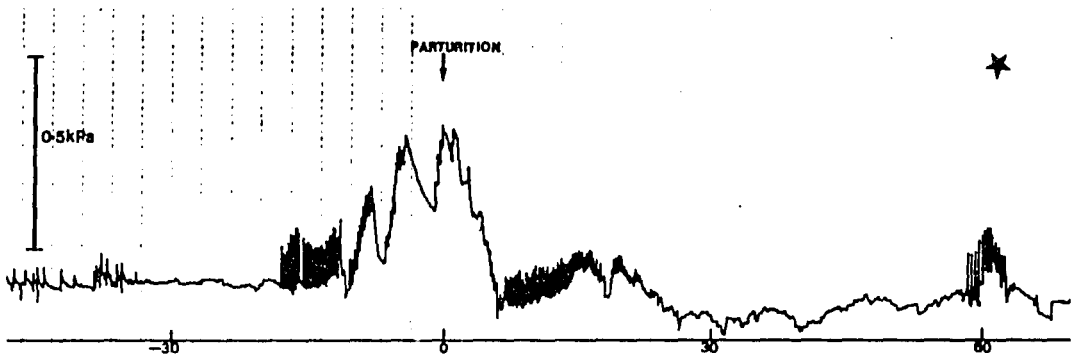

Figure 7.10 Barograms of haemolymph pressure pulses recorded 30 min before, during and 30 min following parturition.

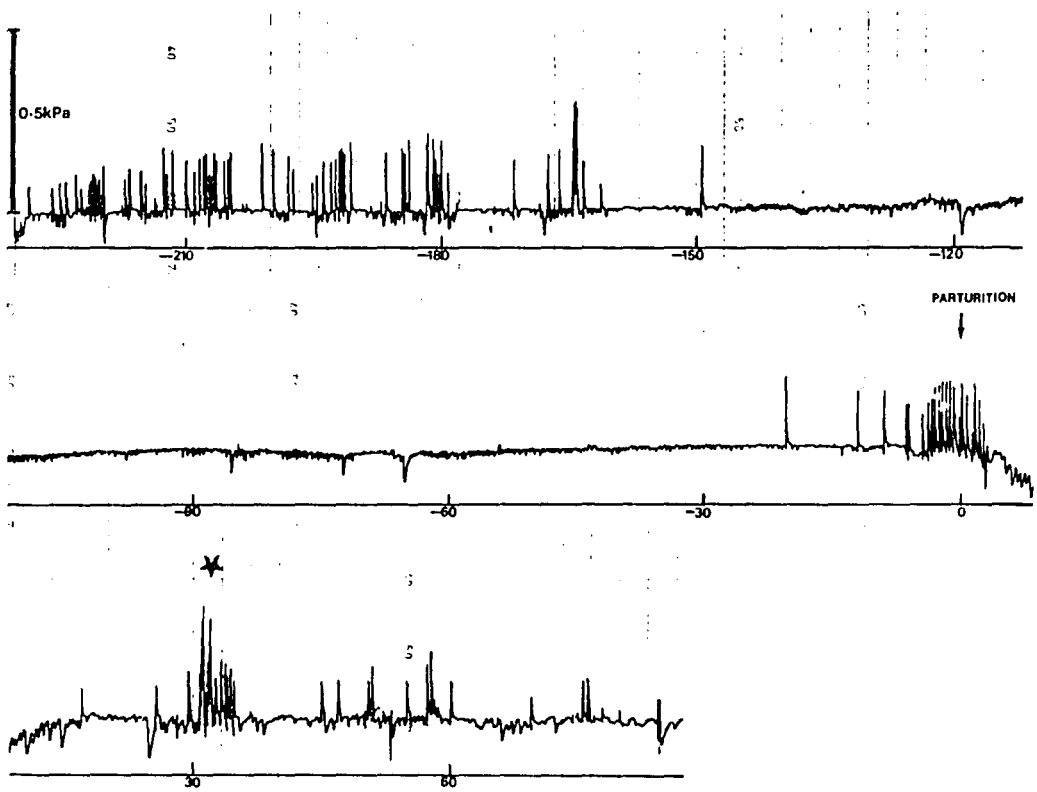

Figure 7.11 Barograms of haemolymph pressure pulses recorded 3 hours before parturition.

monitored in pregnant *G. m. morsitans* females at defined stages of behaviour using a barographic apparatus in which the haemocoel of the female was hydraulically connected at the dorsum of the thorax with a strain gauge transducer. Changes in haemolymph pressure caused by muscular contractions were continuously monitored and recorded. The pressure curves, barograms, served as an objective record of the muscular activity pertinent to parturition and associated reproductive events.

During the periods before and after larviposition,

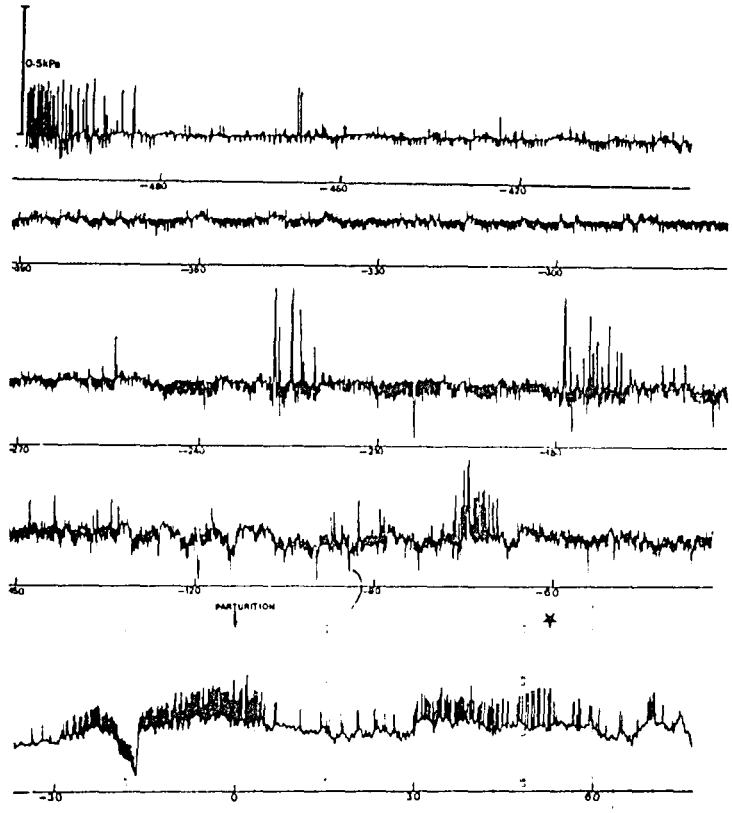

Figure 7.12 Barograms of haemolymph pressure pulses recorded 8 hours before parturition.

the expectant flies were observed to go through a syndrome of repetitive behaviours which occurred in episodes of variable durations, intercalated by periods of quiescence. An episode consisted of any or a combination of the following behavioural manifestations: Jumping up and down the vial; climbing the wall of the vial then falling to the bottom on the back; turning behaviour (fly turns rapidly to the left then to the right); scratching soothingly at the lower abdomen and back with the last pair of legs; swaying of vulval region; arching of back; pushing accompanied by throbbing of the lower abdomen and vulval opening; pushing and scratching lower abdomen and back. Parturition was always preceded by a quiescence period. The process started with a forceful thrust accompanied by throbbing of the base of the proboscis; later, the vulval region was pressed down and eventually the larva slipped out. The actual expulsion of the larva took about 3–5 seconds. After parturition, the fly remained quiet, with the abdomen tacked in, for a fairly protracted period (0.5–1.5 hours) before resuming a display of the same behavioural characteristics as had been observed before the expulsion of the larva.

Barograms of haemolymph pressure pulses, representative of various timecourses before and after parturition, are presented in Figures 7.10, 7.11 and 7.12. In each category, complete records from at least five females were obtained. Recordings made within 30 minutes before parturition (Figure 7.10) depicted only one bout of pressure pulses, mostly positive in relation to the baseline, that gradually increased in frequency and intensity, culminating in expulsion of the larva. Each pulse was associated with a characteristic bobbing of the female's proboscis. The proboscis was initially depressed to well below its normal, horizontal position and then raised. Larviposition was followed by a variable number of positive pulses which then diminished gradually to the baseline. About 0.5–1.5 hours following parturition, additional bout of positive pressure pulses were recorded which were also characterised by bobbing of the proboscis.

When recordings started about 3 hours before parturition (Figure 7.11), another bout of pulses in addition to the one associated with actual larviposition was registered. In cases where about 8 hours elapsed before parturition (Figure 7.12), four other bouts of pressure pulses were registered in addition to the one associated with actual larviposition.

This study has elucidated that larviposition in tsetse simulates parturition in mammals. The phenomenon is preceded by and associated with, a syndrome of complex behavioural characteristics and bouts of haemolymph

pressure pulses, the latter depicting muscular contractions involved in the expulsion of the larva. The study has documented, further, that the muscular contractions which eventually culminate in parturition in tsetse start long before (over 8 hours) the actual expulsion of the mature third instar larva. The contractions occur in pulses and are probably stimulated by myotropin(s) released in aliquots.

SENSORY PHYSIOLOGY RESEARCH UNIT

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8

Sensory Physiology Research Unit

The Sensory Physiology Research Unit (SPRU) supports ICIPE core research programmes through research in insect behaviour and in their sensory systems in order to better understand insect behaviour patterns such as host finding, host selection, feeding, mating and oviposition. Understanding of these patterns is crucial for manipulating behaviour of pest species and in order to formulate effective pest management strategies.

During 1991, the research focused on the following areas:

- *Banana weevil* (Cosmopolites sordidus) *semiochemicals in collaboration with CBRU*
- *Ovarian development of the banana weevil*
- *Mating and oviposition behaviour of the cowpea pod borer* — Maruca testulalis
- *Feeding patterns of third instar* Chilo partellus *larvae*
- *Pheromones of tsetse* (Glossina m. centralis *and* G. m. morsitans) *larvae and larviposition behaviour in collaboration with CBRU*
- *Close range kairomones of tsetse flies in collaboration with CBRU*
- *Artificial feeding technique for the tick,* Rhipicephalus appendiculatus
- *Odour attractants for tropical mosquitoes*
- *In addition, the Unit is playing a major role in the Locust Research Programme's project on semiochemicals of the desert locust,* S. gregaria. *Research on the oviposition-aggregating pheromone, host plant kairomones, and effect of various food plants and their cultivars on the development and phase characteristics are all based in SPRU.*

Important achievements include demonstration of pheromones from tsetse fly larvae which attract gravid females, presence of an oviposition-aggregating pheromone in the desert locust, S. gregaria *and the development of an artificial feeding technique for ixodid ticks.*

8.1 BANANA WEEVIL SEMIOCHEMICALS

W. J. Budenberg, F. W. Karago and I. O. Ndiege

The attraction of female banana weevils, *Cosmopolites sordidus*, by a comparatively resistant cultivar called "Wangae" in Kikuyu (dessert type, AB, also known as "Sukali Ndizi") was compared with that by a susceptible cultivar called "Githumo" in Kikuyu (cooking type, East African Highland AAA), in a dual-choice still-air olfactometer. Bioassays were carried out both with freshly cut rhizomes and pseudostems, and with porapak-trapped volatiles from them. There were no significant differences in the responses of the weevils to the two cultivars for any type of material, but responses were consistently slightly stronger to "Githumo". This suggests that the comparative resistance of "Wangae" is not due to it not being attractive to the weevil. There are, however, qualitative and quantitative differences in the components present in the volatiles collected from the two cultivars (for details see CBRU report).

Studies on the male-produced aggregation pheromone have progressed. Male and female antennae give significant EAGs to collections of volatiles from male weevils, but not to those from females (Figure 8.1). Surface washes of the body and extracts of the hindgut and the remainder of the body were made separately for male and female weevils, using dichloromethane. EAG responses were recorded to the extracts of male hindguts and male bodies, but not to male surface washes. No EAG responses were recorded to the wash or extracts from females. This suggested that the pheromone was released via the hindgut

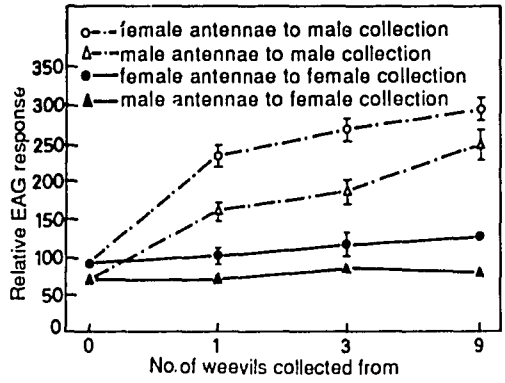

Figure 8.1 The EAG responses (Means ± S.E., as % of response to 10 µl of 10^{-1} nonanol in paraffin oil) of male and female *Cosmopolites sordidus* antennae to volatiles trapped on porapak from different numbers of conspecific males and females.

results from the behavioural bioassay showed that females were attracted to dissected male hindguts, but not to those from females. GC-EAD studies suggest that there are three EAG-active components in the collections of volatiles from males, which are currently being identified.

8.2 OVARIAN DEVELOPMENT OF THE BANANA WEEVIL, *COSMOPOLITES SORDIDUS*

R. P. Uzakah

The ovarian development of the banana weevil is being investigated in order to understand the reproductive biology of the pest. Dissections performed at 2-day intervals on a collection of newly emerged females, each paired with two sexually mature males and kept in an incubator at 25 ± 2°C (12L : 12D), revealed the following: (1) that the earliest age at which insemination occurred in the females of this pest is 6 days after emergence (DAE) and that all females were mated (inseminated) by 18 DAE, (2) that the entire process of ovarian development can be categorised into four distinct stages. Stage I is characterised by the complete absence of oocytes in the ovarioles; and this is typical of adult females from 1–18 DAE. Stage II is characterised by presence of undeveloped oocytes in the vitellarium of ovarioles (17–28 DAE). Stage III is characterised by the presence of developed (but not chorionated) oocytes in the vitellarium (20–56 DAE). The presence of chorionated eggs signifies Stage IV, and this is typical of fully matured and ovipositing adults (32 DAE and above).

Monthly surveys are currently being undertaken to determine the ovarian state of field collected females. These will reveal the egg-laying potential of females throughout the year, and the information obtained here will be useful for planning control practices.

8.3 MATING BEHAVIOUR OF *MARUCA TESTULALIS*

S. M. Waladde, W. Lwande, E. D. Kokwaro, S. A. Ochieng and F. Onyango

Controlled temperature, humidity and reversed light: dark cycle conditions were used when observing the mating habits of the pod borer *Maruca testulalis*. Soon after scotophase onset, some females started exposing their ovipositors and assuming a calling posture while some males displayed their hair-pencils and darted around the cage bumping into stationary females. Just before mating, a male attracted to a calling female, had to immobilise her swiftly waving antennae with a fiber-like material. This material was abundant in the hair-pencils on the male's abdominal tip. Scanning electron microscopy revealed that the hair-pencil material was composed of structures resembling stacks of well-organised hollow beads (Figure 8.2).

Electrophysiological bioassays (electroantennogram EAG tests) of crude extracts from the ovipositors and hair-pencils confirmed that the female antennae were more

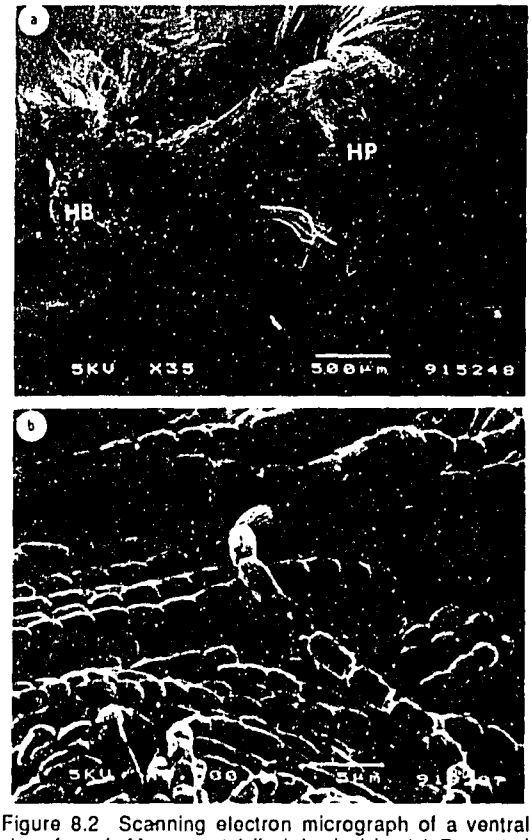

Figure 8.2 Scanning electron micrograph of a ventral view of a male *Maruca testulalis* abdominal tip. (a) Protracted abdominal tip with hair brush (HB) and hair-pencils (HP); arrow indicates location of bead-like structures in the hair-pencils; (b) High magnification of the bead-like structures.

Electrophysiological bioassays (electroantennogram EAG tests) of crude extracts from the ovipositors and hair-pencils confirmed that the female antennae were more sensitive to the hair-pencil odour than to the ovipositor odour, but the reverse was true for the male antennae. Furthermore electroantennographic detector tests (EAD) indicated that the ovipositor odour had a component specifically detectable by the males but not the females. On the other hand none of the hair-pencil extract components was biologically active. The antennae sensilla of both sexes could only respond to the complete blend in that extract.

These results suggest that odours produced by both sexes may be playing vital roles in facilitating successful courtship behaviour and a basis for carrying out further investigations on the pheromone system of this pest has been established.

8.4 SEQUENCE OF EVENTS IN THE OVIPOSITION BEHAVIOUR OF *MARUCA TESTULALIS*

D. D. S. Bawo

Studies on the oviposition behaviour of *Maruca testulalis* were carried out with the aim of establishing how the ovipositing female interacts with host, non-host plants and potential artificial oviposition substrates. This exercise was intended to generate information about the properties of oviposition stimuli and the sensory structures involved in this biological activity. Observations were carried out under laboratory conditions with controlled temperature, humidity and a light regime of 12:12 light:dark cycle.

Gravid females ready to lay eggs displayed the following behavioural events during oviposition bouts on the host plant (cowpea): antennae waving, feeding, flight, walking, abdomen bending, pulsating of the terminal abdominal segments, wing twitching, dragging of the ovipositor tip, and searching with ovipositor before egg deposition. These events occurred in various sequences as shown in Figure 8.3. At onset of darkness, the moth was observed sitting quietly while waving the antennae. Sometimes the antennae touched the surface of the cage

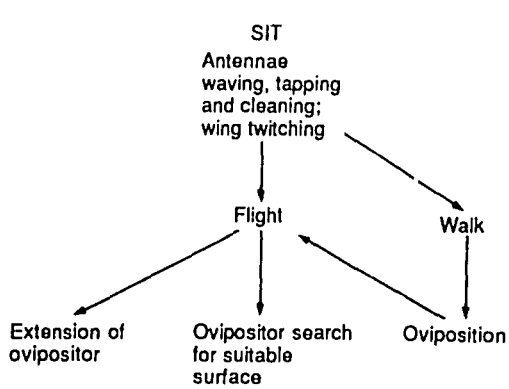

Figure 8.3 Sequence of activity in oviposition behaviour of *Maruca testulalis* on a host plant (cowpea).

in a slow tapping manner. She then flew onto the plant or substrate, bent her abdomen downwards, sometimes dragging the ovipositor tip along the surface while walking. Before releasing an egg the moth paused, extended the ovipositor further while scanning the surface and then an egg was immediately deposited. She immediately flew away and landed on another area and repeated the same procedure. The deposition of eggs at any one position was immediately followed by flight. Each bout of oviposition lasted 6–18 minutes (mean 9 ± 2 min.). On average three bouts were observed within the six hours observation time with rest periods that varied between 32 and 97 minutes. About 4 to 62 eggs were laid in a bout. Most of these activities occurred in the early part of the dark period. The female was generally quiescent in the latter part of the dark period.

The ovipositor and the antennae were very much involved in the oviposition process especially in locating the site for egg deposition. These structures are armed with various types of sensilla. Light and electron microscopy studies are in progress to identify the types of these sensilla and establish their possible role in oviposition behaviour. It is however suggested that these sensilla probably detect chemical and physical stimuli on the oviposition surface.

Studies to investigate how this basic oviposition pattern differs when a female encounters a non-host plant (cotton) are in progress.

8.5 TUNNELLING OF INBRED A MAIZE STEM BY *CHILO PARTELLUS* LARVAE

P. G. N. Njagi and H. M. Kahoro

Third instar and older larvae of *Chilo partellus* were reported to show a distinct distribution of tunnelling in the stems of Inbred A maize in the field (*ICIPE 1989 Annual Report*). Investigations were undertaken to determine whether the observed distribution of the larvae in the stem and other growing parts of Inbred A maize plants e.g. the tassel and ears is influenced by the chemical content in these parts. Stems of Inbred A maize at the tasseling stage (7–8 weeks after emergence) grown in a field cage to prevent damage by the wild population were harvested and divided into various parts; lower, middle, and upper nodes and internodes separately; tassel stalks; tassels; and the young ears. These were freeze-dried, machine ground and extracted in four solvents separately: distilled water (W), methanol (MeOH), Hexane (H), and ethyl acetate (Etac). Extracts of the lower internodes with the first three solvents tested at an equivalent concentration impregnated on cellulose acetate membrane discs, have shown the following sequence of the amount of the substrate ingested as an indicator of their phagostimulatory effectiveness: MeOH> W >>H.

This study is being extended to the various extracts of the other parts of the maize plant. It is intended to find out whether there are differences in the phagostimulatory effectiveness of the various extracts or the components there-in that may correlate with or show a relationship to the observed larval distribution.

8.6 PHEROMONES OF TSETSE LARVAE ATTRACT GRAVID FEMALES TO LARVIPOSITION SITES

D. E. Leonard†, R. K. Saini, J. Andoke and P. Ahuya

In some species of tsetse flies aggregation of puparia can be often found at sites with similar specific characteristics. These aggregations of puparia have been considered to be due to several factors including a putative pheromone. One set of workers demonstrated that the anal exudate of *G. m. morsitans* larvae was attractive to females at parturition; however, their experiments were repeated and the results refuted by other workers.

We examined this phenomenon in *G. m. centralis* and found that pregnant females in a choice test preferred (69%) to larviposit in moist sand previously conditioned by larval pupariations as compared to unconditioned, sterile sand (32%). When we provided gravid *G. m. centralis* a choice of dry conditioned vs dry unconditioned sand, flies displayed no preference indicating that the pheromone is only effective in the presence of moisture. Similar results were obtained with *G. m. morsitans* flies.

To confirm that female *G. m. morsitans* and *G. m. centralis* detected a putative pheromone from sand in which pupariation had occurred, electroantennograms (EAGs) were recorded to hexane extracts of conditioned sand (Figure 8.4). EAGs increased with increasing doses of the pheromone in hexane indicating that the larviposition pheromone is perceived through olfactory receptors on the antennae. Results also indicated that the two sub-species were sensitive to each other's pheromone.

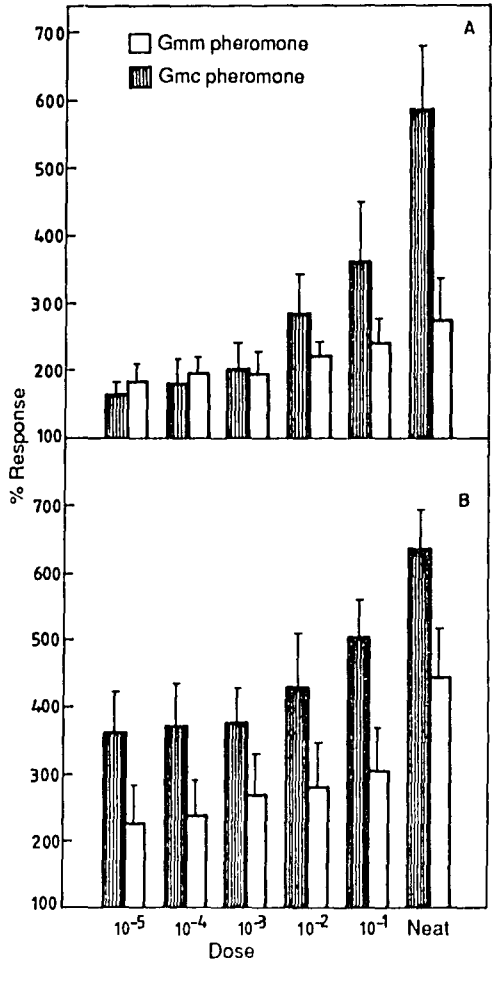

Figure 8.4 EAG responses of *Glossina morsitans centralis* (A) and *G. m. morsitans* (B) to various doses of their own larval pheromone and to the larval pheromone of the other sub-species. Responses are expressed as a percentage of the response to hexane (reference signal) n = 8 antennae.

Current methods to manage tsetse flies rely on odour and visual cues to attract adults to traps or insecticide - impregnated targets. Capture of gravid females by baited traps, however, is extremely rare. This phenomenon reduces the effectiveness of the baited traps. The identification and synthesis of the larviposition pheromone might be of considerable value as an additional odour cue to attract gravid females, and increase the effectiveness of traps and targets.

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8.7 CLOSE-RANGE KAIROMONES OF TSETSE FLIES

R. K. Saini, A. Hassanali, J. A. Andoke, P. Ahuya and E. Nyandat

Kairomones, present on the bodies of host animals, at close range, induce arrestment, alighting and probing in tsetse flies *G. m. morsitans* (See *ICIPE 1990 Annual Report*). Identification of these kairomones is in progress. However, this is quite complex as active compounds are present in all the fractions. Moreover, these compounds of different polarities and functionalities act in a synergistic manner in affecting tsetse behaviour at close range.

8.8 IMPROVEMENTS AND APPLICATIONS OF THE TECHNIQUE FOR FEEDING *RHIPICEPHALUS APPENDICULATUS* ARTIFICIALLY

S. M. Waladde and S. A. Ochieng

The method used to feed *R. appendiculatus* artificially has been consolidated. In addition to feeding adults to repletion, it is now possible to feed nymphs to repletion in large numbers (Figure 8.5). The available set up permits using several feeding devices with different treatments of the feeding media. Work is already in progress to artificially infect *R. appendiculatus* with some of the economically important pathogens. Success in this attempt will open up new experimental work which cannot be done on a live host. Most of this work has been done

Figure 8.5 *Rhipicephalus appendiculatus* nymphs attaching to the artificial membrane and engorging on the cattle blood placed under the membrane.

with regular replenishing and changing of blood presented to the ticks in order to maintain its freshness and palatability. This approach is tedious and demands much attention. In order to overcome this problem a feeding device with continuous blood flow system has been developed (Figure 8.6). When this device is perfected, it will be possible to rear large numbers of ticks without maintaining many expensive natural hosts currently required for tick rearing.

8.9 OVIPOSITION-AGGREGATING PHEROMONE OF THE DESERT LOCUST, *SCHISTOCERCA GREGARIA*

R. K. Saini, M. Rai, A. Hassanali, H. Odongo, J. A. Andoke and P. Ahuya

Behavioural and electrophysiological studies undertaken confirm the presence of an oviposition pheromone which stimulates aggregation of gravid females. Experiments to determine the origin and the chemical nature of the pheromone using behavioural and electrophysiological techniques are in progress. More details of this work are presented in the Locust Research Programme section of this report.

8.10 HOST-PLANT KAIROMONES OF THE DESERT LOCUST, *SCHISTOCERCA GREGARIA*

P. G. N. Njagi

Airborne volatiles from several host plants of the desert locust — *Sorghum bicolor*, wheat seedlings (*Triticum* sp.) and Kikuyu grass shoots (*Pennisetum clandestinum*) that are being used for their mass-rearing — were tested in a Y-olfactometer to determine their attractivity for early fifth instar nymphs of gregarious and solitary reared *S. gregaria*.

Results indicate that, volatiles from plants whose leaves had been artificially damaged attracted a higher proportion of the nymphs than volatiles from intact plants. Also, there was preference for the air-borne volatiles from the host plant used as the rearing food. More details of this work are presented in the section on Locust Research Programme.

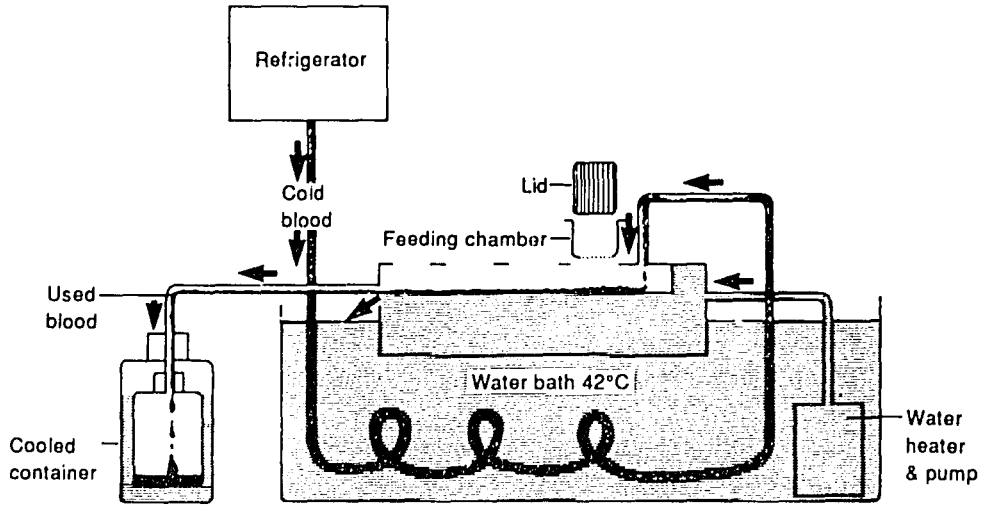

Figure 8.6 Tick feeding device with four feeding chambers supplied with a continuous flow of blood.

8.11 EFFECTS OF VARIOUS FOOD PLANTS ON THE DEVELOPMENT AND PHASE CHARACTERISTICS OF THE DESERT LOCUST, *SCHISTOCERCA GREGARIA*

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

Experiments to study the effects of various food plants on the development and phase characteristics of the desert locust have been initiated. Three types of host plants, *Sorghum bicolor*, *Triticum* sp. (wheat seedlings) and *Pennisetum clandestinum* (Kikuyu grass) were used. First instar nymphs of *S. gregaria* were fed with these three plant varieties from the first day upto adult maturation. Developmental periods, weight of instars, mortality, adult maturation periods, fecundity of adult females and morphometric characters of adults were measured during the parental generation, (this study will be continued till the F_3 generation).

Preliminary results indicated that the period required for hopper development and to complete one generation is lower with *Sorghum* and higher with *Pennisetum*. Mortality during hopper development is also 2–3 times higher with *Pennisetum* than with *Triticum* and *Sorghum*. Colour patterns during hopper and adult stages and morphometric characters showed no significant differences in the parental generation. However, the colour patterns and morphometric characteristics will be monitored till the third filial generation as these may take time to manifest.

8.12 POTENTIAL OF 1-OCTEN-3-OL, ACETONE, 2-BUTANONE AND COW URINE AS ATTRACTANTS FOR TROPICAL MOSQUITOES

L. Nwoke and R. K. Saini

Experiments are in progress to determine the attractancy of various natural and synthetic compounds to tropical mosquitoes. Initially, compounds known to be attractants for other haematophagous insects like tsetse were tested. Studies were initiated to determine the attractancy of 1-octen-3-ol (hereafter referred to as octenol), acetone,2-butanone and cow urine to mosquitoes in Mwea Rice Irrigation Settlement (100 km north-east of Nairobi). Initially the following four preliminary experiments were undertaken.

(1) Experiments were undertaken to determine the optimum release device to be used with CDC traps. Octenol dispensed from 10 ml glass vials covered with aluminium foil with one hole (3.3 mm diameter) with dose of approximately 2.7 mg/h attracted more mosquitoes than from the following devices: (i) when octenol was released from vial closed with rubber septum containing a pin hole (release rate approximately 0.2 mg/h); (ii) vials sealed with rubber septum with a A-shaped wick with the apex of the wick protruding 2 cm from the septum (11.6 mg/h); and (iii) octenol vial with 5 cm protruding wick covered with a Pasteur pipette with an apical aperture of 1.5 mm diameter (dose approximately 1.3 mg/h).

(2) Experiments were conducted to determine the attractancy of mosquitoes to various doses of octenol. Octenol was dispensed from 50 ml glass vials covered with aluminium foil with one, two, or three holes (each hole was 3.3 mm diameter). Octenol released from vials containing two holes with release rate of approximately 3.1 mg/h was found to be a good attractant and increased trap catches 10x relative to unbaited traps (control). The catches decreased with one- or three-hole treatments.

(3) Experiments were also undertaken to determine the best possible position and distance the odour source should be placed from the CDC trap entrance in order to maximise attractancy. Octenol dispensed from vials with two holes was used per treatment. Results indicated that octenol source placed at 6 cm below the trap entrance attracted more mosquitoes than those placed at 6 or 12 cm above or 12 cm side ways from the trap entrance.

(4) Once the dispensing system and the place of the odour bait was ascertained, experiments were undertaken to determine the efficacy of octenol, acetone, cow urine and 2-butanone for attracting mosquitoes. Each odour was released from 50 ml glass vials with one, two or three holes. The experiment for each bait was run for 16 h/day for 4 days. Odour baits were placed at 6 cm below each trap entrance. In all cases, doses of octenol (approximately 3.1 mg/h), acetone (25 mg/h), and cow urine (2 mg/h) released from vials containing two holes attracted more mosquitoes. Decreasing doses (one hole) or increasing doses (three holes) of these baits reduced mosquito catches. However, mosquitoes responded more to 2-butanone doses from three holes with a release rate of approximately 17.6 mg/h than to 2-butanone doses from one or two holes. This result necessitates further investigations into mosquito responses to higher doses of 2-butanone (from 3, 4 or 5 holes). Further experiments indicated that 2-butanone vials containing three holes with a release rate of approximately 19 mg/h attracted more mosquitoes than the doses from four or five hole treatments.

After the above preliminary experiments, the efficacy of octenol, acetone, cow urine and butanone in attracting mosquitoes was investigated in a 4 x 4 Latin square design at two different sites. The baits were dispensed from 50 ml glass vials covered with aluminium foil with two holes for octenol, acetone and cow urine respectively and three holes for butanone. The experiment was run for 16 h/day for 4 days in each site.

Octenol increased trap catches 8x, acetone 6x, 2-butanone 1.3x and cow urine 1x relative to unbaited traps. Eleven mosquito species were trapped by the various odours. The predominantly caught species for all the odours were *Anopheles gambiae*, *Culex quinquefasciatus* and *Anopheles funestus* (Table 8.1). Some males were also caught independently in odour baited traps. The catch of male:female was 1:10 respectively. Why male mosquitoes were attracted to mammalian odour baited traps is not known, though they may be coming to traps for mating.

Table 8.1 Number of mosquitoes caught (log mean catch) per trap per day[1] with CDC traps baited with various odours in Mwea-Tebere Rice Irrigation Scheme

	Baits (with approximate dose release rates)			
Species	Octenol (3.43 mg/h)	Acetone (25.0 mg/h)	Butanone (17.6 mg/h)	Cow urine (2.0 mg/h)
Anopheles gambiae	2.036[a]	1.176[b]	1.623[bc]	1.527[c]
Anopheles pharoensis	1.171[a]	0.942[ab]	0.874[b]	0.887[b]
Anopheles funestus	1.135[a]	1.121[a]	0.968[a]	1.009[a]
Anopheles ziemanni	0.536[a]	0.511[a]	0.410[a]	0.266[a]
Anopheles rufipes	0.473[a]	0.429[a]	0.383[a]	0.353[a]
Culex quinquefasciatus	1.488[a]	1.341[a]	1.123[b]	1.133[b]
Culex poicilipes	0.744[a]	0.574[a]	0.570[a]	0.545[a]
Culex antennatus	0.351[a]	0.232[a]	0.298[a]	0.231[a]
Culex univittatus	0.363[a]	0.329[a]	0.173[a]	0.135[a]
Mansonia uniformis	0.429[a]	0.276[a]	0.270[a]	0.282[a]
Mansonia africana	0.419[a]	0.502[a]	0.282[a]	0.270[a]

[1]n = 8 days.
Means in the same row followed by the same letter are not significantly different ($P > 0.05$); Duncan multiple range test (SAS Institute, 1985) applied to Log(n+1) transformed data.

Out of the 11 species caught, females of seven species and males of two species were trapped in large numbers (Figure 8.7). The response of female *Anopheles gambiae* to odour baited traps is significantly affected by day the experiments were conducted ($P > 0.004$), the odour bait used ($P > 0.001$) and the physiological state (empty, fed half gravid and gravid) of the mosquito ($P > 0.001$). Duncan multiple range test on the physiological state of female *Anopheles gambiae*, showed that hungry mosquitoes with an empty gut (means of 1.66) are significantly more attracted to odour baited traps than the fed (blood fed, half gravid and gravid) mosquitoes with mean catch of 0.89 (Figure 8.8). Microclimatic factors have also been shown to significantly affect the mosquito catches.

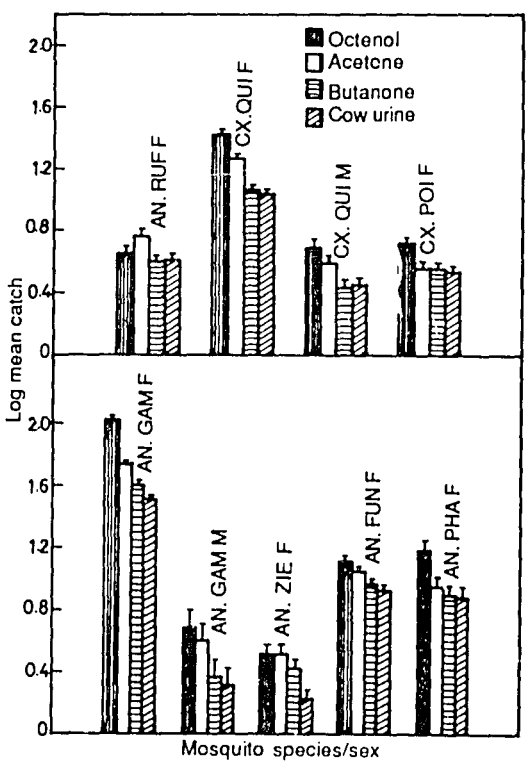

Figure 8.7 Number of mosquitoes caught (expressed as log mean catch) with octenol, acetone, 2-butanone and cow urine in Mwea Irrigation Settlement. An. ruf, *Anopheles rufipes*; Cx. qui, *Culex quinquefasciatus*; Cx. poi; *Culex poicilipes*; An. gam, *Anopheles gambiae*; An. zie, *Anopheles ziemanni*; An. fun, *Anopheles funestus*; An. pha, *Anopheles pharoensis*; M, Male; F, female.

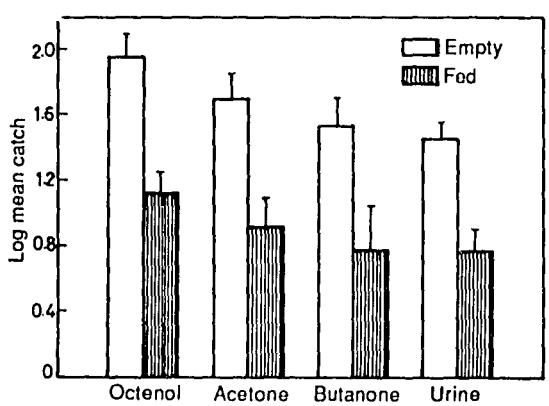

Figure 8.8 Physiological state of female *Anopheles gambiae* caught (expressed as log mean catch) with various odours.

Studies undertaken so far indicate that odour baited trapping is a good tool for sampling and/or controlling mosquito populations. Studies to screen various other natural and synthetic compounds for attractancy to mosquitoes are in progress. Investigations are also being initiated to determine how these odours alone or in various combinations affect mosquito behaviour.

BIOMATHEMATICS RESEARCH UNIT

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9

Biomathematics Research Unit

Activities during the year were largely of consulting (biostatistical and computing) and training nature. Research in modelling continued but at a very slow pace following the long absence from the Centre of the Head of Unit, the departure of a Senior Research Scientist and a Post-doctoral fellow, and delay in the recruitment of new staff. The appointment of a Senior Application Specialist (Statistics) for BMRU at MPFS will strengthen biostatistical support for the Crop Pests Research Programme and the Oyugis sub-Station.

Collaboration with the University of Illinois, Urbana-Champaign, in the Tsetse/GIS USAID funded project was initiated. The overall goal of the project is "the utilisation of ARC/INFO GIS, spatial analysis and expert systems in the development of tsetse management". All the objectives for the first year of the project were accomplished successfully. More particularly, results of the collaboration have enhanced the resources and GIS expertise of researchers at ICIPE and Illinois, and generated summary maps and graphs useful to collaborating researchers outside the GIS project.

Staff of BMRU made substantial contribution to the East/Central/Southern African network of the Biometric Society, and actively participated in the second scientific meeting held in Harare, Zimbabwe.

9.1 BIOSTATISTICAL CONSULTANCY

D. Munyinyi

We devised a new approach which resulted in considerable reduction of time spent on non-statistical routine work, such as data conversion and organisation for onward export to statistical packages. Unlike 1990, the time spent on data management during statistical consultancy was in the range of 35 to 45%; and this was mainly in the area of specialised inputting as certain type of analyses required data to be keyed in a particular pattern.

Table 9.1 shows approximate time spent on data analysis and management by programme/unit, for both Duduville and MPFS.

The low percentage for SSIRU is due to the location of a full time statistician in that unit. The OTHERS portion at Mbita Point combines statistical services provided to ARPPIS students and non-CPRP staff based at MPFS. A considerable amount of time was also spent on certain specialised types of analyses, namely, repeated measures analyses for data sampled from same unit over a period of time.

SAS and MSTATC packages continue to play a central role in our statistical analyses work. The new upgrade of SAS (Release 6.04) contains two very useful and powerful procedures, namely PROC LOGISTIC for handling logistic regression models for binary and ordinal

Table 9.1 Distribution of time for data analysis

Programme/Unit	Per cent time
Duduville	
IBIRU (ARPPIS)	29
LTRP	17
MVRP	15
LRP	7.5
SPRU	7.5
CBRU	6
TRP	6
CPRP	4.5
CRU	1.5
IABU	1.5
SSIRU	1.5
IBIRU (PESTNET)	1.5
Outsiders coming to ICIPE	1.5
Mbita Point	
CPRP	85
Others	15

response data and PROC CALIS for analysing covariance structures, fitting systems of linear structural equations and path analysis. The acquisition of SYSTAT will further boost and enhance our capability, especially in its ability to handle huge data sets with particularly many variables. Its capabilities are being explored together with the data archiving package DATACHAIN from the International Centre for Research in Agroforestry (ICRAF).

9.2 TRAINING

S. Nokoe

Training courses in statistics were conducted during the year. These included the annual 4 weeks ARPPIS Biostatistics course (given by Dr. Nokoe of BMRU and Dr. Oyeke from Anambra State University, Nigeria) at Duduville, and a 3-week group training course on "Efficient data collection, analyses and interpretation in pest management" at MPFS/Duduville. Topics covered in the 3-week group training course included:

- Mathematics in pest management
- Entomological data types
- Qualitative and quantitative variables
- Use of computers in data inputting
- Data collection methods
- Parametric relationships
- Data examination and screening
- Classification analysis
- Construction of sequential charts
- Demonstration of a computer simulated model (SLM3A)
- Descriptive statistical methods for data analysis
- Measuring aggregation
- Measuring diversity
- Computer maintenance and safeguards
- Data analysis on SAS or MSTATC
- Estimation of sample size

A simplified manual, covering the above topics is being prepared.

Formal interval training in computing was deliberately slowed down to assess its impact over the years. Apart from the ARPPIS class, most of our computer training was informal throughout the year. However it was intended to be an observation over a one year period as regular computer classes will resume in 1992.

Two BMRU staff, Onyango Okello and Henry Meena returned from staff development training in Geographic Information Systems, while Japhet Ngoya and Kennedy Chitata (SSIRU) participated in a 4-weeks training workshop on "Statistics in Agriculture" at the University of Zimbabwe.

9.3 COMPUTING

J. M. Otedo

Slide production activities were moved from GIS to Computing (to give the GIS group more time to concentrate on GIS activities), following the appointment of a Graphics Technician.

Repairs of computer hardwares were done entirely internally and most of breakdowns received immediate attention.

The Software Specialist had enough time to analyse, design and implement the following databases:

- Flight Travel Information System — for Communications
- Project Donor and Grant Information System — for PDU
- Library Book Borrowing Information System

It was realised that there should be a central research database for all research activities, possibly networked to several programmes of ICIPE through a local area network. Discussion is under way on the future networking of computer systems of ICIPE; the set-up in the Library serving as a demonstration unit. BMRU has increasingly recognised the need to have a planned Computer System development that takes cognisance of the possibility of future networking. Whatever hardware networking topology is intended to be used, should seriously consider compatibility with other LANs existing in ICIPE as a major priority.

The year 1991 saw the purchase of an additional wordprocessor WordPerfect Ver. 5.1 to supplement the existing Microsoftword. This greatly enhanced the quality of documents for final drafts. Three HP Laserjet Printers were also purchased to boost the single one available in the Library.

The Computer virus menace was finally conquered as more software became available for detection, inoculation and removal.

The use of computerised project planning was finally launched, and started with the teaching of PDU staff on the capabilities and use of INSTAPLAN, a project planning computer program. It is intended to extend this awareness course to Programme Leaders, Research Scientists and their assistants, and ARPPIS students. Plans are also under way to streamline the electronic filing system within ICIPE, to ease tracing of documents from the computer.

9.4 ACTIVITIES OF GEOGRAPHICAL INFORMATION SYSTEM SECTION

J. Mirangi

The section was strengthened with the appointment of a GIS technician who became involved in GIS data acquisition and information production. It is encouraging to note that all the staff in the section have acquired relevant experience and exposure through attendance at short-term training courses.

The section has continued to provide GIS consultancy, environmental data acquisition, map preparation and trainning to ICIPE Staff.

Data for elevation, river distribution, roads network and water points at Tsavo Rhino Sanctuary were digitised as part of a project being carried out by the Tsetse Research Programme in collaboration with Kenya Wildlife Service (KWS) to identify tsetse distribution patterns.

Intensive work has been done in analysing 1987 data and producing stem borer damage levels and yield dis-

tribution maps for Vallee du Kou irrigated rice scheme at Burkina Faso. This project aims at establishing an efficient and profitable insect pest management system. The spatial analysis for 1987 and data analysis for 1986 and 1987–1990 is scheduled for next year.

Agro-climatic information for Kwale, Kilifi, Bungoma, Busia and Siaya districts were acquired for the Bio-control group. The GIS section, teaming up with the Bio-control group, designed a methodology of collecting stem borers distribution data in these districts which can be subjected to analysis using the GIS.

Collaboration with the Graphics team in the computing section of the Unit led to the production of maps of Tsetse distribution in Kenya.

9.5 SYNTHETIC APERTURE RADAR DATA PROCESSING AND ITS APPLICATION AT ICIPE

H. H. Meena

9.5.1 General introduction

Satellite remote sensing is entering a new phase with microwave sensors expected to play a greater role in data collection. The current operational satellites largely employ optical sensors that are limited in their data collection due to the presence of clouds, haze, fog, rainfall and so on which act as barriers between the objects of interest and the satellite sensors. Microwave sensors, e.g. Synthetic Aperture Radar (SAR), are designed to overcome this problem so that reliable and timely data can be gathered, as they can see through atmospheric obstacles.

Since the use of microwaves in remote sensing is a relatively new technology, new methods of processing the data collected are required. Currently the techniques of image processing are based on optical sensors and consequently do not yield satisfactory results e.g. in classification and image rectification when applied to SAR data. This is attributed, among others, to the problems of speckle and geometric distortions in the images.

Remote sensing provides much of the information that is input to a Geographical Information System (GIS). GIS are systems that are designed for the purpose of gathering, storing, processing and providing a wide variety of geographically referenced information that may be relevant to research, management decisions or administrative processes. The development of remote sensing and GIS technologies have been different because each requires different technical skills i.e. remote sensing places emphasis on image processing technique whereas GIS emphasises on spatial analysis, projections and database designs. As a whole both remote sensing and GIS are geared towards the collection, storage, analysis and reporting of information about the earth resources. It is desirable to integrate the two as they provide complementary capabilities. Remote sensing can benefit from GIS information in verifying image analysis and GIS can benefit from remote sensing as a source of most current information available.

9.5.2 Processing of SAR data and application

The analysis of the image was performed on available forestry data in two steps:

i. Visual analysis
ii. Statistical analysis

These were aimed at finding the different stands of trees in the image scene. This classification was based on the age of the trees, previously determined through ground truthing. The first step (visual analysis) involved display of the images in different band and polarisation combinations and noting the information content that was revealed. Though useful (as it gives a feel for the scene of interest), the method did not yield satisfactory results due to the presence of speckle.

The second step (statistical analysis) was then geared towards the reduction of speckle from the image so as to increase the information inherent in the images. Various statistical parameters were computed for each of the band/polarisation i.e. mean, std, mode, median and minimum and maximum. Observations showed the data to be negatively skewed and that the variance was proportional to the mean. Based on this relation, a logarithmic transformation was applied to normalise the data.

Various image analysis processes were attempted on the transformed data to find the method that yielded the highest classification accuracy based on the ground information available.

The best results were obtained from those data that were first median filtered (3*3), then classified using the maximum likelihood decision rule. It is the resulting image then, that was integrated to the Forest management GIS as an additional coverage showing the spatial characteristics of the forest based on tree (stands) ages.

9.5.3 Usefulness to the ICIPE

The need to work with large data sets covering extensive areas that are spatially referenced have contributed significantly to the growth of GIS at the Centre. Coupled with this is the need for regular and complete data sets over the areas of interest which can be provided by remote sensing.

GIS are powerful tools for handling spatial data. Use of them brings the advantages of speed, accuracy and ease in the manipulation of large and often complex data sets. The ability to perform complex spatial analyses provides both quantitative and qualitative advantages (tabular, graphical outputs). This is from the ability to refine e.g. planning scenarios, decision models, change detection, etc. at successive analyses. The ability to assimilate data from different sources like remote sensing, maps and databases ensures that GIS can be applied to a wide variety of activities and by users with a wide range of skills.

The advantages of using remote sensing in data collection cannot be overemphasised. It has been reported elsewhere that human health and disease are typically characterised by marked temporal and spatial patterns that are often directly related to variations in environmental conditions. As it relates to vector-borne diseases, the fields

of parasitology, epidemiology and medical entomology have taken into consideration this aspect of the environmental link. Remote sensing data provides the means of acquiring this temporal and spatial characteristics of the selected environmental variables which influence the population dynamics of specific disease vectors. It is further noted that, any approach in using remote sensing data to study vector-borne diseases will be indirect since the vector population itself is not directly observable. Remote sensing data must therefore be used to address environmental variables such as vegetation, rainfall, temperature which promote or retard the production of specific vector-borne populations.

Other advantages of using remote sensing include :

(i) With remote sensing data coverage is greatly improved. Satellite remote sensing allows for the collection of data in remote areas which otherwise might be void or have limited data supply for reasons of accessibility, financial constraints or political reasons.

(ii) Data are collected by the same sensors providing spatially consistent data as compared to ground data especially those collected across political borders. These tend to be collected using different methods. Matching of such data leads to difficulties of interpretation as compared to RS data.

(iii) Remote sensing data is spatially continuous as compared to point data that tends to be collected on the ground. Over extensive areas, remote sensing provides the best quality data base.

(iv) Data from remote sensing is usually in a format suitable for computer processing. Though data volumes produced are large, suitable subsets can be extracted that correspond to the study area.

(v) As noted from above, frequency of data collection is greatly improved and the introduction of microwave sensors should boost this capability.

The growth of GIS and remote sensing at the Centre reflects the increasing activities and expertise over the years. The challenge ahead is to ensure that the power of GIS technology is channelled in such a way as to advance and consolidate our values and objectives.

9.6 ARC/INFO GIS, SPATIAL ANALYSIS AND EXPERT SYSTEMS FOR TSETSE MANAGEMENT[1]

U. D. Kitron, L. L. Hungerford and W. U. Brigham

9.6.1 Base data collection and familiarisation

Four types of potential data sources were investigated for development of the project: (1) coverages already available in extant ARC/INFO or compatible GIS systems, (2) remotely sensed data, (3) archived collections of information and (4) information gaps which needed to be filled to enable the project.

Communications were initiated through ICIPE and meetings set up for the January 1991 Kenyan trip to discuss data availability with numerous agencies based in Nairobi working with spatially referenced data or performing research on tsetse or ecology. Africa-wide databases were obtained from the United Nations Environmental Monitoring Program-Global Resource Information Database (UNEP/GRID). These were hand-carried to Illinois. These data, originally developed under contract by Environmental Systems Research Institute (ESRI), Redlands, CA, included continent-wide information on soils, vegetative cover, geology, land use, roads, hydrography and general distribution of buffalo. These data will be used in extrapolating results from the specific study sites to the regional level. Files were loaded onto the Illinois GIS and are presently available on-line in Illinois.

The World DataBank II files of administrative boundaries, hydrography, and roads were made available by researchers at the Illinois Natural History Survey. These data were also present at ICIPE in the ARC-PC environment and provided general regional base map information. The resources of the Department of Regional Surveys and Remote Sensing (DRSRS, formerly KREMU), while extensive, contributed no direct transfers of data at this time. Their extensive holdings of remotely sensed imagery were primarily in analog form. No digital images pertinent to the study were identified.

The composite of these resources provided excellent data at the Kenya-wide level and for certain locations, but no sources of GIS data with specific coverages of the Lambwe Valley at the appropriate resolution could be identified for the first stage of the spatial analysis.

Remotely sensed data from a number of formats and points in time were evaluated. Available Landsat Multi Spectral Scanner (MSS) data from 1986 of a 185 x 370 km^2 area with a resolution of 80 m^2, was found to provide an immediately available, inexpensive overview of the Lambwe Valley and surrounding areas. This data also met needs for training ICIPE personnel in data manipulation and classification. A 100 km^2 view of Thematic Mapper (TM) data with a resolution of 30 m per pixel, taken in 1989, had the higher resolution and appropriate spectral bands for vegetation classification, but more expensive and takes longer to acquire. SPOT data, with 20 m^2 resolution but without an important near infrared bank, may become available from one of two sources. ICIPE may be able to acquire the data for use in this project through a cooperative agreement with the Kenyan Ministry of Planning and National Development. Alternatively, the SPOT Image Corporation may provide data at no cost to support comparison of ecologic indices based on combined TM and SPOT data to those based on TM data alone. For georeferencing and manipulation of satellite data, the IDRISI system currently used at ICIPE and the ERDAS system, used at the Illinois GIS and which may become available at ICIPE, were compared.

Most data on variables of interest in this study were not available in computerised form. Dr. Robert Copeland, a researcher with Walter Reed Institute, based in Nairobi, offered access to his computerised data on tsetse populations, collected in the Lambwe Valley in 1988. This will be explored further after compilation of available ICIPE data. Most data relating to tsetse populations and other variables of interest was maintained in hard copy form,

either as chronologic records from specific research projects, or as analog maps. A sample of ICIPE tsetse trap collection data was abstracted to create a test database for interchange with the GIS and spatial analytical systems. Data from suppression trapping programs conducted by KETRI was also identified through discussions with Drs. J.K. Omuse and Elizabeth Opiyo. This included data on fly collections and maps of suppression trap locations. A map of suppression trap locations was made available to project researchers. Large scale analog maps from the Survey of Kenya (1:50,000) were acquired from colleagues in the United States and from ICIPE. These served as basis for digitising information such as topography, roads, park boundaries and hydrology. Maps of vegetation were also obtained from the Survey of Kenya. However, these were at a scale and level of classification which did not allow much differentiation within the region of the pilot study and will be more useful at the regional level. More defined maps of vegetation and wildlife population distributions were available from DRSRS for parts of Kenya; however, maps for South Nyanza district have not yet been completed. Correspondence was initiated to support collection and access to these maps as they become available. All of these data in tabular and analog map forms requires computer entry through keyboard or digitising boards into GIS compatible databases before they can be used in analysis.

Critical information needed to integrate existing data included georeference points for trap sites used by ICIPE and descriptions of habitat and environment surrounding traps. Arrangements were made to visit and catalog trap sites in the Lambwe Valley, Shimba Hills and Nguruman, and to use a global positioning system (GPS) to find geographic coordinates for each site. The GPS is a hand held device which gathers data from a network of satellites to calculate latitude, longitude and elevation at any location. Locations for some prominent land features, potentially identifiable from satellite imagery, were collected although more will be needed after acquisition and evaluation of remotely sensed data.

9.6.2 *Base map of Lambwe Valley*

A detailed base map of the Lambwe Valley was created for both mainframe and ARC-PC environments. Additional information was added as it was acquired, including positions of trap sites generated with the GPS, roads, hydrologic features and park boundaries. Projections were generated using multiple layers.

Sample data were abstracted from archived ICIPE data and KETRI suppression program data. These were assembled into databases georeferenced to trap coordinates and also compatible with standard PC statistical analysis packages. Preliminary plots of these data showed the expected seasonal patterns. More complete data will be abstracted and assembled to allow spatial and temporal analyses and more complete summary mapping for use by ICIPE. GPS coordinates were determined and habitat descriptions and photographs were prepared for trap sites in the Lambwe Valley, Shimba Hills and Nguruman. These were assembled into a GIS coverage of trap locations linked to a database of ecological variables related to fly population patterns. Attributes linked to georeferenced sites included general site description, relationship and orientation from primary thicket to the trap site, distance from and size of the nearest thicket and a per cent of trap site faced by thicket. This will be used in spatial analysis and will provide ground-truth information for validation of satellite classification indices. Versions of these coverages were created for the Illinois GIS system and the ARC-PC environment at ICIPE. Work on databases is proceeding at both locations.

MSS data was received for a 185 x 370 km area, including the Lambwe Valley. As part of the training programme, this data was used to evaluate capabilities of the IDRISI and ERDAS systems and to develop preliminary classification schemes. The ERDAS system was found to present definite advantages in user interface, manipulation of raw satellite data and classification of vegetation types. TM data from a 100 x 100 km^2 moveable window, including the Lambwe Valley, was received, but in a format without referenced coordinate data. Using nine different 1:50,000 maps projected on grids, Elizabeth Cook derived coordinates for discernable features on the satellite image. Thirty control points were chosen and used to georeference the TM data in ERDAS to subpixel precision (within 30 meters).

9.6.3 *Training*

Training of ICIPE personnel was accomplished in three stages. During the 1991 visit to Kenya, Mark Joselyn worked extensively with those using the GIS at ICIPE to review methods and capabilities of ARC/INFO and to trouble shoot the ARC-PC system. Although ARC/INFO was in use, the more limited IDRISI system had been most extensively used for previous projects. Mr. Onyango Okello then travelled to Illinois for more in depth training in ARC/INFO and ERDAS systems. He created overlay projections of the Lambwe Valley to check errors in coding of trap locations, linked trap locations with attributes; digitised roads, rivers and park boundaries and added these to the base map projection; worked with Elizabeth Cook to load satellite data into PC and workstation environments, display and begin classifying data using both IDRISI and ERDAS; and created output maps of the study area and associated data. He visited the Laboratory for Applied Remote Sensing at Purdue University to discuss AVHRR data, which is also available in Nairobi, and attended the ESRI users conference where he gained a broader overview of GIS capabilities and also received specific training on use of the newest version of PC-ARC (3.4D). The third phase of the training programme was conducted at ICIPE by Mr. Okello, following his return. The newest version of ARC-PC was provided to ICIPE with extensive documentation and training manuals and programs suited to training new and continuing users.

9.6.4 *Plans for the second project year (1992)*

During the second year of the project, entry of existing ICIPE and KETRI tsetse trapping and population data will continue, based on structures developed with the sample

data. Classification of TM data into ecologic indices (including integrated classification with SPOT data if it becomes available) and spatial analyses of combined data will be compared to actual site characteristics to ground-truth and allow refinement of calculated indices. Combinations of variables found to associate with tsetse populations in spatial analyses will also be verified through field observations. GPS coordinates will be derived for additional locations and meetings will be held with researchers who collaborate with ICIPE on tsetse research. Spatial analysis will be used to determine critical associations between behaviour of tsetse populations and ecological factors, first in the Lambwe Valley with expansion to include the Shimba Hills and Nguruman regions. This will allow determination of the feasibility of expert decision systems and allow development of a prototype inference engine.

†*A Collaborative project (Tsetse Research Programme, Biomathematics Research Unit and University of Illinois, Dept. of Vet. Pathobiology, Urbana-Champaign); reported by the University of Illinois team.*

INSECT AND ANIMAL BREEDING UNIT

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10 Insect and Animal Breeding Unit

The Insect and Animal Breeding Unit (IABU) was established in June 1991 as a core support services and R&D Unit after reorganisation and consolidation of the former Insect Mass Rearing Technology (IMRT) Unit. The Unit meets its obligation under an organisational framework of the following sections:

- *Phytophagous Arthropod Rearing Section (stem borers, pod borers and locusts)*
- *Haematophagous Arthropod Rearing Section (tsetse and mosquitoes)*
- *Small Mammal Breeding Section (rabbits, rats, mice and hamsters)*

The Unit in 1991 was able to service and support the ICIPE's core research activities by a steady supply of quality, insects and animals. Also, several research and development projects towards improving rearing techniques were undertaken.

10.1 PRODUCTION AND SUPPLY OF *CHILO PARTELLUS*

M. D. O. Bungu, P. E. W. Njoroge, J. O. Osuri, J. O. Maoro, M. O. Chacha, A. Majanje, W. I. Odhiambo, J. N. Kunyu, F. O. Onyango, P. A. Nyakwamba and J. P. R. Ochieng'-Odero

Chilo partellus continued to be the largest single species reared and supplied for research at MPFS. The quantity produced and supplied has been increasing over the years. The Insect and Animal Breeding Unit has been able to meet most of the user demands. The quantity of all stages demanded and produced during 1991 was 30.5 and 34.4 millions, respectively.

10.2 PRODUCTION AND SUPPLY OF *MARUCA TESTULALIS*

P. O. Wagara, A. G. Nyangwara, F. O. Onyango and J. P. R. Ochieng'-Odero

The quantity of *Maruca testulalis* supplied this year was below the previous year. This year, the demand was low due to reduced number of regular users. However, the unit had the capacity to produce and supply as many insects as were required at any given time without increase in labour force. The full production potential has yet to be realised since the introduction of a new artificial medium and an improved rearing technique. The quantity of insects supplied during 1991 was about 80,000, a drop from 117,000 last year.

10.3 PRODUCTION AND SUPPLY OF *BUSSEOLA FUSCA*

E. O. Amboga, B. O. Owiyo, A. G. Nyangwara, F. O. Onyango and J. P. R. Ochieng'-Odero

The colony of *Busseola fusca* has been reared on artificial medium continuously in the laboratory for 10 successive generations. When sucrose was added to the artificial medium as from the 10th generation, larval period was reduced from 42.3 days in the 5th generation to 37.3 days in the 10th generation. The growth index also increased to 1.8 in the 10th generation from 1.6 in the 5th generation, indicating that the artificial medium with sucrose was more suitable for larval growth and development (Table 10.1). The colony of *B. fusca* was increased three-fold since 1990 and four times compared to the quantity supplied in 1990. The production and supply figures for 1990 and 1991 are presented in Figure 10.1.

10.4 COLD STORAGE OF EGGS OF THREE LEPIDOPTERAN SPECIES

F. O. Onyango, J. P. R. Ochieng'-Odero, M. D. O. Bungu, J. M. Okomo and A. G. Nyangwara

Requests for eggs and neonate larvae of lepidopteran insects being reared at MPFS especially *Chilo partellus* for use in host-plant resistance screening trials using artificial infestation usually fall within about the same

Table 10.1 Performance of *Busseola fusca* on artificial diet for 10 successive generations at MPFS

Parameters examined	Generation G1	G5	G10[1]
Per cent survival to pupation	38.2(110)[2]	70.1(422)	68.0(100)
Larval period (days)	70.0(43)	42.3(138)	37.3(68)
Growth Index[3]	0.5	1.6	1.8
Pupal weight(mg)			
Male	160.0(18)	177.4(56)	231.2(30)
Female	164.3(16)	227.6(31)	290.8(23)
Number of eggs/female	158.0(6)	348.1(22)	307.6(12)
Egg hatch (%)	44.8(460)	74.2(3600)	66.5(690)

[1]Sucrose was added to the artificial diet.
[2]Figures in parenthesis are the number of insects evaluated.

$$^{3}\text{Growth index} = \frac{\text{\% Survival to pupation}}{\text{Mean larval period}}$$

week during cropping seasons. Given the limited production capacity relative to the user demands, some of the users have to be supplied earlier than the requested time, while others deferred for a few days. This has often created problems especially when crop phenology is an important factor to consider.

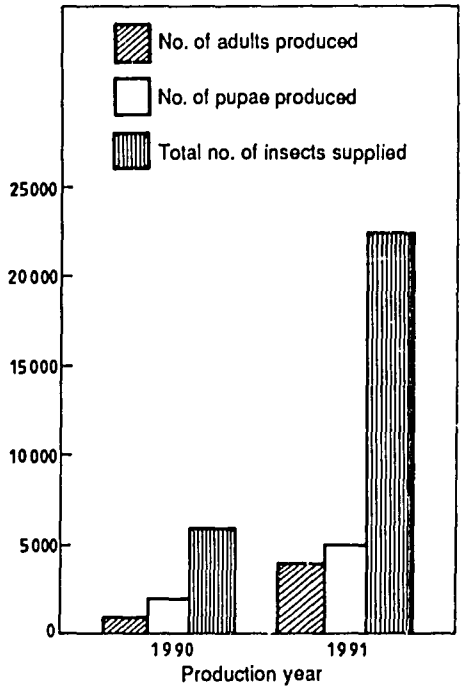

Figure 10.1 Production and supply of *Busseola fusca* during 1990 and 1991.

Therefore, it was necessary to explore the possibility of arresting egg development of *Chilo partellus*, *Busseola fusca*, and *Maruca testulalis* without any adverse effect on the embryonic development and hatchability, in order to facilitate pooling of the eggs for supply without deterioration or loss of quality over time of storage. In this regard, samples of eggs of *C. partellus*, *B. fusca* and *M. testulalis* were kept in the refrigerator at 5 and 10°C for a few days, then placed in the incubator at 27 ± 1°C to hatch. A control sample was kept only in the incubator throughout until hatching.

Eggs kept in the refrigerator at 5°C deteriorated faster with storage days for all the three lepidopteran eggs. Eggs at blackhead stage kept better in the refrigerator at 10°C than fresh eggs. Experiments on the storage of *B. fusca* eggs at blackhead stage were still in progress at the time this report was being compiled. *Chilo partellus* eggs could be kept in the refrigerator at blackhead stage for upto 4 days without significantly reducing the viability, while fresh eggs could be stored for upto 2 days only, beyond which egg hatch is adversely affected. Fresh *B. fusca* eggs could be stored at 10°C for upto 3 day. eyond which hatchability would reduce significantly. Similarly, *M. testulalis* eggs may be stored at blackhead stage at 10°C for upto 3 days while fresh eggs may be stored for only 2 days without hatchability being adversely affected significantly. The total egg duration for the three species was prolonged by the same number of days the eggs were kept in the refrigerator at 10°C which facilitates egg hatch synchronicity.

Therefore, it is possible to incorporate cold storage in the management of eggs of the three lepidopteran species for bulk supplies for host-plant screening or for work on egg parasitoids without sacrifice for the quality of eggs being supplied. The results on the effect of cold

Table 10.2 Effect of cold storage on embryonic development and hatchability of the eggs of three lepidopteran species

Days in cold storage (10°C)	Per cent egg hatch[1]				
	Chilo[2]		*Busseola*[3]	*Maruca*[4]	
	Black-head	Fresh	Fresh	Black-head	Fresh
0	92.9[a]	85.5[a]	59.0[a]	87.0[a]	83.3[a]
1	90.4[a]	88.0[a]	61.1[a]	71.1[a]	72.4[ab]
2	83.1[a]	85.0[a]	52.4[ab]	86.5[a]	74.0[ab]
3	82.2[a]	65.9[b]	52.3[ab]	66.6[a]	50.5[bc]
4	82.7[a]	45.3[c]	23.7[c]	40.1[b]	21.1[cd]
5	66.6[b]	32.6[d]	21.8[cd]	15.4[bc]	5.3[d]
6	–[5]	28.7[d]	6.3[a]	9.1[c]	1.1[d]

[1]Average of 300–400 blackhead stage or fresh eggs per replication. In a column means followed by a common letter are not significantly different at the 5% level by Duncan's multiple range test.
[2]Average of 4 and 8 replications for the blackhead and fresh eggs respectively.
[3]Average of 9 replications.
[4]Average of 4 replications.
[5]Experiment still in progress.

storage of the eggs of the three lepidopteran species at 10°C are presented in Table 10.2.

10.5 COLD STORAGE OF *BUSSEOLA FUSCA* PUPAE

F. O. Onyango, J. P. R. Ochieng'-Odero and D. J. Okode

One of the major constraints of the rearing of *B. fusca* at MPFS is the assynchronous pupation, with the consequence that the early pupae may be all of the same sex when the adults emerge. These adults usually die before sufficient mating pairs are obtained. To overcome this problem, it was vital to find a way to arrest the pupal development so as to synchronise adult emergence to guarantee enough mating pairs for colony perpetuation as well as for the supply of adults, eggs, and neonate larvae. Thus, healthy fresh pupae of *B. fusca* were kept in the refrigerator set at 10°C for days varying from 1–7 only, then exposed to incubator temperature at 27 ± 1°C for eclosion. Control pupae were not kept in a low temperature but exposed to the same incubator temperature throughout

Table 10.3 Effect of cold storage of *Busseola fusca* pupae at 10°C on pupal duration and adult emergence

Days at 10°C	Pupal duration in days (Mean ± S.E.)	Per cent eclosion ± S.E.
0	13.3 ± 1.7[a]	56.7 ± 26.0[a]
1	13.8 ± 2.0[ab]	50.0 ± 20.8[a]
2	14.8 ± 2.4[abcd]	56.7 ± 26.0[a]
3	14.6 ± 2.4[abcd]	63.3 ± 27.0[a]
4	16.6 ± 3.3[abcd]	50.0 ± 20.8[a]
5	16.8 ± 3.4[cd]	50.0 ± 26.5[a]
6	17.5 ± 3.8[cd]	50.0 ± 20.8[a]
7	18.0 ± 4.0[d]	43.3 ± 16.7[a]

Average of five replications, one pupa per replication. In a column, means followed by a common letter are not significantly different at the 5% level by Duncan's multiple range test.

The results of the effect of cold storage of *B. fusca* pupae at 10°C are presented in Table 10.3. Pupal period increased from 13 days for the unrefrigerated pupae to 18 days for the refrigerated pupae in 7 days of storage. Cold storage did not significantly affect adult emergence.

The results indicate that it is possible to store *B. fusca* pupae at 10°C in order to spread their availability as well as those of adults and eggs for supply, and to synchronise eclosion for bulk supply of adults and neonate larvae. The experiment on the effect of cold storage of *B. fusca* pupae beyond 7 days on pupal duration and adult emergence is in progress.

10.6 IMPROVEMENT OF ARTIFICIAL DIET FOR *BUSSEOLA FUSCA*

F. O. Onyango, J. P. R. Ochieng'-Odero, D. J. Okode, E. O. Amboga and B. O. Owiyo

An artificial medium incorporating 6-week-old Serena sorghum leaf factor was previously used to rear *B. fusca* continuously for nine successive generations. The pupae and adults that emerged in the first nine generations were smaller than their wild counterparts. This indicated that the food intake by the insects was not adequate probably due to lack of phagostimulant(s). Therefore, leaves or

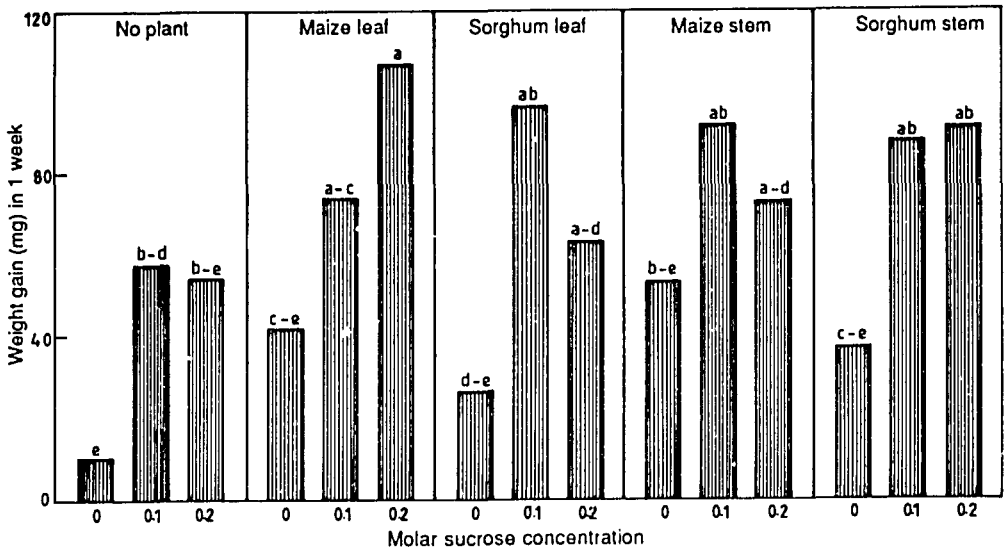

Figure 10.2 Weight gain in larvae of *Busseola fusca* fed on artificial diet with various plant parts and sucrose.

stems of inbred maize and Serena sorghum incorporating sucrose which is more of a universal phagostimulant was tested at 0.1M and 0.2M levels of concentration in the artificial diet for this property.

Fourth instar *B. fusca* larvae starved overnight but water satiated were allowed to feed on artificial media composed of the different plant factors and sucrose concentrations for 7 days. Control insects were fed on media without either any of the plant factors, sucrose or both. The larvae were weighed just before and after feeding. The results are given in Figure 10.2. When both plant factor and sucrose were omitted from the artificial medium, larvae gained only 7.7 mg in one week. However, when sucrose was added and plant factors omitted, the larvae gained 56.3 mg and 54.0 mg in one week for 0.1M and 0.2M sucrose, respectively. Addition of any of the plant factors in the artificial medium resulted in increased weight gain as compared to when no plant factor was incorporated. Larvae fed on artificial diet incorporating maize leaf factor with 0.2 M sucrose gained 107.3 mg in one week compared to 41.0 mg and 54.0 mg when sucrose, sorghum or maize leaf factors were precluded, respectively.

There were no significant differences in weight gain in larvae fed on leaves or stems of maize or sorghum incorporating either 0.1M or 0.2M sucrose. Therefore, both sucrose and plant factors of maize on sorghum play a significant role in the artificial diet for *B. fusca*, whose effects appear to be synergistic in eliciting *B. fusca* phagostimulatory responses. The effect of the addition of sucrose to the artificial diet of *B. fusca* was obvious in the 10th generation (Table 10.1) when larval period was shortened, growth index increased, and heavier pupae obtained as compared to when sucrose was omitted.

10.7 LOW COST ARTIFICIAL MEDIUM FOR REARING *CHILO PARTELLUS* LARVAE

M. D. O. Bungu, J. O. Osuri, F. O. Onyango and J. P. R. Ochieng'-Odero

Improvements on an artificial diet that has no agar, an expensive ingredient, were carried out during the year. A semi-synthetic formulated diet has now proved suitable for rearing *C. partellus* from first instar to pupation without having to change the diet as is done to the agar based standard diet currently being used at ICIPE (Tables 10.4 and 10.5). After trying several gelling substances, fruit jelly was found to perform better among the alternatives. The gelling quality, though not exactly like agar, offered an opportunity for two consecutive generations of larvae to feed on the same diet until pupation without much

Table 10.4 The *Chilo partellus* diet prepared with vanilla fruit jelly

Ingredient	Amount
Bean powder (*Phaseola* sp.)	100.0 g
Sorghum leaf powder	100.0 g
Brewers' yeast + Yestermin	36.0 g
Sorbic acid	1.2 g
Methyl-*p*-hydrochloroxybenzoate	2.2 g
Varndezant Vit. mix	3.0 g
Wesson's Salt mix	2.5 g
Formaldehyde, 40%	2.0 ml
Fruit Jelly (Vanilla)	60.0 g
Water	1000.0 ml

Table 10.5 Development of *C. partellus* on the fruit jelly and agar based diets

	n		Min		Max		Mean	
Parameter	Agar	Jelly	Agar	Jelly	Agar	Jelly	Agar	Jelly
Life cycle (days) L1–Adult	55	99	33	34	40	50	39.1	40.5
Pupal weight (mg)	39	26	46	45	150	150	82.4	88.5
Adult longevity (days) M	10	10	2	2	9	9	5.2	6.4
F	10	10	2	3	7	9	4.2	4.7
Mean fecundity	10	10	157	157	733	647	339.6	354.4
Per cent egg hatch	10	10	90	90	95	97	93.6	94.8

spoilage. Research, however, is still continuing on this formulation to replace most of the expensive commercial ingredients that are not locally produced and to improve on the dispensing flow of the diet.

10.8 STATUS OF REARING DESERT LOCUST, *SCHISTOCERCA GREGARIA*

S. M. Ndugo, J. P. R. Ochieng'-Odero J. T. Kilori, S. A. Patya, J. H. Ongudha and G. M. Ng'ang'a

Materials for rearing the desert locust originated from two sources. First, from the egg pods from a colony maintained at the DLCO-EA headquarters in Addis Ababa, Ethiopia, and the second, from individuals collected from the Red Sea coast of Sudan in late 1990.

For rearing the crowded colony, two rooms, each 4.5 x 4.5 m are used. They have a capacity of 56 cages each of 50 x 50 x 50 cm and the total insect capacity is between 8400 and 11,200 adult locusts. The room temperature is maintained at 35 ± 2°C and 30 ± 2°C during day time and night time respectively. The photoperiod has remained at 12:12 hours ratio of light to darkness while the relative humidity ranges between 40 and 50%. The diet mainly consisted of sorghum (Serena) as green feed and wheat bran as dry feed. The colony now in the 11th generation has been healthy with a mortality of 5% on average. A total of five generations have been reared during the year.

Two systems are used to rear the isolated locusts: Pener system and Closed system. In Pener system two adjacent rooms each 4.5 x 1.5 m are used. Each room has a capacity of 10 trollies which carry compartments of 10 x 10 x 24 cm. The room conditions are same as for the crowded colony. Sorghum (Serena) is used as green feed and wheat bran as dry feed. A total of five generations of each strain were reared during the year. Mortality has been less than 7% per generation on average for both strains.

The Closed system tries to eliminate gaseous exchange between individual locusts. Each rearing jar is provided with an air supply from a compressed air cylinder connected with PVC and copper tubings. The jars are 1 litre in capacity and are fitted into a circular rack with 10 compartments for 10 individual jars. Room temperature ranges between 28 ± 1°C and 30 ± 1°C while the rest of the room conditions are same as for the Pener system. The diet is the same as for the Pener system but the wheat bran is sprinkled into the jar while the green feed is tied at the base with moist cotton wool and aluminium foil to minimise moisture loss. Two generations have been reared under this system but the number involved was small and high mortality figures of 53 and 35%, respectively, were recorded.

A total of 19,154 insects were supplied from the crowded colony to different users during the year. On the other hand, 650 were supplied from the solitary colony.

10.9 RESEARCH ON DIET PREFERENCE BY DESERT LOCUST, *SCHISTOCERCA GREGARIA*

S. M. Ndugo, J. P. R. Ochieng'-Odero and S. El Bashir

An experiment to investigate green feed preference of the desert locust was carried out on wheat, millet, sorghum and Kikuyu grass, *Pennisetum clandestinum* using various nymphal instars. The insects were fed on a mixture of the four feeds from the time they hatched. All the four feeds were introduced to each cage and the number of insects on each feed was recorded after 10 minutes. The percentage of insects responding to each feed was calculated. The amount of feed consumed after 30 minutes was also recorded. The results show that different nymphal instars prefer different feed. Also it was evident that the feed most preferred was not necessarily the one that was consumed most and therefore maybe other factors were also involved.

Since the gregarious locust is known to be polyphagous, an experiment to determine the effect of a diet consisting of a mixture of green feed and that of sorghum alone on the locust was carried out. One set of locust was reared on a mixture of leaves of maize, sorghum, millet, wheat and the grass *P. clandestinum* while another set was reared on sorghum leaves only. Both sets were provided with wheat bran as dry feed. The mature weight of both sets was then taken for comparison. Morphometrics of both sets was also taken for comparison. There was

no significant difference between the mature weights of the set fed on a mixture and that fed on sorghum alone. The FC and EF ratios of the two sets did not show any significant difference between the two sets. Additional experiments on diets are being conducted so that a standard diet for rearing desert locust at ICIPE can be found.

10.10 PRODUCTION AND SUPPLY OF *GLOSSINA PALLIDIPES*

J. A. Ojude, H. K. Bandah, J. K. Gitegi, J. O. Opere, W.O. Oganda, F. O. Onyango and J. P. R. Ochieng'-Odero

The colony of *G. pallidipes* at MPFS was replaced with wild flies from Lambwe valley as from September, 1989. The colony progressed steadily, meeting all scientific demand until March 1991. Between April and October 1991, however, the pupal production declined from over 10,000 pupae to 400 pupae as given in Figure 10.3. Adult mortality ranged between 0.5 and 2.0 Fecundity also declined between March and August, after which wild flies were introduced from Lambwe valley as indicated

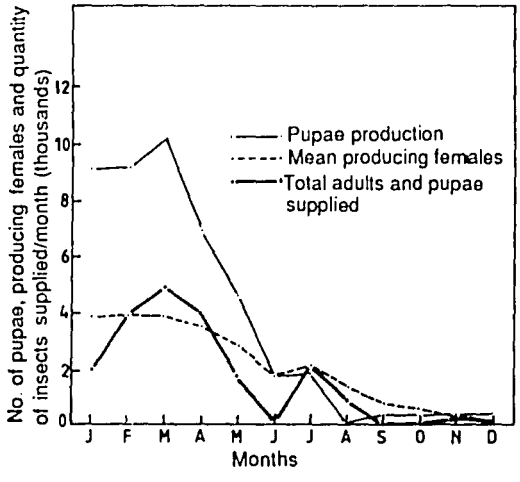

Figure 10.3 *Glossina pallidipes* production and supply.

in Figure 10.4.

As from April 1991, the laboratory females were not receptive to the laboratory males. An attempt to mate the laboratory females with wild males conversely proved unsuccessful. Similar problems were encountered in 1988. The reason for the low propensity to mate after successive generations of laboratory rearing are yet unknown. However, the problems are thought to be related to nutritional, physiological, pathological or genetic factors. Investigations are in progress to determine the specific cause(s) and how to overcome the problem.

A total of 3058 females from Lambwe valley were introduced into the laboratory between June and October, 1991. By the end of December, the colony strength stood at only 200 females, as a result of lack of mating.

During the first quarter of the year, all requests for *G. pallidipes* were supplied. However, as from May 1991,

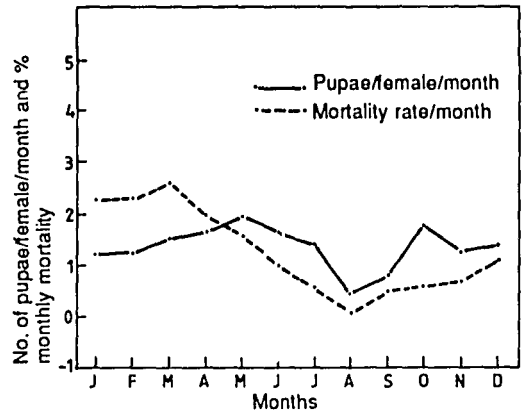

Figure 10.4 Fecundity and mortality in the *Glossina pallidipes* colony.

the quantity of flies supplied was far below the quantity demanded.

10.11 PRODUCTION AND SUPPLY OF *GLOSSINA MORSITANS MORSITANS* AND *G. M. CENTRALIS*

J. U. Wanyonje, H. K. Bandah, E. O. Awuoche, R. G. C. Kariuki, N. M. Mwikya and J. P. R. Ochieng'-Odero

During the year 1991, *G. morsitans morsitans* and *G. m. centralis* were reared, maintained and supplied to all research programmes requiring them for experimental purposes. The main user of tsetse was the Tsetse Research

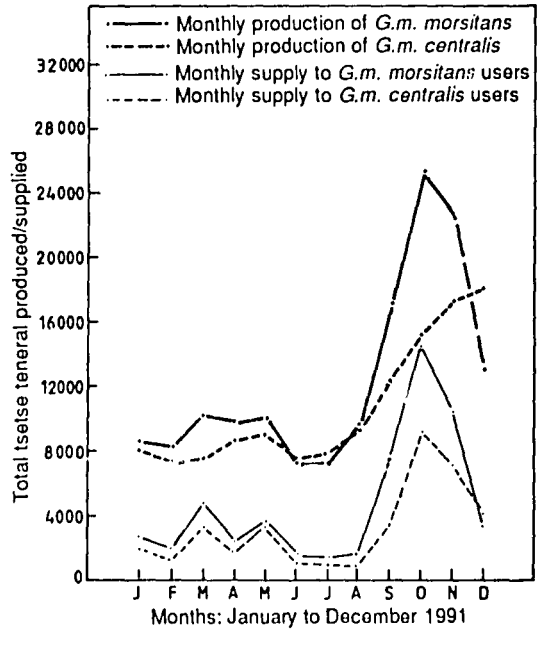

Figure 10.5 *Glossina morsitans centralis* and *G. m. morsitans* production and supply.

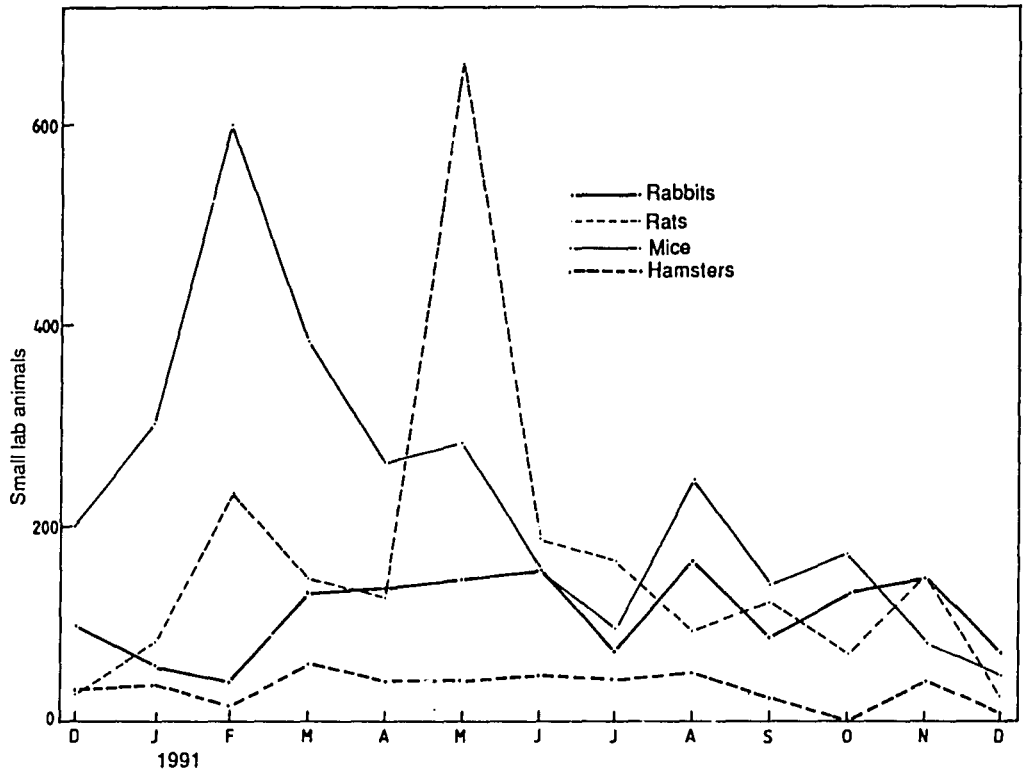

Figure 10.6 Supply of small laboratory animals during 1991.

Programme. The other users were the Chemistry and Biochemistry Research Unit, the Cell Biology Research Unit and the Sensory Physiology Research Unit.

During the year, the production and the supply of *G.m. morsitans* were at their peak between August and November (Figure 10.5). Due to the high demand and supply in September, October and November, we were left with a few females to put back to the colony, and as a result a drop in performance was noted in November and December. Another factor causing the sharp drop in the colony was that the mortality increased in the females from 1.8 to 2.8.

The rearing of the *G.m. centralis* was maintained such that the production rose steadily from 7883 in July to 18,149 in December. This was mainly because the demand was not as high as in the case of *G. m. morsitans*.

10.12 INTRODUCTION OF *GLOSSINA FUSCIPES*

H. K. Bandah

A colony of *G. fuscipes* was introduced at MPFS during the year. The colony strength by the end of December stood at over 3000 producing females.

10.13 BREEDING, MAINTENANCE AND SUPPLY OF SMALL LABORATORY MAMMALS

J. M. Kagoiya, A. S. Ikhunyalo, R. O. Agan, S. M. Mbugua, J. O. Oguk, J. O. Kaleb and J. P. R. Ochieng'-Odero

The mammals bred, namely, rabbits, rats, mice and hamsters, are used for feeding target haematophagous arthropods and for experimental work by ICIPE's research programmes and units. Breeding of quality animals is essential for research work carried out at the ICIPE. During 1991, a large number of mammals was bred. Numbers of animals supplied are shown in Figure 10.6.

10.14 RESEARCH AND DEVELOPMENT WORK ON ANIMALS

J. M. Kagoiya, J. P. R. Ochieng'-Odero, J. U. Wanyonje and H. K. Bandah

10.14.1 Effect of tsetse feeding on haematological characteristics of rabbits

Six male rabbits, 12 weeks old, were used to feed *G. m. morsitans* for 90 days. Haematological profiles were

investigated weekly. In general, the haematological profiles were not affected by feeding 300 tsetse flies per rabbit, per day, weekly. Hence a density of 300 tsetse flies is not injurious to the health and physiology of a rabbit.

10.14.2 Effect of coccidiostat on tsetse development
Two groups of rabbits were used to provide blood meal to tsetse flies. The first group was maintained on a diet free of coccidiostat while the other was raised on a coccidiostat diet. Data on tsetse reproduction and development was collected. The general conclusion of the experiment was that coccidiostat at a level of 0.08% in rabbit pellets does not affect tsetse performance.

SOCIAL SCIENCE INTERFACE RESEARCH UNIT

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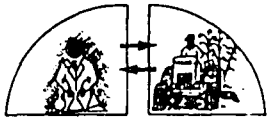

Social Science Interface Research Unit

The Social Science Interface Research Unit (SSIRU) plays a key role in the interdisciplinary process of development of integrated pest and vector management technologies at ICIPE. In 1991, the Unit has not only undertaken a substantial number of research activities collaborating with the various research programmes, but has also contributed significantly to centre-wide efforts to promote new interdisciplinary research ventures and research development in general.

The year 1991 has also been a year of systematic research planning. All SSIRU research activities are now based on a plan developed and adopted in conjunction with the Research Committee of the Centre. The plan will be updated as the need arises in the course of the succeeding year.

SSIRU has also planned and executed a number of training activities and seminars in 1991. These have included training programmes for ARPPIS students and for its own field personnel. Quarterly scientific seminars were also held in which SSIRU staff as well as representatives of core programmes presented research and discussion papers. The seminars have served effectively as fora for sharing research findings and stimulating interdisciplinary discussions among the scientists.

In an effort to promote closer interdisciplinary collaboration at ICIPE, SSIRU has also taken the initiative to launch in 1991 a periodical entitled Dialogue, *whose purpose is to promote better communication between social and natural scientists.*

11.1 OVERVIEW OF RESEARCH ACTIVITIES

F. G. Kiros

SSIRU's research activities in 1991 have encompassed studies relating to the core research programmes including CPRP, TRP, LTRP and MVRP. The research projects and their objectives have varied, reflecting the particular needs and stages of research and development in the various core programmes.

Work relating to CPRP has produced some research results pertaining to the socio-economic characteristics of farmers in South Nyanza, the patterns of diffusion of IPM technologies and some preliminary cost-benefit data.

Research related to TRP has included the generation of basic information on indigenous knowledge of tsetse and trypanosomiasis as well as general knowledge, perceptions and practices relating to the vector and the disease. An effort was also made to design an appropriate method for the assessment of the impact of ICIPE's tsetse trapping technology.

SSIRU's research activities pertaining to LTRP have been concerned with studies of control methods such as the potential of using chicken as predators of livestock ticks as well as the evaluation of the costs and affordability of those methods being used by farmers. A study on indigenous veterinary knowledge and practices has also identified scores of medicinal plants which are expected to be screened by LTRP in 1992.

Work reported in relation to MVRP has concerned itself with behavioural factors which may increase the risk of exposure to disease, an assessment of local resources potentially available for disease control and preliminary inquiry into the consequences of malaria and leishmaniasis at Marigat.

The research activities of SSIRU have therefore covered a fairly wide spectrum. In addition to research that has been in progress, substantial work has also been done in the development of new research projects. Among these have been those spearheaded by the Head of Unit. Field work on studies relating to the identification of "resource-poor" farmers, agricultural production systems,

and production capacity of female-headed households are expected to be initiated early in 1992.

11.2 SOCIO-ECONOMIC CHARACTERISTICS OF FARMERS IN LAMBWE AND KIBIRI LOCATIONS OF SOUTH NYANZA DISTRICT

P. O. Chitere

Systematic sampling methods were used to select 68 farmers from a few villages in Lambwe and Kibiri Locations of South Nyanza District. Emphasis was placed upon wealth status as one of the criteria for defining resource-limited farmers for participation in ICIPE's IPM projects. Weighted scores were assigned to its different indicators which included, off-farm employment and size of land, numbers of livestock, ox-plough(s), wheelbarrows, carts and commercial properties. The total possible score that could be obtained by each farmer was 28 points, but the highest scorers obtained only 15 points. This suggested that the wealth status of farmers sampled was generally low. However, a significant difference was observed in the wealth status scores between Lambwe and Kibiri farmers sampled (Table 11.1).

Table 11.1 Wealth status score of Lambwe and Kibiri farmers sampled in South Nyanza District

Wealth status scores	Lambwe	Kibiri	Total
High (>12 scores)	11	5	16
Medium (9–11 scores)	10	7	17
Low (6–8 scores)	11	6	17
Very low (<5 scores)	3	15	18
	35	33	68

$\chi^2 = 12.88$, df = 3, $P > 0.01$.

Lambwe farmers had larger farms, more livestock, ox-ploughs, commercial properties and off-farm employment opportunities. It was concluded that 40% of Lambwe and 64% of Kibiri farmers sampled whose wealth status was low or very low could constitute the IPM target group of resource limited farmers.

11.3 DIFFUSION OF IPM TECHNOLOGIES

P. O. Chitere

This study sought to find out how far the ICIPE/ECA project objective of ensuring diffusion of IPM technologies from farmers participating in the project to non-participating ones had been accomplished. Quota sampling method was used to sample 98 non-participaing farmers in the project areas of Oyugis and Kendu Bay. For each project farmer, two non-participating farmers were sampled whose homesteads were 0.25 to 1.0 km away.

The results of the study showed that 72% Oyugis compared to 85.4% Kendu Bay farmers sampled knew ICIPE and its research work which was reported mainly as helping farmers with farm inputs, services and know-how, and carrying out research on insect pests affecting crops. Two-thirds of both Oyugis and Kendu Bay farmers sampled knew ICIPE/ECA project farmers, and 54% Oyugis and 45.8% Kendu Bay farmers had visited project farmers' experimental plots. Adoption of IPM components was indicated by 30% Oyugis and 16.7% Kendu Bay farmers sampled. Pest resistant cultivars were the most adopted, followed by line planting. One component was adopted by 20% Oyugis and 10.4% Kendu Bay farmers, and two components by 8% Oyugis and 6.3% Kendu Bay farmers, and more than three components by 2% Oyugis farmers.

Despite lack of adoption of IPM components by a majority, about two-thirds of the non-participating farmers expressed the desire to work with ICIPE; a few of them had already made efforts to join the IPM project. The main conclusion of the study was that since it is not possible to work with each and every farmer of an IPM project site, deliberate efforts need to be made to ensure effective diffusion of proven IPM technologies to non-participating farmers.

11.4 SOCIO-ECONOMIC ASPECTS OF THE OYUGIS/KENDU BAY IPM PROJECT

M. M. Mwangi

The socio-economic studies in Oyugis and Kendu Bay have sought the farmers responses to the CPRP IPM components and have also investigated the farmers' local conditions that may influence technology adoption. The following issues were investigated in 1991.

11.4.1 Granary and crop residue management

This work aimed at studying granary use, sanitation, and comparison of use of traditional and improved granaries. Also studied was crop residue management, relative to the recommendation to burn stover.

Results of the study showed that over 70% of the farmers reported various economic uses for maize and sorghum crop residue at the farm level. These include use as fuel, cattle feed, construction of sheds and mulch. Only about 25% of the farmers burnt their crop residue.

Since the various uses of crop residue are gradual, the stems were often stored in the compound where some were found to harbour insects up to the short-rains season.

11.4.2 Factors affecting agricultural marketing

A study on marketing of farm produce and related aspects started in 1990 and continued into 1991. The study covered the level of grain marketing, price fluctuations and constraints to marketing.

It was found that influx of grain from other parts of the country, especially Kisii and Rift Valley, has suppressed the prices of maize in both Oyugis and Kendu Bay divisions. Low yield levels and large family sizes are also responsible for the low levels of marketing by the farmers.

11.4.3 Labour component of IPM

The labour studies aimed at investigating the labour component in IPM which has previously been reported as being a constraint. A comparative study of labour use in the IPM Experimental Plots versus the Farmers' Own Plots was carried out. Data were collected on amount of labour utilised in the major farming operations viz. ploughing, harrowing, planting, weeding and harvesting. Also collected were the labour costs in both types of farms.

A further study on labour use compares amount of time used under various cropping pattern , with a view to recommending the most efficient crop ıg pattern to the local farmers. Data analysis and write-. of the labour studies are in progress.

11.5 THE COST-BENEFIT ANALYSIS (CBA) OF THE ICIPE IPM/IVM TECHNOLOGIES

G. T. Lako

Attempts to use CBA in the economic evaluation of the ICIPE IPM/IVM menus are being made and most studies are at the state of data collection or compilation. It is nonetheless important to highlight these attempts in relation to various ICIPE Programmes where technologies have been developed and are already or about to be adopted.

11.5.1 CBA application in crop pests management in Oyugis and Kendu Bay

Since 1986, ICIPE has been testing a multi-faceted crop pests management menu in Oyugis and Kendu Bay Divisions of South Nyanza Province. It was considered important therefore, to test whether this IPM menu was economically viable. For this, a partial budget analysis was undertaken and a Marginal Rate of Return (MRR) was computed for the different IPM menus tested in each Division. Only the costs and benefits that could be affected by the alternative treatments (IPM menus) were considered. The analysis was based on the costs and benefits figures for 1988 only. These costs and benefits were for the experimental plots but were also compared with the farmers' own cropping systems. The variable costs included seed, labour and fertiliser while benefits were based on yields only.

The results of the analysis of the sorghum-based cropping system showed that the introduction of the ICIPE IPM menus resulted in greater MRR in both Oyugis and Kendu Bay, i.e. the farmers earned greater net benefits by adopting the ICIPE IPM menus than in their own systems.

In the case of the maize-based cropping system, the analysis of the data for 1988 long and short rainy seasons showed that the MRR for the maize varieties (V-37 and LRM 1) introduced and grown as mono-crop or as inter-crop with cowpea (ICV 2 variety) were higher for the ICIPE supervised plots than for the farmers' own plots but less than the experimental or the farmers' plots using commercial hybrids.

Data for 1987 and 1989 are being compiled, and that of 1990 and 1991 being gathered. The analysis of these data covering the 5 years will enable a sensitivity analysis to be performed and more conclusive results to be obtained.

11.5.2 CBA application in tick management in Kaloleni Division

At present there are five (5) methods of livestock ticks control being applied in Kaloleni Division. They are: topical application of acaricides, spraying, dipping, deticking and traditional methods. The study seeks to determine the costs of the various tick control methods and the effective demand for each of them. Data on costs and farmers' incomes and expenditures are being collected and are expected to be completed by January, 1992.

In order for the cost-benefit analysis to be completed benefits data need to be collected. Productivity data required are similar to those required in the evaluation of the impact of the ICIPE NGU trap in Nguruman (described below).

11.5.3 CBA application in the tsetse management in Nguruman

ICIPE's mandate or goal is geared towards improving the welfare of the resource-poor farmer. In cost-benefit terms, this means enabling the resource-poor farmer to realise greater net benefits (yields, income) over and above the costs of using new technology(ies). The best technique for measuring the impact of the NGU trap, is to examine its private costs and private benefits. Attempts are being made toward this end.

In the meantime, in the absence of quantitative benefits data, a cost-effectiveness analysis is being made to assess the impact of the technology qualitatively, including the social, environmental and related aspects.

11.6 AN ASSESSMENT OF CURRENT KNOWLEDGE OF TSETSE AND ANIMAL TRYPANOSOMIASIS: THE IMPACT OF NGU TRAP IN TSETSE AND DISEASE CONTROL

G. T. Lako

SSIRU is currently undertaking various socio-economic studies in Nguruman in relation to the impact of tsetse trapping technology in terms of acceptance of the technology, community participation and cost-benefit. This study is the first in the series and the data were obtained from a random sample survey of 120 households covering 12 major villages of which Nguruman town is one. The analysis of the data is nearing completion. We highlight here, the salient features of the results that have emerged so far on household utilisation of labour in cattle rearing, perceptions of tsetse, and perceptions of the tsetse trap as a control method.

Although cattle owners are well-known for their reluctance to reveal the number of animals they own, our sample showed that only less than 10% of the respondents said that they had no cattle. The vast majority of the respondents (>60%) reported to own between 20

to 100 head of cattle. Households also keep other types of livestock with highest number being goats, followed by sheep and the least number, donkeys.

For all the sample of the household-heads interviewed, the security of the cattle in the homestead is their sole responsibility. When grazing, it is mainly sons (40% of households said so) who look after the cattle and on occasions the household-head would do so himself. Significantly, the sample showed that a few people (6.7%) hire others to graze their animals. Milking cattle is left mainly to wives according to 86.2% of the sample, although female relatives may assist at times. Sick animals are looked after by the household-head as indicated by about 60% of the sample; sometimes wives assist.

All the respondents (100%) said that the tsetse (or *olkimpai* in Maasai) was common in the area. The combined reasons given for this by 70% respondents are the forests and the presence of wild animals.

At the personal level, all 120 persons considered tsetse to be a problem. According to 93.3% of the sample the drugs used for treating animals which become sick from tsetse-bites are expensive. In addition, tsetse prevent them from grazing their animals in some areas.

Asked as to how they thought tsetse affected cattle, 90% said that the tsetse transmitted trypanosomiasis (*olkitana*) to livestock.

People use both the traditional method of keeping cattle away from tsetse-infested areas and "modern" method of dipping. But the use of veterinary drugs to treat *olkitana* is well-known too. Most respondents (73.1%) consider Noridium as the most effective drug, but 11.5% also include Berenil and 15.4% believe only Berenil as the most effective.

In response to the question whether or not the interviewees observed any change(s) in the phenomenon of tsetse menace during the recent past (e.g. in the last 2 years), over 70% said that change has taken place because of the ICIPE trap reducing the numbers (or presence) of tsetse.

All of the 120 respondents are aware of the ICIPE trap, and 82.8% of them think that traps should be deployed as a group or community activity. For most (91.7%), there was no problem in doing so as far as they could see.

To utilise the trapping technology better, 46.7% of the respondents suggested that the ICIPE should deploy traps in infested areas whereas 6.7% thought that the ICIPE should cooperate with group ranches. Another 43.3% did not have any suggestions. The remaining 3.3% of the sample did not respond.

11.7 INDIGENOUS KNOWLEDGE OF TSETSE AND TSETSE-BORNE DISEASES IN LAMBWE VALLEY

A. W. Oendo

This study represented an attempt to explore the knowledge that people have of the varieties of tsetse in the area and their understanding of tsetse habitat, behaviour and vectorial roles. The main purpose of the study was to find out if the farmers' perceptions and beliefs on tsetse and tsetse borne diseases had any behavioural components which might be relevant to the efforts to control tsetse. The study involved the use of structured and informal interviews of 50 farmers randomly selected from three locations in Lambwe Valley.

The preliminary findings of this initial phase of the study indicate that the residents of Lambwe Valley employ seven names to describe what they perceive to be different types of tsetse. The names are descriptive and refer to the sizes and/or colours of the flies. The variety of flies mentioned by farmers differed depending on the locality. The farmers appeared, on the whole, to have an understanding of the general conditions in which tsetse reproduce and thrive. However, their perceptions regarding the habitat and preferred hosts of the various types of tsetse differed markedly. On the control of tsetse, a number of farmers claimed to be unaware of any effective means of dealing with the problem. The majority, however, are aware of and have opinions on the effectiveness of the various means of controlling tsetse. The strategies cited included bush clearing or burning, hand spraying of bushes and thickets, chemical poisoning, using tsetse traps and eliminating hosts, particularly the wild pigs.

There was also a wide range of opinions regarding the diseases that tsetse transmit. The majority of the farmers were aware that tsetse was responsible for transmitting human and animal trypanosomiasis. In addition, however, there was a wide variety of diseases that most farmers believed tsetse transmits both to human beings and animals.

There were a number of oral traditions which people narrated dealing with the origin of tsetse flies and the problems they cause. These oral traditions refer to ancient interethnic and communal conflicts on the one hand, and their perceptions of pre-colonial and colonial relations and events on the other. Our tentative finding, however, is that these oral traditions do not have any significant bearing on what the farmers consider to be the appropriate means of dealing with tsetse.

11.8 CATTLE REARING IN THE ECONOMY OF THE DIGO OF MUHAKA

A. W. Oendo

This study was carried out among the Digo of Muhaka as an attempt to understand both the relative importance of cattle rearing in the area, and the particular function which cattle play in their economy. It involved a sample of 220 farmers, of whom only 120 were cattle owners. The majority of the respondents (about 80 per cent) were Digo while the rest were mainly members of the immigrant Kamba population. The large majority of the residents engaged in the production of food crops as the main economic activity. The rest produced cash crops as the second single most important activity. On the other hand, although a number of farmers kept cattle, it was found that there was no case in which cattle rearing was practised as the most important activity.

Cattle in Digo community were traditionally regarded as a form of savings and a source of material security.

However, the changing perceptions of the role of cattle, which led to the relative decline of this traditional role are, to a considerable extent, responsible for the increased interest in cattle rearing.

The main functions of cattle according to the respondents were as follows:

Milk	47.8%
Manure	19.4%
Savings/Security	16.9%
Traction	15.9%

For the majority of the respondents (55 per cent), milk production is primarily for personal consumption. Most of the remainder, (about 30 per cent) use their milk primarily for sale while the rest claimed to give away most of their milk to relatives and needy members of the extended family. The use of manure is only beginning to be recognised as being important. However, it was only infrequently cited as a primary motive for keeping cattle. Similarly, the use of cattle as a source of draught power is also a recent innovation and is, moreover, regarded as an important function for a relatively small number of farmers.

The role of cattle as a means of savings seems to have been an important consideration mainly for the wealthier farmers. Perhaps largely as a result of the ascendancy of milk, manure and draught power as motives for keeping cattle, there is a tendency to adopt practices which appear to be conducive for the future development of cattle rearing in the area. Among these is the apparent willingness by the farmers to learn and adopt new practices from neighbouring cultural groups, such as using oxen for ploughing which they have learnt from the Kamba. There is also considerable reliance on veterinary services in dealing with livestock diseases. These are tendencies which would appear to improve the chances of success of any technologies which may be introduced with the purpose of controlling livestock pests or generally improving the quality of cattle in the area.

11.9 THE FEASIBILITY OF USING CHICKENS AS PREDATORS OF LIVESTOCK TICKS ON RUSINGA ISLAND: A PRELIMINARY ASSESSMENT

J. W. Ssennyonga and P. Mungai

The biological potential of chickens as predators of livestock chickens has been demonstrated (*ICIPE Annual Reports 1989 , 1990*). This study aims to determine the socio-economic feasibility of using chickens as predators of livestock ticks (FUCPLT). Three measurable indicators of FUCPLT, namely demographic trends, distribution and management, are being investigated in a two-phase research project (1991–1993). In phase I, March – December 1991, information was collected mainly from a physcial count of 813 chickens in 53 homesteads comprising 104 households.

11.9.1 Distribution

Livestock and poultry are owned and managed at two different levels and by two different sets of producers. Whereas livestock are owned exclusively by men, chickens are owned and managed by women (96%) at household level. Chickens are reared in all livestock-owning homesteads, resulting in favourable ratios of livestock to chickens (see Table 11.2).

However owners of cattle and chickens will have to alter their production goals to bring them in line with FUCPLT. Furthermore, current shelter arrangements do

Table 11.2 Ratios of livestock to chickens on Rusinga Island

	Cattle:Chickens		Goats:Chickens		Sheep:Chickens	
Ratios	Frequency	%	Frequency	%	Frequency	%
Less than 1	16	41.0	17	51.6	5	41.7
1–1.99	12	30.8	7	21.2	2	16.7
2–2.99	4	10.3	4	12.1	1	8.3
3–3.99	3	7.7	1	3.0	2	16.7
4–4.99	0	0.0	1	3.0	0	0.0
5–5.99	0	0.0	0	0.0	0	0.0
6–6.99	0	0.0	0	0.0	1	8.3
7–7.99	0	0.0	1	3.0	0	0.0
8–8.99	0	0.0	1	3.0	0	0.0
9–9.99	0	0.0	0	0.0	0	0.0
10–14.99	4	10.3	1	3.0	1	8.3
Total	39	100	33	100	12	100

not give chickens ready access to cattle; cattle shades are changed periodically to enhance soil fertility; only 11% have erected shelters for chickens; others keep them in the living houses, kitchens or on the verandah.

11.9.2 Demographic parameters

Flocks are dominated by chicks and female chickens. Fertility is relatively low while mortality is very high mainly due to frequent outbreaks of epidemics and very poor veterinary services. Offtake is high especially for male adults while acquisitions are low. Net balance was, in 1990/91 a negative value of 344, likely indicating an unstable population.

In phase II, a management and demographic model will be developed to serve the purposes of FUCPLT.

11.10 COSTS AND AFFORDABILITY OF TICK CONTROL METHODS USED IN KALOLENI DIVISION, KENYA COAST

J. W. Ssennyonga, G. T. Lako and O. Nyapela

Study of the costs and affordability of the tick control methods used by farmers in Kaloleni Division is the fourth component of the Mariakani Project (see *ICIPE Annual Reports 1989 , 1990*). Costs are of three kinds, namely cash, labour and materials some of which, such as medicinal plants, do not have price tags. Affordability is measured in terms of farmers' incomes and expenditures.

Activities completed so far are: selection of field sites and farmers as well as the designing and pre-testing of the research protocol. Data collection, well under way, is due for completion in February 1992.

11.11 ETHNOVETERINARY STUDIES

J. W. Ssennyonga, O. Nyapela and P. Mungai

Ethnoveterinary studies in Kaloleni Division, Kenya Coast and Rusinga Island, South Nyanza *(ICIPE Annual Reports 1989 , 1990)* seek to determine the potential and constraints of indigenous veterinary knowledge and practices to the R & D of Integrated Tick Management (ITM) technologies.

Socio-economic basic research has been completed and 80% of the 105 medicinal plants collected have been identified. Arrangements are underway to screen the samples for activity.

INSTITUTIONAL BUILDING AND INTERACTIVE RESEARCH UNIT

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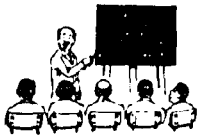

12

Institutional Building and Interactive Research Unit

During 1991, IBIRU strengthened its activities to assist national institutions to improve their capabilities in the following areas:

- *Education for leadership in developing and validating IPM/IVM technologies;*
- *Training of practitioners for implementing new IPM/IVM techniques;*
- *Facilitating interactions and exchange of information among national programme scientists and international centres through PESTNET.*

EDUCATION

1. The African Regional Postgraduate Programme in Insect Science (ARPPIS) is now a fully functional collaborative Ph.D. graduate training network comprising the ICIPE and 21 African universities. By the end of 1991, 31 ARPPIS students had been awarded their Ph.D. degree from the Participating Universities, seven had submitted their theses and eight were finalising their theses prior to submission. All ARPPIS students continue to work in Africa.

2. Participants of the "International Conference on Innovative Approaches for Sustainable Capacity Building for Insect Science Leadership in Africa" known as the Bellagio II Meeting, made strong recommendations for upgrading and enlarging the present ARPPIS Network by including four Sub-Regional Centres for Masters Degree Programmes at selected African universities and the ICIPE Graduate School.

3. The next follow-up meeting — the "International Planning Conference on Establishing Sub-Regional Centres for Masters Degree Programme in Insect Science in Africa" was organised by the ICIPE on behalf of the ARPPIS Academic Board in collaboration with the Jomo Kenyatta University College of Agriculture and Technology (JKUCAT) between 5 and 7 August 1991. The participants endorsed the proposal of Sub-Regional Centres offering Masters Degree Programmes in Insect Science at selected universities and agreed to cooperate through the sharing of resources in establishing the programme as a part of ARPPIS Network. The first M.Sc. degree programme in Tropical Entomology will admit its first class in March 1992 at the University of Zimbabwe.

TRAINING PRACTITIONERS

Five group training courses were offered to insect science practitioners and frontline personnel within the National Agricultural Research and Extension Services (NARES). Sixty-eight scientists and technicians from 21 countries participated in four courses on: tsetse and livestock tick management, plant resistance to pests, IPM/IVM information and documentation, and data collection, analysis and interpretation in pest and vector management. A prioritised register of the training needs of national research systems in IPM/IVM (mainly in PESTNET network countries) has been established for the next 5 years and curricula of courses developed for all levels of training.

PESTNET

Efforts have been made to strengthen the National Agricultural Research Systems (NARS) in selected activities in the area of insect pest management under the auspices of the Pest Management Research and Development Network (PESTNET). These activities are grouped in three areas: interactive technology development, training and exchange of information.

The aim is to develop integrated pest management systems that significantly improve the food supply of member countries who have problems with those pests currently studied in the network.

Scientific information and methodologies which can be adapted for integrated management of pests in four countries having PESTNET resident teams, i.e., Kenya, Zambia, Rwanda and Somalia have been generated and a facility for testing and demonstrating these methodologies in different agro-ecological zones within the network has been established.

The 8th PESTNET Steering committee (7 September 1991) and Annual Research Conference held in Arusha, 28–31 October 1991, noting that PESTNET has been operational for the last 4 years and a number of achievements have been realised, made recommendations to introduce a new PESTNET Management structure to improve close partnership and interactions with national programmes.

The proposed "PESTNET Policy Council" as a senior policy level decision making body at the apex of PESTNET, should consist of Directors of Research in Agriculture and/or Livestock Development from all the PESTNET member countries. The present Scientific Steering Committee should be re-named as "PESTNET Technical Advisory Committee" to advise on the scientific/technical activities of PESTNET.

PESTNET has also intensified its activities in developing of a data base that would satisfy the needs of the network members for retrieval, collation and dissemination of scientific information. In order to achieve this, PESTNET has established a computerised centre called Pest Management Documentation, Information, System and Service (PMDISS) dealing with the documentation and information relating to insect pest and vector management that will serve the information needs of PESTNET and other users in the developing world, especially Africa.

INTERNATIONAL CONFERENCES/WORKSHOPS/MEETINGS

The IBIRU staff represented the ICIPE and presented papers in 12 international conferences and meetings. ARPPIS and PESTNET organised four international meetings with approximately 230 participants in 1991.

12.1 IMPORTANT ARPPIS ACTIVITIES IN 1991

Z. T. Dabrowski

The eighth 1990 ARPPIS class of 14 Ph.D. scholars started their research projects in January 1991 in various ICIPE research programmes. The subject areas are: Effect of cultural practices on the bean fly damages bean plants (one student from Rwanda); biological control of locusts (Kenyan, Sudanese and Burkina Faso students); behaviour of banana weevil (Nigerian); behaviour and sensory physiology of mosquitoes (Nigerian); natural resistance to ticks in cattle (Ethiopian and Beninoise students); tsetse ecology in Ethiopia (Ethiopian); physiology of locust (two Kenyan students); *Bacillus thuringiensis* strains for mosquito control (Nigerian) and immune response of stem borers and African armyworm to pathogenic micro-organisms (Zimbabwean).

The ninth ARPPIS class of 14 students joined the ARPPIS Ph.D. programme on 1 March 1991 (Figure 12.1). They come from the following nine countries: Kenya (5); Tanzania (2); Sudan (1); Sierra Leone (1); Zaire (1); Cameroon (1); Zambia (1); Uganda (1) and Ethiopia (1), and between 15 March and 15 September 1991 they were taught six basic courses and three supplementary courses (Table 12.1).

Certificates of Completion were presented to eight students from 1988 class on 1 March 1991 by Professor Joseph Mungai, Secretary to the Commission for Higher Education, Kenya, who delivered a Distinguished lecture entitled "Debriefing and Readjusting High-Tech Insect Scientists for Social Services and Responsibility". The names of the ARPPIS 1988 students are given in Table 12.2.

Two scholars of the 1989 class, Ms Rosetta B. Bob-Manuel and Mr. Francis Nwilene presented their research on the biological control of cassava green spider mite during the 21st Annual Research Conference, 1–4 May 1991. Some research data collected by Mr. B. E. M. A. Uronu and Mr. A. S. S. Mbwana both (in 1989 class) has been presented during the conference by ICIPE senior scientists involved in the

Figure 12.1 The ninth ARPPIS Class of 14 scholars from nine countries with Dr. K. J. Mbata (left) and Professor Z. T. Dabrowski (right).

Table 12.1 Details of courses given in 1991 ARPPIS teaching semester

Course	Instructors	Instructor's institution	Duration of course
BASIC COURSES:			
Insect Taxonomy	Prof. A. E. Akingbohungbe (core lectures)	Obafemi Awolowo University Ile-Ife, Nigeria	13 March–5 April 1991
	Dr. R. Bagine (Seminar series and practicals)	National Museums of Kenya, Nairobi, Kenya	29 July–2 August 1991
Insect Functional Morphology	Dr. K. J. Mbata	University of Zambia Lusaka, Zambia	8–26 April, 1991
	Dr. W. Jura	ICIPE, Nairobi, Kenya	
Insect Physiology and Biochemistry	Dr. M. F. B. Chaudhury	ICIPE, Nairobi, Kenya	29 April–31 May 1991
	Dr. R. K. Saini	"	
	Dr. E. O. Osir	"	
Biological Control	Dr. G. P. Kaaya	ICIPE, Nairobi, Kenya	3–21 June 1991
	Dr. M. O. Odindo	"	
	Dr. M. J. Chacko	"	
	Dr. N. K. Maniania	"	
	Dr. W. Overholt	ICIPE/WAU Project, ICIPE, Nairobi, Kenya	
Introduction to Micro-computers	Dr. S. Nokoe	ICIPE, Nairobi, Kenya	24–28 June 1991
	Mr. J. M. Otedo	ICIPE, Nairobi, Kenya	
Biostatistics and Experimental Design	Dr. S. Nokoe	ICIPE, Nairobi, Kenya	1–27 July 1991
	Prof. I. C. A. Oyeka	Anambra State University of Technology, Awka Campus, Nigeria	
Insect Ecology	Prof. H. Morgan	University of Sierra Leone	5–16 August 1991
	Prof. J. Elkinton	University of Massachusetts, USA	
	Dr. C. M. Mutero	ICIPE, Nairobi, Kenya	
	Dr. L. Smith	"	
SUPPLEMENTARY COURSES:			
Documentation and Information Retrieval	Mr. N. S. M. Nsubuga	ICIPE, Nairobi, Kenya	2–3 September 1991
	Ms E. N. Kahuhu	"	
	Ms D. W. Barasa	"	
The Role of Social Science in Insect Pest Management	Prof. F. G. Kiros	ICIPE, Nairobi, Kenya	4–6 September 1991
	Dr. J. W. Ssennyonga	"	
	Dr. G. T. Lako	"	
	Dr. I. B. Bassir	"	
Project Identification, Formulation, Evaluation and Budgeting	Mrs. R. A. Odingo	"	9–11 September 1991
	Dr. W. A. Otieno	"	
	Mr. J. R. Kapkirwok	"	

BEST AVAILABLE DOCUMENT

Table 12.2 The 1988 ARPPIS class: Ph.D theses, supervision and registering university

Name of the candidate	Country	Abridged thesis title	ICIPE supervisors	University supervisors	Registering university
Mukolo C. Taguma	Zambia	Contribution and inheritance of the major components of resistance in certain maize cultivars to the stem borer *Chilo partellus* (Swinhoe) (Lepidoptera:Pyralidae)	Prof. K. N. Saxena Dr. R. S. Pathak	Dr. D Lungu	University of Zambia, Lusaka, Zambia
Salah M. Kheir	Sudan	Immune responses of rabbits to experimental inoculation with salivary gland antigens from *R. appendiculatus* and *A. variegatum* (Acarina:Ixodidae)	Prof. O. O. Dipeolu Dr. A. O. Mongi	Dr. H. S. Abdalla	University of Khartoum Sudan
Malik A. Mohamed	Sudan	Studies on pathological aspects and biocontrol potentials of the entomopathogenic fungus, *Beauveria bassiana* (Deuteromycetes: Fungi Imperfecti) to legume pod borer, *Maruca testulalis* (Lepidoptera: Pyralidae)	Dr. G. P. Kaaya Dr. M. O. Odindo	Dr. S. M. El Hassan	University of Khartoum, Sudan
Charles F. Mugoya	Uganda	Feeding behaviour of *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae) in relation to its host and non-host plants	Dr. S. M. Waladde Prof. K. N. Saxena	Prof. R. Kumar	Rivers State University of Science and Technology, Port Harcourt, Nigeria
A. E. Onyido	Nigeria	Spatial distribution of *Sergentomyia garnhami* in a kala-azar endemic area of Tseikuru, Kitui District, Kenya	Dr. J. M. Mutinga	Prof. R. Kumar	Rivers State University of Science and Technology, Port Harcourt, Nigeria
Beth A. Rapuoda	Kenya	Ecological and behavioural studies on the population of mosquitoes in the Mwea Tebere Irrigation Scheme (Kenya) with a special emphasis on *Anopheles arabiensis* (Diptera: Culicidae)	Dr. J. M. Mutinga Dr.C. M. Mutero	Dr. J. M. Mueke	Kenyatta University, Kenya
Seter Siziya	Zambia	Modelling tsetse movement and distribution in Nguruman escarpment, South-western Kenya	Dr. B. Williams Dr. R. Dransfield	Prof. J. J. Moore	University of Zambia, Lusaka, Zambia
I. Abu-Zinid	Sudan	Estimation of longevity, survival rate and rate of loss and gain of the robber fly *Alcimus* sp. (Diptera Asilidae) by a capture recapture method	Dr. R .D. Dransfield Dr. G. P. Kaaya Dr. B. Williams	Dr. M. O. Bashir	University of Khartoum, Sudan

development of IPM strategies for controlling banana pests.

The ARPPIS Academic Board met twice on 6 June 1991 and 5 December 1991. Both meetings discussed and endorsed establishment of four sub-regional centres at selected African universities for Masters Degree Programme in Insect Science and the ICIPE Graduate School. During its June 1991 meeting, the Board selected 15 candidates out of 68 qualifying applications for the 1992 class.

The eighth ARPPIS Annual Scientific Meeting was held on 4 December 1991, where the 19 ARPPIS Ph.D. scholars of the 1989 and 1990 classes presented their last year achievements. The presentations, methodology used and quality of results were independently evaluated by the Academic Board Members, the ICIPE supervisors and invited visitors. The Board members recommended that the Scientific Meeting be expanded to 2 days and the first year students will present their Ph.D. research proposals.

The ARPPIS network now encompasses 22 African universities. Vice-Chancellors of new universities who have signed the Memorandum of Agreement and joined the Network in 1991 are: (i) National university of Abidjan, Côte d'Ivoire — January 1991; (ii) University of Nairobi, Kenya — June 1991; (iii) Ogun State University, Nigeria — June 1991; and (iv) University of Nigeria (Nsukka), Nigeria — August 1991.

The following university supervisors visited the ICIPE to evaluate the ARPPIS students research projects: Professor J. M. Mueke from Kenyatta University, Kenya visited Mbita Point Field Station three times to evaluate and assist Mr. Eric Ndhine in his research project on biological control and discussed the supervision of other students with Dr. K.V. Seshu Reddy. He travelled to Tanzania (26-31 January 1991) to evaluate Mr. B.E.M.A. Uronu's (1989 class) research on banana weevil. Professor J. M. Mueke also visited Mwea Irrigation Scheme two times to evaluate research project of Mrs. Beth Rapuoda (1988 class) on ecology and behaviour of

mosquito species with special emphasis on *Anopheles arabiensis*.

Professor Hamid S. Abdalla, Department of Parasitology (supervisor of Mr. Salah Kheir) and Dr. Siddig Mohammed El Hassan (supervisor of Mr. Malik Alian Mohamed), Department of Crop Protection, University of Khartoum, Sudan, visited the ARPPIS for 2 weeks in March/April 1991. Professor Magzoub Omer Bashir, Department of Crop Protection, University of Khartoum, supervisor of Mr. I.M.I. Abu-Zinid visited ARPPIS between 24 May to 7 June 1991. The University of Khartoum supervisors were assisting the Sudanese scholars in their final writing-up of their theses.

The ARPPIS sponsored the visit of Professor Abdel Khattab, Secretary, Academic Affairs, University of Khartoum, Sudan, to the ICIPE during the 1991 Annual Research Conference (1–4 May 1991) and the ICIPE Alumni Association Symposium on Community-Based and Environmentally Safe Pest Management between 6–9 May 1991.

Dr. Han Sun Heat, Associate Professor (Biological Control Specialist), University of Abidjan, Côte d'Ivoire, the University Supervisor of Mr. Dona Dakouo (1990 class) visited ARPPIS between 29 April to 6 May 1991. He informed the ARPPIS Coordinator that the University of Abidjan is presently offering a one year course for an advanced degree, equivalent to the M.Sc.; and that the University will not register ARPPIS scholars having only Diploma degree from universities of French-speaking countries.

12.2 ENHANCEMENT OF ADVANCED EDUCATION IN INSECT SCIENCE THROUGH THE ARPPIS NETWORK

Z. T. Dabrowski, R. A. Odingo and R. A. Washika

12.2.1 Innovative approaches in leadership training for insect science

"The International Conference on Innovative Approaches for Sustainable Capacity Building for Insect Science Leadership in Africa" was organised between 24–28 June 1991 at the Rockefeller Foundation Bellagio Study and Conference Centre, Bellagio, Italy, to review the present state of African universities (and especially their postgraduate programmes); needs for training African scientific leaders in Africa; different models involving research centres in advanced education; and enhancing the present ARPPIS Ph.D. programme into the ICIPE Graduate School as a model (Figure 12.2).

The Vice-Chancellors and representatives of the Association of African Universities (AAU) present at the Bellagio II conference indicated that the present economic crisis and the pressure for the expanding undergraduate education at the universities adversely affected their postgraduate programmes. Recent review missions undertaken by the AAU confirmed that universities are not well equipped and prepared to offer Ph.D. programmes.

Figure 12.2 Participants of the Bellagio II conference on Innovative Approaches for Sustainable Capacity Building in Insect Science Leadership in Africa, including the Minister for Higher Education in Zambia, Prof. L. Goma (sitting third from left).

UNESCO's studies also confirm that Africa is under pressure from many crises and, therefore, it has neglected science; and that it needs to identify centres of excellence to further its frontiers of science. UNESCO will support the most feasible and cost-effective models which will complement the universities in the development of scientific human resources.

It was noted that Africa has not yet considered up to now the scientific potential of centres of excellence for advanced training in spite of recommendations of meetings organised over the last 5 years by Deans and Directors of postgraduate studies and the Association of Faculties of Agriculture in Africa (AFAA). These meetings made strong recommendations to African countries to involve National Agricultural Research Systems (NARS) defined as "all institutions/organisations in a given country actually or potentially involved in agricultural research and technology development".

Different successful models involving centres of excellence in postgraduate training in India and Venezuela were presented at the Conference. These centres offer much broader programmes than the classical departments at the universities. Newly developed research centres in Africa have the potential to be involved in postgraduate training to complement the national universities. These centres have the opportunity to offer interdisciplinary programmes which the universities would not offer.

The Vice-Chancellors present at the Conference were unanimous in supporting the establishment of the ICIPE Graduate School as a logical process in strengthening postgraduate training. They did not foresee any competition with the universities, rather, the programme would stop the present brain-drain and promote brain circulation in the continent. The Association of African Universities (AAU) confirmed this view.

The participants, therefore, agreed that the ICIPE, as a centre of excellence in insect science, should assist in establishing the ICIPE Graduate School and concentrating on Ph.D. programme. The proposed Graduate School will consolidate the present ARPPIS Ph.D. programme and serve as a model for other research institutions in Africa. They emphasised that the ICIPE Graduate School programme should offer multi-disciplinary opportunities to students. The Academic programme should offer courses on present state-of-the-art knowledge, not only in insect science, but also in related disciplines such as biostatistics and computer science, chemical ecology, molecular science, genetics, research management and social science. This model, where an international research centre maintains links with universities, was encouraged by UNESCO. In effect these "supranational" institutions would serve Africa well in identified disciplines in science.

12.3 ESTABLISHING FOUR ARPPIS SUB-REGIONAL CENTRES FOR MASTER'S DEGREE PROGRAMME IN INSECT SCIENCE IN AFRICA

Z. T. Dabrowski and R. Runo

The setting up of the Sub-Regional Centres is an important attempt to strengthen higher education in African universities and to produce course structures and project supervision that meet the needs of NAR & ES and universities at the M.Sc. level. ICIPE, on behalf of the ARPPIS Academic Board organised "The International Planning Conference on Establishing Sub-Regional Centres for Masters Degree Programme in Insect Science in Africa" in collaboration with the Jomo Kenyatta University College of Agriculture and Technology (JKUCAT) between 5 and 7 August 1991.

Eighteen rectors, vice-chancellors, principals, in addition to the ARPPIS Academic Board members and representatives from other universities interested in participating in the masters degree programme and representatives from the donor community (IDRC, DAAD, SACCAR, Rockefeller Foundation) attended the conference.

The participants endorsed the proposal of Sub-Regional Centres offering Masters Degree Programmes in Insect Science at selected universities and agreed to cooperate through the sharing of resources in establishing the programme as part of an ARPPIS network.

12.4 SHORT PRACTITIONER COURSES

R. Runo and Z. T. Dabrowski

Sixty-eight participants nominated by the agricultural and veterinary research institutions, extension services and universities in Africa attended five group training courses (Table 12.3). Four of the courses were organised on IPM/IVM technology development, validation and implementation and one on IPM/IVM information collection and dissemination.

Two of the four Short Practitioner Courses held in ICIPE in 1991, were EEC-sponsored courses on the Management of Vectors for the Control of Trypanosomiasis and East Coast Fever in Livestock Production. Participation was restricted to Ethiopia, Kenya, Sudan and Zambia.

12.4.1 Tick Management Course

The Tick Management Course was held at the ICIPE, Duduville, Nairobi, from 11 May to 8 June 1991. The

Table 12.3 Number of participants who attended five group training courses in 1991 from various African countries

Country	Number of participants
Burundi	2
Cameroon, Chad	1 from each country
Ethiopia	3
Ghana	1
Kenya	13
Malawi	2
Mali, Mauritius, Mozambique	
Namibia, Nigeria, Senegal	1 from each country
Rwanda, Somalia	
Sudan	8
Swaziland	1
Tanzania	5
Uganda	14
Zambia	8
Zimbabwe	1
21 countries	68 participants

training programme was conducted using lectures, laboratory practicals, and field work and covered:

- Tick ecology
- Behaviour
- Population dynamics and modelling
- Tick/host relationship
- Distribution
- Tick immunology and biochemistry
- Rearing techniques
- Identification and taxonomy
- Role of social sciences in tick control.

The nine participants (three each from Kenya, Sudan and Zambia) were awarded certificates on the successful completion of the course.

12.4.2 Tsetse Management Course

This course was held at the ICIPE headquarters from 15 June to 15 July 1991. Eight trainees participated, two each from Kenya, Sudan, Zambia and Ethiopia. The course objective was to provide sound understanding of ecological and epidemiological constraints on tsetse control technologies. After undergoing the course, trainees were able to assess the appropriateness of different technologies available in their own countries.

12.4.3 Group Training Course on Methodologies for Plant Resistance to Insect Pests for Integrated Pest Management

This 5-day course was held at the ICIPE's Mbita Point Field Station (MPFS) from 9–14 June 1991. Seven participants were selected from Burundi, Malawi, Kenya, Rwanda, Uganda and Tanzania.

The course objectives were to:

- demonstrate the crucial importance of plant resistance in insect management that is environmentally friendly and easy to adopt;
- share information on standardised methodologies of identifying plant resistance varieties in maize, sorghum and cowpeas;
- identify plant resistant varieties in maize, sorghum and cowpeas.

It was hoped that trainees would train technical staff on techniques and methodologies learnt during the training period; and incorporate pest resistance in national breeding programmes for improvement and development of crop varieties. The course had been sponsored by USAID and UNDP grants to the ICIPE.

12.4.4 Group Training Course on Efficient Data Collection, Analysis and Interpretation in Pest Management

This was the first course under the Government of Netherlands-sponsored courses in the theme "Human Resource Development for Scientific and Technological Capability in Africa". Twenty-three trainees from 18 different African countries participated in this course. Five participants were women from Burundi, Cameroon, Mozambique, Namibia and Tanzania.

The course content included four major topics:

- Use of mathematics in pest management
- Entomological data types
- Qualitative and quantitative dependent and independent variables
- Data collection methodologies
  - — Sampling
  - — Experimentation
  - — Practical data collection procedures.

Lectures, practicals, field excursions were organised for this course. Resource persons were drawn from ICIPE's Biomathematics Research Unit, KETRI and AMREF.

12.5 IN-SERVICE TRAINING

R. Runo

This scheme gives scientists from national programmes and universities the opportunity to work at the ICIPE with special reference to PESTNET collaborative activities among others. Seven nominees from four countries participated in the individually designed in-service training programmes. The details of the training are given in Table 12.4.

12.6 PESTNET COORDINATING ACTIVITIES

E. O. Omolo

The concept and objectives of PESTNET remained the same and in order to realise the benefits of the interactive approach, PESTNET has developed a strong training and education programme for strengthening national scientific leadership and capabilities at all levels in insect science and pest

Table 12.4 Trainees under the in-service training scheme at the ICIPE in 1991

Officer's name	Country	Area of specialisation	Area(s) of training at the ICIPE
Osman A. E. Fahal	Sudan	Crop Protection	Biocontrol and Computer use in Plant Protection
El Hadi E. T. Mohamed	Sudan	Crop Protection	Biocontrol and Computer use in Plant Protection
Abdel Karim Ibrahim	Sudan	Veterinary Research	Tsetse Biological Control Methods
Yassir O. Mustafa	Sudan	Veterinary Research	Ticks Biological Control Methods
Said M. Jamale	Somalia	Crop Pests	Bases of Plant Resistance to Insect Attack Crop Loss Assessment
M. Mulumba	Zambia	Veterinary Research	Use of Computers in Research
Abebe Mekonnen	Ethiopia	Veterinary Research	Tick Management

management, thereby creating a critical mass of insect scientists in Africa and other tropical countries; and a computerised documentation system known as Pest Management Documentation, Information System and Service (PMDISS) to enable the exchange of scientific information within and between PESTNET member states.

Research and development (R&D) activities are being conducted in four countries which are agro-ecologically representative of the participating countries so that scientific information generated, and developed into IPM technological packages can be disseminated in the region after validation and demonstration in these four countries: Kenya, Zambia, Rwanda and Somalia.

12.7 PESTNET: TECHNOLOGY DIFFUSION IN IPM PILOT PROJECTS

E. O. Omolo

Under PESTNET, components of IPM technologies have been developed, validated and demonstrated in Kenya and to a lesser extent, in Zambia and Somalia. These technologies are now ready to be disseminated to other PESTNET member countries for validation and further adjustment to fit their own local specific requirements.

In Kenya, this has been done in the Oyugis-Kendu Pilot Project in Western Kenya where PESTNET and the Ministry of Agriculture have jointly worked together to promote the use of IPM technologies (plant resistance, cultural practices and biological control in small-scale farms to reduce food losses due to insects pests). This project has worked with 25 participating farmers from Oyugis and 25 from Kendu Bay. There are also the same number of non-participating farmers in the project. The information being generated provides a strong basis for future replication of the project in other African countries.

12.8 THE 8TH PESTNET STEERING COMMITTEE MEETING AND THE PESTNET 1991 ANNUAL CONFERENCE

E. O. Omolo

The 8th Steering Committee Meeting was convened on 7 September 1991. Some far reaching decisions were taken that will strengthen and develop the next phase of PESTNET.

The Directors of Agriculture, Livestock Development and Medical Health participating in the Directors' Forum (4–6 September 1991) were invited as special guests to this Steering Committee Meeting and contributed significantly to the decisions taken.

The 4th PESTNET Annual Conference held from 28–31 October 1991 in Arusha, Tanzania endorsed the Steering Committee recommendations and a communique was duly signed by the PESTNET national coordinators and/or representatives present. They made the following recommendations:

1. The PESTNET Conference be held once every 2 years and in this General Meeting, all the national representatives will participate. However, participation is open to other scientists involved in the development and validation of IPM provided they are privately supported. The meetings will rotate among the member states.

2. There should be a senior policy level decision making body in PESTNET. The proposed PESTNET Policy Council should consist of Directors of Research in Agriculture and/or Livestock Development from all the PESTNET member states, meeting once every two years to set down policy guidelines and decide on programme priorities.

3. Noting the role the present Scientific Steering Committee has played, they recommended the change of name from "Steering Committee" to "PESTNET Technical Advisory Committee (PTAC)" to advise on the scientific/technical activities of PESTNET and meet once a year. Each zone will be represented by one member, and in addition, there will be four eminent scientists representing the four disciplines; ticks, tsetse, crop pests and information. These scientists would be proposed and elected by the Biannual Conference. The additional specialists in other disciplines should be added as PESTNET includes these in its operation.

The Committee will be made up of eight members plus the PESTNET Coordinator as an Ex-Officio member who will also serve as the Secretary and the Chairman will be elected from the members. The Terms of Reference for the PESTNET Technical Advisory Committee and operational guidelines based on those of the Steering Committee will be drafted by the Secretariat and endorsed by the Council.

4. In addition to the support given by PESTNET, they recommended that member governments should show their interest and commitment by utilising their limited available resources to support PESTNET activities, and PESTNET will assist in the development of project proposals on IPM for donor support.

12.9 UNDP EVALUATION OF PESTNET

E. O. Omolo

PESTNET was evaluated in-depth by the UNDP from 3–29 June 1991. The Team Leader was Dr. A. Morton of Agrisystem assisted by Mr. John J. Ondieki, Executive Secretary of the National Pesticide Control Board, Kenya.

The two-man Review Mission visited the PESTNET Resident Teams in three countries (Kenya, Zambia and Rwanda) except Somalia where civil strife could not make this possible. In the course of their deliberations, they had detailed discussions with PESTNET scientists, national scientific counterparts, government officials and the farmers. The team recommended that PESTNET Project should be supported by UNDP for another 5 years.

12.10 PESTNET ACTIVITIES IN ZAMBIA

H. O. Okech and K. Chisembu

In Zambia the PESTNET activities were focused on insect pests of maize which is the country's staple food. All the activities carried out during 1989/90 were continued in the 1990/91 cropping season. These included:

(i) Assessing pest status and damage on early and late

planted maize for recommendations on adjustment of time of planting.

(ii) Screening of germplasm for resistance to maize streak virus (MSV) and *Chilo partellus*

(iii) Evaluation of potential *Tephrosia vogelii* for control management of stalk borers.

(iv) Survey and determination of the role of indigenous parasitoids in suppression of stalk borer populations.

(v) Assessment of yield losses caused by *C. partellus*.

(vi) Mobilisation of personnel for reaching the farmers and establishment of collaboration with the Adaptive Research and Planning Team (ARPT).

(vii) Sensitisation of farmers and initiation of transfer of some validated technology components. This included time of planting vis-a-vis insecticides.

12.10.1 Seasonal population patterns of stalk borers

Population patterns of the larvae of the three stalk borer species (*Busseola fusca*, *C. partellus* and *Sesamia calamistis*) were monitored on maize at Golden Valley, and Mount Makulu (representing region II) and Mansa (representing region III). The data was obtained by dissecting 40 plants and recording the species and number of larvae found in them every 2 weeks, starting 5 weeks after emergence (WAE) until harvesting.

Busseola fusca pheromone trap was also installed at Mount Makulu in 1990/91 season starting on 1 October 1990 to monitor the adult population.

The data obtained at Golden Valley showed that the population reached 10 larvae per plant. The attack came in very early (5 to 11 WAE) (Figure 12.3) and was mainly *C. partellus*. *Sesamia calamistis* was also present at the beginning of the season but its population was very low until towards the end of the season when it became predominant. *Busseola fusca* came late (11 WAE) and its population was more or less the same as that of *C. partellus*. At Mount Makulu *C. partellus* was predominant throughout the season followed by *B. fusca*. *Sesamia calamistis* was minor (Figure 12.4). Number of larvae per plant was also low (<0.9/plant).

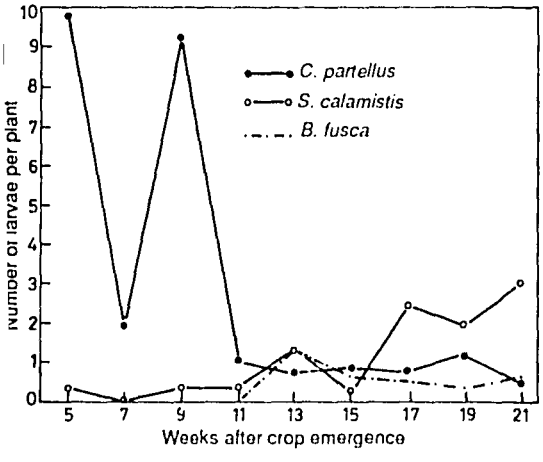

Figure 12.3. Population patterns of stalk borers in maize at Golden Valley, Zambia (1990/91 season).

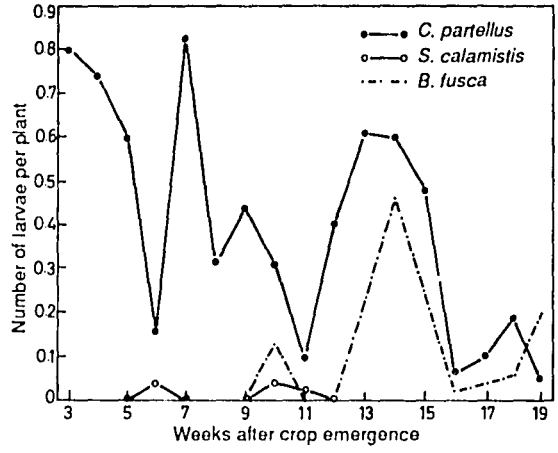

Figure 12.4. Population patterns of stalk borers in maize at Mount Makulu, Zambia (1990/91 season).

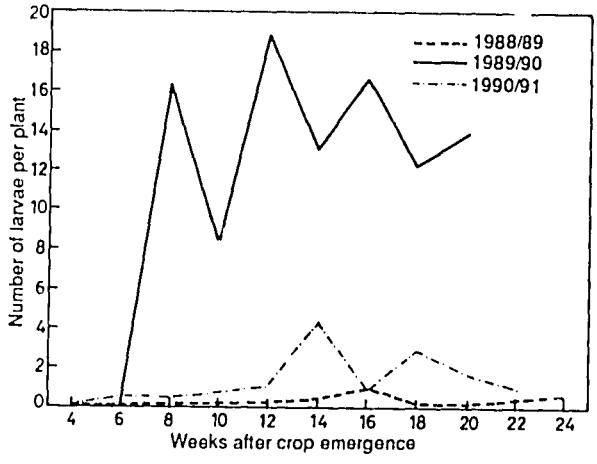

Figure 12.5. Population patterns of stalk borers at Mansa, Zambia (1990/91 season).

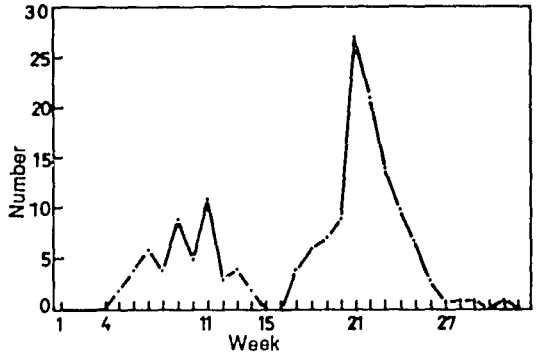

Figure 12.6 Weekly catches of male *Busseola fusca* moths using synthetic pheromone at Mount Makulu, Zambia (1990/91 season). Week 1, 26 Oct.–1 Nov. 1990; Week 4, 16–22 Nov. 1990; Week 11, 4–10 Jan. 1991; Week 15, 1–7 Feb. 1991; Week 21, 15–21 Mar. 1991; Week 27, 26 Apr.–2 May 1991; Week 32, 1–7 June 1991.

At Mansa the population was less than five larvae per plant (Figure 12.5) and was mainly *B. fusca*, *Chilo partellus* was absent.

The *B. fusca* pheromone trap data at Mount Makulu showed that the adults started to emerge from mid November and there were two distinct peaks which indicates two generations (Figure 12.6). The first peak was smaller (about 10 moths per week) and was recorded between mid December and mid January. The second peak appeared in March and was the biggest with about 25 moths per week.

12.10.2 *Effect of time of planting on the incidence and damage by stalk borers and MSV and yield losses due to their attack on maize*

Use of time of planting in pest management involves adjustments in dates of planting so that the most susceptible stage of crop development coincides with the time when the pest is least abundant. Incidence, damage, and yield loss due to stalk borers and MSV in relation to time of planting was studied in selected sites, Golden Valley representing rainfall region II and Luapula Regional Research Station (Mansa) representing region III.

The earliest date of planting depended on the onset of rains. Later plantings were delayed with an interval of 15 days each. At Mansa, planting was done on 10 and 25 December 1990, and 7 January 1991. At Golden Valley planting was done on 13 and 28 December 1990 and 12 January 1991. MM752 hybrid variety was used. Carbofuran 5g (Furadan) was to protect some plots so as to quantify the amount of loss due to stalk borers and MSV. Per cent stalk borer attack and larval densities were recorded at 35, 65, 95, and 125 days after emergence (DAE). Per cent MSV attack and damage rating was taken at 9 weeks after emergence (WAE). The yield was recorded at 12.5% moisture content after harvest.

Unlike the previous seasons the incidence of stalk borers at Golden Valley was higher on the first planting than on the second and third planting (Table 12.5). MSV incidence was higher than in the previous seasons. Yield between the first and second planting were not significantly different, but third planting had a significantly lower yield than the first and the second planting. Protected crop significantly yielded more than the unprotected crop (Table 12.6). Per cent yield loss in the first and second planting were not significantly different and were lower compared to the loss in the third planting. Yield loss in the first planting could be attributed mainly to stalk borers because MSV incidence was negligible. However, MSV may have contributed significantly to the losses in the second and third planting.

Data from Mansa showed a similar trend with the data obtained in 1989/90 season. The MSV incidence was very high. Per cent yield losses were also higher than in 1989/90

Table 12.5 Mean % (± S.E.) stalk borer attack on early and late planted maize at Golden Valley during 1990/91 cropping season

Date of planting	Unprotected crop	Protected crop (Furadan)	$LSD_{0.05}$
35 DAE			
13 Dec. 1990	27.7 ± 3.3[a]	4.0 ± 3.6[a]	
28 Dec. 1990	17.8 ± 3.0[b]	2.1 ± 1.9[a]	
12 Jan. 1991	8.8 ± 1.4[c]	2.5 ± 1.1[a]	
Mean	18.1	2.9	12.5
65 DAE			
13 Dec. 1990	46.4 ± 8.7[a]	12.0 ± 5.0[ab]	
28 Dec. 1990	30.8 ± 7.7[b]	17.3 ± 4.3[a]	
12 Jan. 1991	25.9 ± 2.3[c]	6.2 ± 1.6[b]	
Mean	34.4	11.9	10.7
95 DAE			
13 Dec. 1990	54.2 ± 6.6[a]	17.3 ± 4.1[b]	
28 Dec. 1990	37.9 ± 9.4[b]	29.1 ± 5.0[a]	
12 Jan. 1991	33.4 ± 2.6[b]	8.6 ± 1.6[c]	
Mean	41.8		8.9
125 DAE			
13 Dec. 1990	54.4 ± 3.6[a]	30.5 ± 5.8[b]	
28 Dec. 1990	45.2 ± 9.0[b]	41.6 ± 6.8[a]	
12 Jan. 1991	41.8 ± 3.6[b]	20.8 ± 2.6[c]	
Mean	47.1	31.0	8.7

For each DAE means followed by the same letter in a column are significantly different ($P = 0.05$) by DMRT (DAE = Days after emergence).

Table 12.6 Yield in tonnes (Mean ± S.E./ha) of early and late planted maize during 1990/91 cropping season

Date of planting	Unprotected crop	Protected crop (Furadan)	% Yield loss
Mansa			
10 Dec. 1990	5.70 ± 0.30[a]	8.10 ± 0.10[a]	31.80 ± 5.30[b]
25 Dec. 1990	2.60 ± 0.20[b]	6.10 ± 0.50[b]	55.60 ± 7.70[a]
7 Jan. 1991	1.10 ± 0.20[c]	2.20 ± 0.10[b]	49.40 ± 11.40[a]
Golden Valley			
13 Dec. 1990	5.20 ± 0.20[a]	6.20 ± 0.40[a]	16.40 ± 4.40[a]
28 Dec. 1990	4.90 ± 0.40[a]	6.20 ± 0.70[a]	20.60 ± 8.30[a]
12 Jan. 1991	2.40 ± 0.20[b]	3.80 ± 0.20[b]	33.90 ± 10.40[b]

In each site means followed with the same letter in a column are not significantly different ($P = 0.05$) by DMRT. To compare unprotected and protected crop, $LSD_{0.05}$ = 0.77t/ha for Golden Valley, $LSD_{0.05}$ = 0.82t/ha for Mansa.

season. Yield loss was lower on the first planting than on the second and third planting.

The data from Golden Valley suggests that incidence of stalk borer on the maize crop changes with time of planting. However, the changes are not consistent and depends on the season. In some seasons the early planted crop gets heavy attack than the late planted crop but in other seasons the late planted crop suffers more than the early crop (report for 1990). This phenomenon may be influenced by seasonal changes in the species composition.

The MSV has a potential of becoming a problem at Golden Valley. The incidence was very low during 1988/89 and 1989/90 but in 1990/91 there was a surge which affected late planted crop. Therefore even if early planting may not contribute significantly to the management of stalk borers at Golden Valley, it should still be observed and encouraged as an insurance against MSV.

Since *B. fusca* comes late into the maize crop, late planted crop is likely to suffer more than early crop in those sites like Mansa which are infested with *B. fusca*. The data also indicates that Furadan is effective in controlling stalk borers and MSV. However, its efficiency depends on the pest pressure especially for MSV. Late planting in Mansa encourages high pressure of stalk borers and MSV. Early planting is therefore an important cultural management practice for both stalk borers and MSV in this region.

12.10.3 Potential of Tephrosia vogelii *water extract for controlling maize stalk borer,* Chilo partellus

Tephrosia vogelii is a wild leguminous plant native to Africa. It is commonly known as "Ububa" in Bemba language in Zambia and is common in Central, Northern and Luapula Provinces of the country. The plant is perennial with branching radius of up to 2 m and may attain a height of 2 to 3 m. In Zambia the indigenous farmers of the above provinces have been using *T. vogelii* water extract for fishing and controlling stalk borers for many years. However, their extraction procedure and concentrations have not been standardised. Data on its efficacy on control of stalk borers is also not available. Bioassays of water extract of *T. vogelii* was conducted on *C. partellus* in the laboratory. Incidence of stalk borers on field plots of maize sprayed with the extract was also monitored.

Laboratory studies were conducted at Mount Makulu Central Agricultural Research Station and at the Livestock and Pest Research Institute of the National Council for Scientific Research of Zambia. Field studies were conducted at Golden Valley Research Station. All other studies were conducted using extracts of young leaflets after the plants had attained the age of 12 months and above. This age was selected because the plant usually has many branches and leaves at this stage.

Extraction. Fresh young leaflets of *T. vogelii* were collected and 50 g weighed out. The samples were macerated in a blender for 5 minutes, then extracted with 500 ml distilled water on mechanical shaker for 60 minutes at room temperature. The extract was then filtered *in vacuo* through standard cotton wool to give a 10% (w/v) stock solution from which serial dilutions for bioassays were made.

Laboratory bioassay: Bioassays were conducted using first and third instar larvae of *C. partellus* reared in the laboratory for four generations. For first instar larvae, the extract was serially diluted into 2.5000, 0.6250, 0.1560, 0.0391, 0.0098% (w/v). Leaf discs (20 mm diameter) were prepared (using cork borer) from the middle part of the central whorl leaf of 30 days old maize plants (commercial hybrid — MM752) collected from the field. The discs were weighed and then dipped into the extracts for one minute and placed singly in glass petri dishes (8.5 cm diameter) lined with filter paper which had been moistened with 1 ml distilled water. Control discs were dipped in distilled water.

The results showed that the amount of feeding on control discs was higher than that on the extract-treated discs. Mortality of the first instar larvae increased progressively with the increase in the concentration of the extract (ranging from 24% in the lowest concentration to 81.67% in the highest concentration after 12 hours) (Table 12.7).

Field tests. The tests were carried out on early and late planted maize in a split plot design with four replications. *T. vogelii* extract and control (unsprayed) formed the main plot. Subplots comprised three dates of planting as follows: 13 December 1990, 28 December 1990, and 12 January 1991. Each crop was sprayed twice at 21 days after emergence (DAE) and 42 DAE with the extract at a concentration of 4% (w/v). Leaf damage was rated at 35 DAE. Ten plants were sampled randomly per plot at 35, 65, 95, and 125 DAE to estimate per cent stalk borer attack and larval densities. Grain yield was recorded in kg/plot at 12.5% moisture content then extrapolated into tons per hectare.

The results of field observations show that the mean per cent stalk infestations by borer, number of borer larvae per plant and leaf damage rating were significantly lower ($P > 0.05$) on the plots sprayed with *T. vogelii* extract than on plots which were not sprayed when planting was done early. But when the crop was planted on 28 December 1990, (second planting) the differences were not significant. Plots sprayed with the extract also gave significantly higher yield than unsprayed plots in the earliest planted crop. Differences in yield from sprayed and unsprayed plots were not significant in the second and third planted crop (Table 12.8).

Table 12.7 Mortality of first instar *Chilo partellus* larvae after treatment with water extract of *Tephrosia vogelii* leaves (% Mean ± S.E.)

Concentration (% w/v)	Mortality	
	12 hours	24 hours
0.0098	23.33 ± 5.6	20.00 ± 3.3[d]
0.0391	43.33 ± 5.8[c]	33.34 ± 3.3[c]
0.1560	50.00 ± 8.8[c]	43.34 ± 9.0[c]
0.6250	60.00 ± 3.3[b]	50.00 ± 3.3[b]
2.500	81.00 ± 3.3[a]	63.34 ± 3.3[a]

Means followed by the same letter in a column are not significantly different ($P = 0.05$) by DMRT.

Table 12.8 Yield of maize (t/ha) planted on different dates and treated with *Tephrosia vogelii* water extract (Mean ± S.E.)

	Date of planting		
Treatment	13 Dec. 1990	28 Dec. 1990	12 Jan. 1991
T. vogelii	6.2 + 0.3[a]	5.5 + 0.6[a]	2.3 + 0.2[a]
Control (Unsprayed)	5.5 + 0.2[b]	4.9 + 0.4[a]	2.4 + 0.2[a]

Means followed with the same letter in a column are not significantly different ($P = 0.05$) by DMRT.

These results demonstrate that *T. vogelii* water extract can cause mortality to both first and third instar *C. partellus* when applied on the surface of the maize leaf. The cause of mortality seems to be due to an antifeedant effect and the insects die of starvation.

Further studies are still required on effect of *T. vogelii* on other species of stalk borers and appropriate regimes of application. Extract from plants of different ages should also be tested.

12.10.4 Mass rearing of stalk borers

Rearing of *B. fusca* has been a problem due to its diapausing behaviour. The technology for its rearing has just been developed at ICIPE and arrangements have been made to adopt it.

A new insectary has now been acquired at Mount Makulu. The new facility consists of two larval rearing rooms (3.5 x 2.9 m) for *C. partellus* and (3.3 x 4.0 m) for *B. fusca*. The room for *C. partellus* can hold a maximum of 56,000 larvae while the room for *B. fusca* can hold 22,400 larvae. There are also separate rooms for preparation of the diet, storage of the ingredients, oviposition, processing of ingredients and cleaning of the rearing jars. The rearing room for *C. partellus* is fitted with the environmental control equipment and its temperature is maintained at 27 ± 2°C while humidity is maintained at 65 – 75%.

12.10.5 Evaluation of maize germplasm for resistance to MSV

The objective was to evaluate the level of resistance to MSV in the commercial varieties which have been released in Zambia and the local inbred lines with a view to incorporating resistance into the commercial varieties being developed.

Screening was done under artificial infestation at Mount Makulu Research Station (Region II) and under natural infestation at Luapula Regional Research Station in Mansa in region III. Mansa is a hot spot for MSV.

One hundred and forty-eight varieties and lines were screened in 1989/90 season under natural infestation from where the top ranking 40 varieties were selected. During 1990/91 season 56 varieties which included those which had been selected from the previous season and additional 16 from other sources were screened. The plants at Mount Makulu were artificially infested using viruliferous *Cicadulina mbila* leafhoppers which had been reared in the greenhouse. Plant height and yield from the inoculated plots and clean plots was recorded for each variety. At Mansa, where screening was done under natural infestation, the disease rating was done only once at 9 weeks after crop emergence.

The MSV incidence depended on the variety and the method of screening. Per cent attack ranged from 96–100% on artificially infested plots at Mount Makulu. Per cent attack under natural infestation at Mansa ranged from 0–80. Symptoms were visible 2 weeks after inoculation. Two varieties, Population 10 and MMV 400 showed a high level of resistance with a damage rating of 2.2 and 2.8 respectively at 6 WAI. Although a reduction of 12.8 and 15.7% in plant height was recorded in them there was not any reduction in their potential yield under the management level which was used.

The other varieties with a good level of resistance were Pool 16 and TZMi 407. Pool 16 had a damage rating of 3.0 and a reduction of 3.5% of the potential yield. TZMi 407 showed a very high level of tolerance. It had a symptom rating of 3.8 but reduction in its plant height was only 9.5% and reduction in its yield was 2.8%. Yield loss in the remaining varieties ranged from 27–100%. Yield reduction in the current commercial hybrids was 49.6, 73.6, 43.1, 37.0, and 56.3% in MM 502, MM 752, MM 612, MM 603 and MM 501 respectively.

Population 10 is an open pollinated variety which originated from Tanzania but was converted to streak resistant. MMV 400 is a streak resistant version of CIMMYT population 30. The original MMV 400 from this population is not resistant to streak. Pool 16 is a streak resistant version of the early dent CIMMYT population and TZMi 407 is an inbred line from IITA derived from a national programme variety with streak resistance conversion.

12.10.6 Screening for resistance to stalk borers

All the 56 varieties which were screened for resistance to MSV were also challenged with *C. partellus* at Golden Valley. Each of the plants were infested with 20 blackhead *C. partellus* eggs at 28 days after emergence (DAE). Foliar leaf damage rating on a scale of 1–9 (1 = highly resistant and 9 = highly susceptible) was taken 3 weeks after infestation.

Varieties with a rating of 1–3 were regarded as resistant and have been selected for further screening in multi row testing in the coming season. These included L7X17/1-7-5-3, (L13XL7) x L2/1-5-2XL12/5-1-1-1-2, Inbred local material—1 165, T56-3, MT, outcross/1-6-2XL12/9-1-1-3-1, Inbred local material—1 167, MMV400, Pool 16, N3 T55-2, TZMi 407 Mt. outcross/1-8-1X112/1-3-3-1-3, L7XN3/4 and TZMi 102. Three varieties MMV 400, Pool 16 and TZmi 407 were also resistant to MSV and are, therefore, very important because they seem to have multiple resistance. Conclusion will be made after screening them under artificial infestation in multiple rows.

12.10.7 Interaction with adaptive research planning team (ARPT) and farmers

In Zambia, the Adaptive Research Planning Team (ARPT) provides the link between research, extension services and the farmers. Advanced research results are supposed to be tested in the farmers field in collaboration with the above parties before final recommendation for adoption. PESTNET initiated its collaboration with ARPT in 1990. Mansa district in Luapula Province was selected for a start because the

District is composed of small scale farmers which is the target of the project, maize stalk borers and maize streak virus (MSV) which the project is focusing on are serious and current ARPT activities in the area require assistance of pest management specialist.

The initial trials were started on three farms. The effect of time of planting on the incidence of stalk borers and MSV was tested in collaboration with the farmers. Each farmer reserved 0.5 ha for the trial. The plot was divided into two. One portion was protected with Furadan and the other portion was unprotected (control). Planting was staggered as follows: 2 December 1990, 17 December and 1 January 1991. The farmers were assisted with seed (MM752 variety), fertiliser and the chemical only. All the operations were done by the farmers themselves following the advise of the experts. Assessment of the pest incidence was done by PESTNET personnel. Sampling for borers was done at 35 and 65 DAE. MSV was recorded at 50 DAE.

The borer and MSV incidence increased with the delay in time of planting. The borer incidence in the first planting was zero in both protected and unprotected crop at 35 DAE. Application of Furadan significantly reduced the borer and MSV incidence in the second and third planting compared to the unprotected plots. The data indicates that farmers may not need insecticides to protect their maize crop against stalk borers and MSV when they plant within the first week of December. Since this is a one season data in the farmers field, there is a need to repeat the trial for two more seasons due to fluctuations in weather pattern.

The above interaction is the beginning of the technology transfer through PESTNET in Zambia. The ARPT has requested an increase in the number of farmers in the programme.

- In those areas where the species overlap *C. partellus* attacks the crop earlier (2–5 weeks after germination) while major attack by *B. fusca* takes place from 9 weeks after germination and is usually the second generation.
- Early planting (within first week of December) is effective in minimising borer problem in region III but not in region II. This is probably because of the overlap of the species of the borers in region II where all the three species do occur. In region III only *B. fusca* and *S. calamistis* do occur. These species normally attack the crop late.
- *Tephrosia vogelii* has potential for controlling stalk borers but further studies are still required.
- MMV 400 variety showed a moderate level of resistance to *Chilo partellus* in a single test. Further screening in multiple rows is still required. It should also be challenged with *B. fusca* before its resistance to the borers is confirmed. A colony of *C. partellus* is well established at Mount Makulu but *B. fusca* has been a problem to rear. Attempts are underway to develop a colony of *B. fusca*.

12.11 PESTNET ACTIVITIES IN KENYA

S. Kyamanywa

PESTNET activities for Kenya are based in the Kenya Agricultural Research Institute (KARI) which is under the Ministry of Science and Technology. KARI has the mandate to conduct agricultural research in Kenya and has Research Centres located in the main agro-ecological zones of Kenya.

PESTNET collaborative activities have been initiated in four of KARI's research Centres of Kitale, Embu, Katumani and Mtwapa which represent high potential, medium potential, semi arid and sub-humid agro-ecological zones respectively. The entomologists in these centres are conducting PESTNET research activities which are co-ordinated by the PESTNET Resident Scientist based at KARI Coast Regional Research Centre, Mtwapa.

The main objectives of PESTNET/KARI collaboration are to: (i) generate information on selected major insect pests of important food crops in Kenya, and to test and validate effectiveness of IPM components in controlling the pests and integrate them into a menu of pest control packages, and (ii) promote a national approach in tackling pest management problems, through strengthening interaction between KARI scientists, training and exchange of scientific information.

PESTNET in Kenya started by concentrating on the major pests of maize, beans and cowpea, which are the most important food crops in the country. Emphasis has been placed on the stem borers, and the following experiments were conducted in 1990 and 1991.

12.11.1 Comparative studies on the efficacy and economics of a recommended pesticide, Dipterex, versus intercropping as an alternative control measure against Busseola fusca *in Trans-Nzoia District*

PESTNET, in collaboration with Mrs. Mulaa, Entomologist NARC-Kitale, conducted studies in which efficacy and economics of Dipterex, a recommended pesticide, on *B. fusca* was compared with intercropping. The studies were conducted in a farmer's field at Endebess and at NARC Kitale during the long rains of 1989 and 1990. The results indicated that intercropping reduced the incidence and damage of *B. fusca* almost to the same extent as Dipterex. But economic analysis revealed that while application of Dipterex did not result in a significant gain in revenue compared to the control, intercropping maize with beans significantly increased net revenue. These results suggest that the recommendation to use Dipterex should be re-examined based on economic injury levels.

12.11.2 Methodology for determining economic injury levels of stalk borers on maize in farmers fields

In Kenya, information on losses caused by crop borers and their economic injury levels (EIL) at farmers' level is scanty and in some cases contradictory. Due to lack of this information it is difficult to test and validate effects of IPM components on pest population and damage as it would not be clear whether the method reduced the pest incidence below EILs. Therefore, in 1991, PESTNET initiated studies, first of all to develop a simple method of determining economic injury level based on natural field infestation and secondly to determine losses caused by stalk borers on maize and their EILS in different agro-ecological zones represented by KARI centres of Embu, Katumani, Kitale and Mtwapa.

In the work conducted at KARI Mtwapa, single plant analysis method was used to determine maize yield/damage

relationships associated with stalk borers, to categorise effects of time of infestation on yield losses and to calculate EILs based on leaf damage rating, under natural field infestation. The results indicated that the losses caused by stem borers depended on time when maize plant were infested. Plants affected in the first 4 weeks after emergence of maize (WAE), suffered the greatest reduction in yield followed by those infested between 4–8 WAE, and least or no loss at all in those plants infested late 8 WAE and above. They also showed that relationships between damage parameters (holes, percentage tunnelling and leaf damage rating) and yield were significant and negatively correlated. The correlation coefficient decreased with late infestations suggesting that late infestation, 8 weeks and above, did not reduce yield significantly.

The EILs for *Chilo* sp. on different stages of growth of maize var. Coast Composite were also calculated based on leaf damage rating data obtained from single plant analysis.

Thus the single plant analysis method has been identified as an appropriate method of determining EILs of stalk borers in the field under natural infestation. It is being used to determine EILs of stalk borers in the other three KARI Centres and on farmer's fields; the method is simple and will even be easier for peasant farmers to use once EILs based on % plants infested per unit area are calculated. Detailed results from all the centres will be included in PESTNET-Kenya report for the year 1991–1992.

12.11.3 Non-research activity

(i) Planning meeting

In April 1991 a one-day meeting was held at Duduville to discuss PESTNET research activities in Kenya. It was attended by Entomologists from Embu, Katumani, Kitale, Mtwapa, Head of Crop Pests Research Programme, PESTNET Coordinator and Head of IBIRU.

(ii) On field training

KARI entomologists participating in PESTNET and their technicians were visited and trained on single plant analysis sampling method for determining EILs. They were also shown how to identify the stalk borers.

(iii) National PESTNET co-ordinator's visit

In July 1991, the national PESTNET Co-ordinator, Dr. Wanjama, spent 4 days visiting KARI Centres where PESTNET activities are taking place. The purpose of the trip was to see PESTNET's field experiments and to discuss with Centre Directors on PESTNET Kenya.

12.12 PESTNET ACTIVITIES IN RWANDA

S. K. Firempong

A survey carried out in Rwanda, revealed that *Busseola fusca* was the most predominant borer in these zones accounting for 60–70% with *Sesamia calamistis* and *Eldana saccharina* making up the rest.

Both local and exotic maize lines were screened and promising source of maize lines resistant to stem borer attack have been identified. Some of these lines were commercial hybrids from Kenya and Tanzania hybrid formed from the parental lines originally obtained from Kenya (Tanzania version of Kenyan hybrids). This is the first time Kenyan hybrids have been tested for stem borer resistance apart from the work done by the ICIPE scientists.

The Rwandese Government has requested that more emphasis should be placed on bananas and their pests, namely banana weevil, *Cosmopolites sordidus*, followed by beanfly *Ophiomyia phaseoli*. The Resident Scientist in Rwanda, will in future liaise very closely with the ICIPE's research team based at Bukoba, Tanzania who are working on banana in collaboration with Tanzania Agricultural Research Organisation (TARO).

12.13 PESTNET ACTIVITIES IN ETHIOPIA

G. Tikubet

The Ministry of Agriculture, Livestock and Fisheries of the Ethiopian Government and the International Centre of Insect Physiology and Ecology signed a Memorandum of Understanding in February 1988. They have since jointly developed a research and development protocol on sustainable tsetse management in South-western Ethiopia. In addition, the ICIPE has established an operational base in the Institute of Pathobiology, Addis Ababa University.

Research protocols are also being developed in tick and tick-borne diseases. It is expected that other co-operative programmes will be initiated as the demands from the national programmes arise.

It is further planned to organise various workshops, seminars, conferences and exhibitions to promote and popularise effective community-based integrated pest management (IPM) packages.

In the area of high-level man-power training, the ICIPE has already signed a memorandum of agreement and initiated a Ph.D. programme in collaboration with Addis Ababa University. ICIPE has awarded scholarships to four Ethiopian entomologists who are currently undertaking research in Ethiopia and Kenya. Furthermore, Addis Ababa University has also been nominated to host the regional M.Sc. programme for Insect Science for the Northern and Eastern parts of Africa.

12.14 THE PEST MANAGEMENT DOCUMENTATION AND INFORMATION SYSTEM AND SERVICE (PMDISS)

D. Barasa

The major goal of PMDISS is to facilitate the provision and exchange of information on insect pests and disease vectors in support of the Pest Management Research and Development Network (PESTNET) activities and to meet the information needs of other users of insect science in the tropical developing world, especially Africa.

Following the groundwork during the previous year, much progress was made during 1991 in setting up the PMDISS database and other activities of the Network.

12.14.1 Setting up of the National Coordinating Centres (NCCs)

During the month of May, 1991, the Documentalist travelled

to Mozambique, Zambia and Uganda to set up the first group of NCCs. The fourth country in this category is Rwanda, but due to communication problems, the trip was deferred. The specific aim of the trips was to assess the facilities and resources available in each country, discuss the documentation needed, and to formalise activities and to work out the modalities on how the NCCs will operate.

12.14.2 PMDISS Regional Training Workshop on Information and Documentation, 5–8 August 1991, Entebbe, Uganda

The training workshop was convened by PMDISS in collaboration with the Ministry of Agriculture, Animal Industry and Fisheries of Uganda. The main goal of the workshop was to give the documentalists, librarians, information officers and scientists from PESTNET countries training to act as contact person in PMDISS National Coordinating Centres.

The specific objectives of the training workshop were:

- to brief the participants on the goals and objectives of PMDISS;
- to establish the status of information in the participating countries;
- to train the participants on information retrieval and processing for PMDISS;
- to provide a forum for information specialists to exchange ideas; and
- to undertake preliminary testing and evaluation of PMDISS information working tools with participants in the Network;

The workshop was attended by 21 participants from five NCCs, Ugandan agricultural and academic institutes, the African Academy of Sciences (AAS) and the International Centre of Insect Physiology and Ecology (ICIPE). The countries represented were Kenya, Uganda, Zambia, Mozambique and Zimbabwe.

The level of representation by the Ugandan Government at the workshop was high, and included the Hon. Minister for Agriculture, Animal Industry and Fisheries, the Permanent Secretary, the Secretary for Research, and several senior officers from the same Ministry.

12.14.3 Presentations at workshops/seminars

The Documentalist made several presentations at workshops and seminars on the various roles of PMDISS and information in general. These included the following:

- PMDISS Training Workshop, 5–8 August, 1991, Entebbe, Uganda;
- Financial and Administrative Management of Research Projects in Eastern Africa (FAMESA)/ Zimbabwe Institute for Development Studies (ZIDS) National Workshop on R & D Institute-Constituency Relationship, 20–23 August, 1991, Harare, Zimbabwe;
- Workshop on Effective Networking of Research and Development on Environmentally Sustainable Locust Control Methods, among Locust Affected Countries 16–18 September, 1991, Duduville, Nairobi, Kenya;
- PESTNET 4th Annual Conference, Arusha, Tanzania, 28–31 October, 1991.

The workshops provided a good forum for publicity for PMDISS and its activities especially to the scientific community. For the first time, an information expert, Mr. M. Hailu, Head of Information and Documentation Services at ICRAF attended the PESTNET Steering Committee Meeting. It is expected that, as a result, key policy issues on information in the future should reflect expert views.

12.14.4 Information exchange and current awareness

The PMDISS headquarters has completed setting up the main database and has distributed input sheets and the manual for information processing to most of the Centres. Information is expected to flow in following this action. The incorporation of the Selective Dissemination of Information (SDI) programme on the main database using micro CDS/ ISIS software has been completed, and questionnaires on the same will be going out soon. Some of the NCCs have also started sending information on pest management. The year also saw the production of the first issue of the *PMDISS Bibliography* which will come out quarterly and will contain records from PMDISS participating centres in addition to all publications at the PMDISS regional headquarters at Duduville, Kenya.

In addition to the above basic services, PMDISS is providing:

- question and answer services
- computer searches on both the in-house databases and external databases
- identifies and locates information sources, and
- depository services for local and external documents and data.

12.15 TRAINING ATTACHMENT FOR SOMALIA-BASED TEAM

E. O. Omolo

Civil strife in the Republic of Somalia interfered with the work of the ICIPE's Resident Scientific Team in Mogadishu, Afgoye and Baidoa research centres, ICIPE successfully re-organised the team in Kenya and a training programme on environmentally sound integrated pest management (IPM) for the Somalia-based staff currently in Kenya has been formulated. The attachment is initially for 6 months.

The training package includes field experiments, laboratory work as well as extensive field visits to IPM demonstration sites at contrasting agro-ecological zones all over the Republic of Kenya. This training will be of much value when the ICIPE Resident team returns to Somalia to resume their activities.

12.16 TRAINING AND EDUCATION FOR PESTNET COUNTRIES

Z. T. Dabrowski

Majority of the ARPPIS Programme Ph.D. students are nominated from National Agriculture and Veterinary

Research Systems in Africa. The first PESTNET sponsored Ph.D. candidate from Zambia, Mrs. M. Taguma has completed her studies and she has gone back to Zambia to work with the National Programme.

PESTNET needs for training are met by the ICIPE organised group courses. PESTNET nominated and sponsored candidates from NARS to two International Group Training Courses on: "Methodologies for Plant Resistance to Insect Pests for Integrated Pest Management" and "Efficient Data Collection, Analysis and Interpretation in Pest Management" in 1991.

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Administration and Information Division

A major concern of the Administration and Information Division during the year was the commencement of a critical review of the Centre's human resource base, which has doubled in size from about 400 in 1985 to 806 as at December 1991. This tremendous growth in staff numbers has been due to several factors, among them the establishment and expansion of Mbita Point Field Station as the Centre's principal field research facility, with all the necessary infrastructure, and with some satellite sub-stations and research sites; the introduction of new research programmmes and units, such as the Locust Research Programme and the Social Science Interface Research Unit; and the expansion of the Centre's training and capacity building programmes, particularly ARPPIS. These developments, together with the corresponding growth in technical and administrative support services, have resulted in a steady increase in staff numbers over the past 8 years or so, with staff-related costs accounting for a much higher proportion of the Centre's core budget than can be sustained.

The ongoing staff retrenchment exercise, due to be completed by March 1993, is expected to trim down the establishment to about 580, at which level the Centre can then consolidate as it prepares itself for the challenges of the medium-term future.

Three special meetings co-sponsored or convened by the ICIPE during the year also need to be highlighted: the International Conference on Innovative Approaches for Sustainable Capacity Building for Insect Science Leadership in Africa (Bellagio II) held in Bellagio, Italy, from 24 to 28 June 1991; the International Planning Conference on Establishing Sub-Regional Centres for the Masters Degree in Insect Science in Africa, hosted by the Jomo Kenyatta University College of Agriculture and Technology (JKUCAT) from 5 to 8 August 1991; and the Directors Forum for ICIPE's Strategic Framework for the 1990s and its Linkages with the National Programmes, held at the ICIPE Headquarters in Duduville from 3 to 6 September 1991. All the three meetings were aimed at helping the ICIPE to redefine its goals and strategies for the 1990s and beyond. In the case of Bellagio II and the JKUCAT planning conference the focus was on ICIPE's training and capacity building programmes, while the Directors Forum focused on interactive research and development, with the ICIPE and the National Programmes working together as equal partners.

Of the three meetings Bellagio II and the JKUCAT conference were planned under the overall leadership of IBIRU, with the usual inputs from LIDS and ICIPE Science Press; while the Directors Forum was conceptualised, planned and executed with the Administration and Information Division taking the lead role. The Forum was a singular success, and it gave the Centre a rare and unique opportunity to discuss its agenda and strategies with top-ranking policy makers and scientists from the National Programmes in Africa.

With the successful completion and commissioning in April 1991 of the Swiss-funded Information Resource Centre, which houses the Library and Documentation Services, the major part of the Duduville Headquarters Capital

Development Programme is now drawing to a close. The original Headquarters masterplan included some elements which are still lacking, and for which fund-raising efforts will continue. Among these are a conference centre and a training complex. In addition, over the past 2 years the Management has been discussing with the Governing Council preliminary proposals for a staff housing scheme in Nairobi, and it is hoped that in the near future funding will be available for at least the most essential part of such a scheme.

13.1 CAPITAL DEVELOPMENT

L. Okola

On the very last day of the year, 31 December 1991, the tender for the construction of Muhaka Field Station in the Coast Province of Kenya was awarded to Messrs Premji Dungar and Sons, a Nairobi construction firm. The projected capital development programme for the new field station is a modest one, and the tender that was awarded was for a small building to house a tsetse laboratory and an insectary. This was to be followed by another small building for the Crop Pests Research Programme.

Essential services such as piped water, electricity, and telephone are still not available at the site, but will be provided in due course. In the case of electricity, a DANIDA-funded rural electrification project has already brought power close to the site, while work on telephone services is also underway. Water is a more difficult problem in the area, and initially a borehole will be necessary.

Muhaka is ICIPE's largest single field research site in Kenya, comprising some 320 acres of humid coastal land. Of this about two-thirds is forested and is to be preserved as such, while the remaining one-third is arable and is already being used by the Crop Pests Research Programme. The forest is tsetse infested, and scientists from the Tsetse Research Programme have been working there for a number of years.

The new Field Station will enable the Centre to consolidate its research and development activities in the Coast Province and apart from Crop Pests, Tsetse Research Programme and the Social Science Interface Research Unit are also going to benefit from the consolidation.

13.2 COMMUNICATION SERVICES DEPARTMENT

R. W. Washika

13.2.1 Directors Forum for ICIPE's Strategic Framework for the 1990s and its Research and Development Linkages with National Programmes

The success of international centres such as the ICIPE ultimately depends on the extent to which they are able to interact and cooperate with the national programmes, through which they can reach the end-users and beneficiaries of their research results: the farmers. The ICIPE considers this partnership critical to successful execution of its mandate. In recognition of this, a distinguished gathering of prominent scientists, policy-makers, donors and administrators representing various institutions and governments in the tropical developing world assembled at the ICIPE for a 3-day high level consultative forum.

This forum was convened to bring together a cross-section of the top leadership of the national programmes in Africa to discuss ICIPE's proposed research and capacity-building agenda for the 1990s and its plans for R&D linkages with national programmes. And in this way, they would recommend ways of making that agenda even more relevant, more effective and more responsive to the needs of the target beneficiaries.

The forum was officially opened by Hon. George Saitoti, the Vice-President of Kenya and Minister for Finance. Under the very able chairmanship of Hon. Anna Abdalla, Minister for Agriculture, Livestock and Co-operatives in the Republic of Tanzania, the forum, in principle, endorsed the ICIPE's "Vision and Strategic Framework for the 1990s" as laid out in its draft statement and came up with a set of recommendations for the ICIPE, the National Agricultural Research Systems, Donors and Agricultural Networks.

13.2.2 The Third ICIPE Mobile Seminar

The Third ICIPE International Mobile Seminar was held in New York on 22 October, 1991 with the theme "Developing Community-based Technology in Agriculture, Health and Food Security". The co-sponsors were The United Nations Development Fund for Women (UNIFEM), which focused on low income women in developing countries, the African-America Institute (AAI), the largest and oldest private US organisation devoted exclusively to Africa-America relations, the United Nations Development Programme (UNDP), and the International Centre of Insect Physiology and Ecology (ICIPE).

ICIPE's International Mobile Seminars are designed to introduce the Centre's work to the international communities in key metropolitan cities of the world.

The seminar in New York, was the third in the series. The first was held in Stockholm, Sweden, in 1989 for all Nordic countries. The second seminar was held at the EEC headquarters in Brussels, Belgium in 1990.

The New York seminar addressed ICIPE's work aimed at improving rural health in the tropics through management of disease vectors; improvement of livestock production through livestock disease control; the strengthening of farmers' technological capacity for food

security through crop pests management, and the role of women in sustainable rural health and food security in Africa.

13.3 ICIPE SCIENCE PRESS (ISP)

L. Okola and S.W. Mwanycky

13.3.1 Production and Marketing

The Press had another good year, and was able to maintain its high standards in print design and production, perhaps best exemplified by the 1990 edition of the Annual Report, which was very well received.

A notable development during the year was the establishment of a marketing department, and the appointment of Miss Agnes Katama as a Marketing and Information Executive. The new department has been charged with the responsibility of developing and implementing an aggressive strategy for promoting and marketing all ISP publications, including the international journal, *Insect Science and its Application*. It will also market other ISP services such as graphic design and scientific editing and typesetting.

Marketing is going to be a major preoccupation of the ISP over the next 2 years or so, as the Press moves gradually towards financial autonomy and semi-commercialisation, and away from direct ICIPE sponsorship.

ISP Publications Catalogue was produced during the year, being one of the first initiatives of the marketing department. Another noteworthy publication was the Proceedings of the 1988 Bellagio Symposium on Scientific Institution Building in Africa, sponsored jointly by the ICIPE Foundation (as its last activity before dissolving itself), the African Academy of Sciences, and the US National Academy of Sciences.

The Press is now in a position to enter into co-publication and distribution arrangements with other science publishers worldwide.

Enquiries about the ISP and its publications, and requests for the ISP catalogue, should be addressed to the publisher, ICIPE Science Press, P.O. Box [illegible]913, Nairobi: Fax (0254)-803360.

13.3.2 Scientific Editorial Unit

Insect Science and its Application, the international journal of tropical insect science has become one of the most internationally renowned science journals in the world. We receive papers from all over the world of a multi-disciplinary nature, without losing sight of their relevance in research efforts aimed at alleviating hunger problems in the tropical world. Our subscribers are also world-wide.

The journal in its 12th Volume has been on schedule, bimonthly, with the publication of the dates on the cover to facilitate the keeping of records, especially in libraries, our main subscribers.

This year we produced two Special Issues: Volume 12 Number 1/2/3, on Current Topics in Tropical Entomology based on the Second International Conference on Tropical Entomology and Volume 12 Number 5/6 on Aspects of Pest Management in Relation to Agricultural Production and Environmental Conservation in Africa based on Meetings of the African Association of Insect Scientists (AAIS) and the Entomological Society of Zambia.

In addition to the refereeing, editing and proofreading of the journal, the unit also undertakes all proofreading for ICIPE Science Press. This includes Programmes, Posters, Annual Report, Manuals, Proceedings, Newsletters, Advertisements, etc.

13.4 HUMAN RESOURCES DEPARTMENT

V. O. Musewe

In the past, the annual report on Human Resources Department (HRD) was covered under a broad statement on Administration and Information Division. However, in view of the Department's distinct role and the important changes that take place in ICIPE staff structure, it has been decided that the HRD prepare a separate statement starting with the ICIPE's Nineteenth Annual Report.

In this first report we have found it important to appraise the readers on the ICIPE's staff growth in the last decade, during which time the Centre steadily expanded its research and development as well as training activities and, therefore, the staff establishment. The ICIPE Governing Council has designated the level of International Professional Staff (IPS) to be one of the indicators of the size of the Centre in terms of cost-effectiveness. Over the last 6 years, this number has been fixed at 50, while the actual number in position grew from 42 to 44. The scientific staff are supported by a professional, technical and administrative support staff. The growth of core staff over the last decade is presented in Table 13.1.

The core staff are complemented by other professional scientists consisting of Postdoctoral Research Fellows (PDF), and Visiting Scientists (VS) in the form of Scientists-in-Residence and Research Associates.All professional staff, including IPS, PDF, VS and Other Professional Staff (OPS) of middle cadre scientific officers and senior Administrative and technical staff are hired through an international competitive recruitment system, which recognises merit as well as the needs of developing countries.

The year 1991 saw a marked turn-over in the ICIPE staff establishment as well as internal reorganisation through staff redeployment. Professor Olusegun O. Dipeolu, the former Programme Leader of Livestock Ticks Research Programme left ICIPE service when his contract expired on 31 May 1991. He was replaced by Dr. Godwin G. P. Kaaya, who was promoted on transfer from Tsetse Research Programme, through a competitive selection process. The year also saw the appointment of Professor

Table 13.1 ICIPE staff growth

Staff Category	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
International Professional Staff	42	44	44	47	44	44	44	44	44	44
Other Professional Staff										
Scientific	21	18	14	11	17	22	19	38	44	42
Administration	10	11	11	11	16	14	13	10	18	20
Sub-Total	73	76	69	69	77	80	76	92	106	106
Technical and Administration Staff										
Direct Support for Research	130	131	150	120	229	232	228	287	301	326
Indirect Support for Research	115	130	165	145	192	202	209	264	276	282
Sub-Total	245	261	315	265	421	434	437	551	577	608
TOTAL	318	337	384	334	498	514	513	643	683	714

Table 13.2 The 1991 staff distribution by Programme and category as at 31 December 1991

				OPS		TAS					
Programme	IPS[1]	VS	PDF	SCI	ADM	DSR	ISR	TOTAL	%	GS	LTA
Crop Pests	10	6	6	5	–	73	–	100	13.3	3	7
Livestock Ticks	5	1	1	4	–	33	–	44	5.9	–	–
Medical Vectors	3	–	3	3	–	26	–	35	4.6	–	–
Tsetse	3	4	4	1	–	30	–	42	5.6	–	–
Locust	5	1	2	4	–	8	–	20	2.7	–	–
IBIRU	1	–	–	–	5	–	13	19	2.5	33	–
Chemistry and Biochemistry	3	–	2	5	–	9	–	19	2.5	–	–
Cell Biology	3	–	1	–	–	6	–	10	1.3	–	–
Sensory Physiology	2	–	1	–	–	6	–	9	1.2	–	–
Biomathematics	1	–	1	4	7	–	13	1.7		–	–
Social Science Interface	3	2	2	1	–	18	–	26	3.5	–	–
Insect and Animal Breeding	–	–	–	2	–	34	–	36	4.8	–	–
Workshops	–	–	–	4	–	17	–	21	2.8	–	
Mbita Point Field Station (including Field Research Sites)	–	–	–	3	1	43	64	111	14.8	–	–
Muhaka Field Station	–	–	–	1	–	1	–	2	0.3	–	–
Library and Information	–	–	–	1	1	5	3	10	1.3	–	–
ICIPE Science Press	1	–	–	4	10	15	2.0	–	2.0	–	–
International Guest Centre System	–	–	–	–	1	–	59	60	8.0	–	–
Medical and Clinical Services	–	–	–	–	–	–	17	17	2.3	–	–
Mbita Point International School	–	–	–	–	1	–	10	11	1.5	–	–
Office of the Director	3	–	–	–	4	–	19	26	3.5	–	–
Administration and Information Division	1	–	–	–	3	–	73	77	10.2	–	–
Finance Division	–	–	–	–	4	–	24	28	3.7	–	–
TOTAL	44	14	23	42	20	326	282	751	100	36	7
% of Total Staff	5.8	1.9	3.1	5.6	2.7	43.4	37.5	100			

[1]IPS, International professional staff (senior scientists and managers); VS, Visiting scientist; PDF, Postdoctoral Research Fellow; OPS, Other professional staff; SCI, Scientific Officers and Senior Technical Staff; ADM, Senior Administrative Staff; TAS, Technical and administrative support staff; DSR, Direct Support for Research; ISR, Indirect Support for Research; GS, Graduate Scholar; LTA, Staff on Secondment from the Government of Kenya.

Fassil Gebre Kiros to the position of Principal Research Scientist and Unit Head of the Social Science Interface Research Unit (SSIRU) with effect from 19 June 1991. Professor Kiros was previously a Senior Research Fellow and Associate Professor at the Institute of Development Research of Addis Ababa University, Ethiopia.

Other senior appointments included that of Dr. Ramesh Chandra Saxena (Senior Principal Research Scientist, CPRP), Professor George Albert Schaefers (Visiting Scientist, SSIRU), Dr. Analee N'geny' Mengech (Senior Science Editor, ISP), Dr. Slawomir Antoni Lux (Senior Research Scientist, CPRP), Dr. Katsuhisa Kuramochi (Visiting Scientist, TRP) and Dr. Baldwin Torto (Research Scientist, LRP). New appointments on internal promotions included those of Dr. M.F.B. Chaudhury (Principal Science Editor, ISP) and Mr. Joshua Fredrick Omange (Station Manager, MPFS). Also joining the ICIPE during the year were 8 Postdoctoral Research Fellows, 3 Research Associates and 4 Scientific Officers. The staffing levels and staff distribution by category and base programme as at 31 December 1991 are shown in Table 13.2, while the full staff list is given on page 193, as the 1991 personnel.

1991 Seminars Hosted by ICIPE

SPEAKER	TITLE
A. Onyido, ARPPIS Scholar, ICIPE	Ecology of *Sergentomyia garnhami* Heishch, Guggisberg and Teesdale 1956 (Diptera: Psychodidae) in a kala-azar endemic area of Tseikuru, Kitui District, Kenya
Dr. Senayayan, Entomology Research Institute, Loyola College, Madras, India	Nutrition and behavioural dynamics of some entomophagous insects: Their importance in biological control
Dr. S. L. Taneja, ICRISAT, Patancheru, Andhra Pradesh, India	Insect mass rearing in an IPM programme
Dr. J. A. N. Obeta, Department of Microbiology, University of Nigeria, Nsukka, Nigeria	Production of *Bacillus thuringiensis* and bioassay using the tobacco budworm *Heliothis virescens*
Dr. B. Williams, Biomathematics Research Unit, ICIPE	Use of remote sensing in the study of tsetse fly habitats and distributions
Mrs. B. A. Rapuoda, ARPPIS Scholar, 1988 Class, Kenya	Ecological and behavioural studies of mosquito species in the Mwea Irrigation Scheme with special emphasis on *Anopheles arabiensis*
Prof. A. Nageswara Rao, Alemaya University of Agriculture, Ethiopia	Appropriate strategies for effective Integrated Pest Management (IPM)
Prof. I. I. Ihimodu, University of Ilorin, Nigeria	The role of international agricultural trade in economic development: Special reference to Nigeria
Dr. S. Mueller,	Application of social science in development
Prof. K. N. Saxena, Crop Pests Research Programme, ICIPE	Orientation behaviour of the stem borer *Chilo partellus* in relation to its colonisation of sorghum plants

Dr. W. M. Ciesla, Forest Resources Development Branch, Italy	Insects and fire in the forests of the Pacific North-West in USA
Mr. S. M. Kheir, ARPPIS Scholar, 1988 Class, Sudan	Immune responses of rabbits to experimental inoculation with salivary gland antigens and natural infestation using *Rhipicephalus appendiculatus* and *Amblyomma* ticks (Acarina:Ixodidae)
Dr. E. T. Jolayemi, University of Ilorin, Nigeria	Autoregressive error situation for ANOVA models
Dr. B. S. Hansson, Lund University, Sweden	Evolutionary and genetic aspects of moth pheromone communication
Dr. E. O. Osir, Chemistry and Biochemistry, Research Unit, ICIPE	Evidence for a transformation promoting factor for trypanosomes in the tsetse fly midgut
Prof. O. A. Akinboade, University of Ibadan, Nigeria	African ixodids: Ecology and management
Dr. S. Lux, Warsaw Agricultural University, Warsaw, Poland	Development and practical application of computer models of insect behaviour
Dr. S. M. Waladde, Sensory Physiology Research Unit, ICIPE	Artificial feeding of haematophagous arthropods with specific reference to ticks
Dr. J. P. Ochieng'-Odero, Insect and Animal Breeding Unit, ICIPE	Pupal and adult indices of quality of Lepidoptera: Examples from *Cnephasia jactatana* Walker (Lepidoptera: Tortricidae) and *Chilo partellus*
Prof. R. T. Carde, University of Massachusetts, USA	How does a male gypsy moth find a female in the forest?
Dr. W. Overholt, ICIPE/Wageningen University Collaborative Project, ICIPE	Colonisation and evaluation of exotic parasitoids against the South-Western corn borer in Texas and implications for biological control of *Chilo partellus* in Kenya
M. C. Taguma, ARPPIS Scholar, 1988 Class, Zambia	Contribution and inheritance of three damage parameters in maize resistance to *Chilo partellus*
Dr. S. Sithanantham, Makera Research Station, Chipata, Zambia	Some aspects of biological control of *Chilo* and *Heliothis* in India
Dr. M. E. Smalley, ILCA, Addis Ababa, Ethiopia	Training activities at ILCA
Dr. M. K. Limo, Livestock Ticks Research Programme, ICIPE	Production of antigens using recombinant DNA techniques

Dr. S. K. Raina, Locust Research Programme, ICIPE	Pathogenesis of the protozoan, *Malamoeba locustae* in the desert locust *Schistocerca gregaria*
Dr. H. S. Abdalla, University of Khartoum, Sudan	Parasitism: A challenge to animal wealth in the Sudan
Dr. R. J. Tatchell, United Kingdom	Problems associated with Integrated Tick Management
Prof. A. Hassanali, Chemistry and Biochemistry Research Unit, ICIPE	Chemical communication in tsetse: Some unanswered questions
Prof. M. H. Madbouly, National Research Centre, Cairo, Egypt	Recent strategies in the control of ticks infesting livestock
Dr. G. Popov, 129A Hammersmith Grove, London W6 0WJ, United Kingdom	A discussion of the current plague prevention strategies with special reference to the ICIPE Desert Locust Research Project
Dr. J. B. Okeyo-Owuor, ICIPE/Wageningen Collaborative Project, ICIPE	Population ecology of stem borers of maize and sorghum in Somalia
Prof. O. O. Dipeolu, Livestock Ticks Research Programme, ICIPE	Advances in studies on biology of livestock ticks in Africa
Dr. J. Zdarek, Czechoslovak Academy of Sciences, Prague, Czechoslovakia	New findings on tsetse metamorphosis
Prof. O. O. Dipeolu, Livestock Ticks Research Programme, ICIPE	New approaches to control of livestock ticks in Africa
Dr. C. Inayatullah, Locust Research Programme, ICIPE	Strain occurrence in *Cotesia flavipes* and its impact on biological control of stem borers
Dr. J. W. Ssennyonga, Social Science Interface Research Unit, ICIPE	Towards a common definition of the tick problem by researchers and farmers
Dr. G. P. Kaaya, Livestock Ticks Research Programme, ICIPE	Insect immune mechanisms
Dr. F. Were, Kenyatta National Hospital, College of Health Sciences, University of Nairobi	Sexually transmitted diseases and the new born
Dr. L. C. Madubunyi, Tsetse Research Programme, ICIPE	Ecology of *Glossina* species inhabiting peridomestic agroecosystems in relation to tsetse control options

Dr. R. K. Saini, Sensory Physiology Research Unit, ICIPE	Close-range behaviour of tsetse flies, *Glossina morsitans morsitans* to host body odour and to the sex pheromone
Mrs. M. A. Owaga, Tsetse Research Programme, ICIPE	Activity pattern and responses of tsetse fly, *G. austeni* to olfactory stimulants under field and laboratory conditions
Mrs. R. A. Odingo, Planning and Development Unit, ICIPE	Search, innovate and deliver menus for pest and vector management for ICIPE in the 1990s
Dr. J. A. Odera, Kenya Forestry Research Institute, Nairobi	Social forestry for planned land use: A Kenya perspective
Ms. S. Fischer, Institute for Scientific Information, (ISI), Oxbridge, United Kingdom	Science citation index with special reference to its CD-ROM version
Dr. J. Stiles, Tsetse Research Programme, ICIPE	Influence of tsetse gut environment in trypanosome development
Ms. R. Bob-Manuel, ARPPIS Scholar, 1988 Class	An introduction to modelling with special reference to *Mononychellus tanajoa* and its fungal pathogen, *Hirsutella thompsonii*
Dr. A. Mnzava, Medical Vectors Research Programme, ICIPE	Malaria-vector control trials in two populations of the *Anopheles gambiae* complex in Tanzania
Mr. S. Lota, Biomathematics Research Unit, ICIPE	Computer viruses: An update
Dr. D. E. Ashhurst, St. Georges Hospital Medical School, University of London, United Kingdom	Insect connective tissues -- how similar are they to those of the mammals?
Prof. J. H. Law, University of Arizona, Tuscon, Arizona, USA	Insect haemolymph proteins
Prof. A. Robinson, Institute of Molecular Biology and Biotech., Heraklion, Crete, Greece	Molecular entomology
Prof. G. Gasperi, Institute of Molecular Biology and Biotech., Heraklion, Crete, Greece	Population genetics of the Mediterranean fruitfly, *Ceratitis capitata*
Dr. I. Tittawella, Institute for Applied Cell and Molecular Biology, University of Umea, Umea, Sweden	Proteins associating with the trypanosome kinetoplast; could they be targets for chemotherapy?

Dr. K. Kibwana, University of Nairobi, Kenya	AIDS and the law
Dr. E. D. Kokwaro, Cell Biology Research Unit, ICIPE	Effects of accessory reproductive gland immunoglobulins on tsetse, *Glossina morsitans*
Mr. H. Kiara, ARPPIS Scholar, 1989 Class	Immunisation of rabbits with integral membrane proteins of the midgut of *Amblyomma variegatum*
Mr. D. Munyinyi, Biomathematics Research Unit, ICIPE	Practical value of logistic regression in insect science
Ms. S. Hill, CABI, United Kingdom	Demonstration of CABI CD-Rom
Dr. R. C. Saxena, Crop Pests Research Programme, ICIPE	Plant resistance to insect pests: The rice experience
Dr. C. Mutero, Medical Vectors Research Programme, ICIPE	Sandfly ecology: Some recent developments at ICIPE
Dr. S. Mihok, Tsetse Research Programme, ICIPE	Elusive trypanosomes: do we know what is out there?
Dr. L. P. J. J. Noldus, Noldus Information Technology BV, Wageningen, The Netherlands	Measuring and analysing insect behaviour: A technological review
Dr. A. O. J. Amoo, Livestock Ticks Research Programme, ICIPE	Tick control within and out with the context of East Coast fever immunisation
Dr. I. O. Ndiege, Chemistry and Biochemistry Research Unit, ICIPE	Orientation and aggregation mechanism of the banana weevil, *Cosmopolites sordidus*
Mr. J. J. Ondieki, Pest Control Products Board, Ministry of Agriculture, Kenya	Integrated Pest Management
Dr. B. Amoako-Atta, University of Liberia, Monrovia, Liberia	PESTNET Africa: A priority need
Dr. E. A. Akinsola, West African Rice Development Association, Bouake, Côte d'Ivoire	Integrated Pest Management: A holistic approach towards protecting crop health and saving the environment
Dr. O. M. Osman, Ministry of Agriculture, Khartoum, Sudan	Integrated Pest Management: Situation analysis of tick infestation in the Sudan

Dr. Baldwin Torto, Locust Research Programme, ICIPE	Rational approach to the design of novel insect antifeedants
Prof. Dr. M. G. Peter, University of Bonn, Germany	Chitin metabolism inhibition by natural products and analogues
Dr. J. M. Gopo, University of Zimbabwe, Zimbabwe	Mycoplasmas of the yellow type of plant disease, as causative agents for the cypress-aphid disease in Kenya and sub-Saharan Africa

1991 Conferences Attended by ICIPE staff

American Association for the Advancement of Science Symposium on Biotechnology. Washington, DC, 14–19 February 1991.
E. O. Osir

International Atomic Energy Agency/Food and Agricultural Organisation Seminar for Africa on Animal Trypanosomiasis: Tsetse Control Diagnosis and Chemotherapy using Nuclear Techniques. Muguga, Kenya, 11–15 February 1991.
R. K. Saini

UNIDO-sponsored Expert Group Meeting to Work on Developing a Code of Conduct for the Release of Genetically Modified Organisms (GMOs) to the Environment. Vienna, 6–9 March 1991.
A. Hassanali

Training Workshop on Statistics/SAS to Zambia National Programme Scientists. 18–23 March 1991.
D. M. Munyinyi

5th Workshop on Quality Control of Mass-reared Arthropods. Wageningen, The Netherlands, 25–28 March 1991.
J. P. R. Ochieng'-Odero

Workshop on Co-operation Between Social Scientists in International Centres, NARS and Universities in Eastern and Southern Africa. ILRAD, Nairobi, 12–13 April 1991.
I. B. Bassir, J. W. Ssennyonga

Biological Control of Locusts and Grasshoppers: State of the Art. Cotonou, Republic of Benin, 29 April –1 May 1991.
S. K. Raina

21st ICIPE Annual Research Conference. Nairobi, 1–10 May 1991.
Attended by all ICIPE scientific and technical staff

ICIPE/ICIPE Alumni Association Symposium on Community Based and Environmentally Safe Pest Management. Nairobi, Kenya, 6–9 May 1991.
R. K. Saini, J. W. Ssennyonga

Directors' Forum for ICIPE's Strategic Framework for the 1990s. Duduville, 7–9 May 1991.
F. G. Kiros

United Nations Conference on Environment and Development Ad Hoc Workshop of Senior Experts on International Procedures for Assessing and Managing Biotechnology Risks. London, 17–19 June 1991.
A. Hassanali

8th Annual Meeting of the International Society of Chemical Ecology. Dijon, France, 2–7 July 1991.
I. O. Ndiege

Workshop on Surveillance, Treatment and Prevention of Malaria. (KEMRI) Silver Springs Hotel, Nairobi, July 1991.
I. B. Bassir

CFTC-sponsored Workshop on "Computer Software of Relevance to Africa". 8–21 July 1991.
D. M. Munyinyi

The Sub-regional Workshop on the Control of Locusts and Grasshoppers in Eastern and Southern Africa and Inter-Agency Meeting on Migratory Locust and Grasshoppers in Africa. Lusaka, Zambia, 22–26 July 1991.
S. El Bashir

Workshop on Impregnated Bed Nets in Kenya and Tanzania. MOH/UNICEF/USAID, Nairobi, August, 1991.
M. J. Mutinga, C. M. Mutero, M. Basimike, A. P. Mnzava

22nd International Ethological Conference. August 1991.
A. P. Mnzava, R. K. Saini

IV International Congress on Malaria and Babesiosis. Rio de Janeiro, Brazil, August 1991.
C. M. Mutero

The 66th Annual Meeting of the American Society of Parasitologists. Madison, Wisconsin, USA, 4–8 August 1991.
D. K. Punyua

Invertebrate Pathology Conference. Flagstaff, Arizona, 4–10 August 1991.
G. P. Kaaya

XXIV World Veterinary Congress: Tick Control Within and Without the Context of East Coast Fever Immunisation. Rio de Janeiro, Brazil, 18–23 August 1991.
A. O. J. Amoo

Infrastructure, Environment, Water and People. Organised by the Water, Engineering and Development Centre, Loughborough University of Technology, United Nations Centre for Human Settlements, Nairobi, Kenya, 19–23 August 1991.
J. W. Ssennyonga, I. B. Bassir

1st International Symposium on Phlebotomine Sandflies. Rome, Italy, September 1991.
M. J. Mutinga, C. M. Mutero, M. Basimike

Ticks and Tick-borne Disease Control in Eastern and Central Africa. Organised by OAU/FAO/ILRAD. Kampala, Uganda, 12–14, September 1991.
J. W. Ssennyonga

OAU/FAO/ILRAD Workshop on Ticks and Tick-borne Diseases Control and Effective Control of Ticks. 12–17 September 1991.
E. Essuman

A Workshop on "Effective Networking of R&D on Environmentally Sustainable Locust Control Methods Among Locust-affected Countries". Duduville, Nairobi, Kenya, 16–18 September 1991.
S. El Bashir, J. P. R. Ochieng-Odero, S. K. Raina

INIBAP East African Regional Advisory Committee. Kampala, Uganda, 23–25 September 1991.
W. Budenberg

AAIS Symposium on Exotic Pests in Africa, their Prevention and Control. Accra, Ghana 23–27 September, 1991.
M. Imbuga

Symposium on Exotic Pests in Africa. Accra, Ghana. 23–27 September 1991.
S. M. Waladde

The International Congress on Alleviation of Natural Disasters. Arusha, Tanzania, 23–26 September 1991.
S. El Bashir

PESTNET Annual Research Conference. Arusha, 29–31 October 1991.
F. G. Kiros

Second European Symposium on Insect Taste and Olfaction. Schloss Ringberg, Federal Republic of Germany. 1–5 October 1991.
S. M. Waladde

21st Regular Session of the Governing Council of Ministers of the International Red Locust Control Organisation for Central and Southern Africa. Gaborone, Botswana, 3–4 October 1991.
S. El Bashir

The Third ICIPE Mobile Seminar: A Science Symposium on Developing Community-Based Technology in Agriculture, Health and Food Security. The Rockefeller University, New York, 22 October 1991.
I. B. Bassir

Workshop on Agriculture in Africa. Schomberg Centre for Black Culture, Harlem, New York, 23 October 1991.
I. B. Bassir

Proposed IDRC Workshop on Leishmaniasis Control Strategies: A Critical Review of 15 IDRC Supported Projects. Merida, Mexico, November 1991.
M. J. Mutinga

Pan-African Conference on Environment and Development in Africa: Scientific Initiatives. Mbabane, Swaziland, 11–14 November 1991.
A. Hassanali

Research Coordination Meeting for Biological and Integrated Control of Highland Banana and Plantain Pests and Diseases. IITA Biological Control Centre for Africa, Cotonou, Benin, 12–14 November 1991.
W. Budenberg

Biochemical Society of Kenya (BSK) Annual Symposium. Egerton University, Nakuru, Kenya, 7–8 November 1991.
E. O. Osir, M. Imbuga, V. W. Vundla

National Malaria Workshop (Ministry of Health/USAID). Nairobi Safari Park Hotel, 19–20 November 1991.
I. B. Bassir

International Conference for Biocontrol in Tropical Agriculture. Kuala Lumpur, Malaysia.
E. N. Mwangi

2nd Scientific Meeting of East/Central African Network. Harare, Zimbabwe, 23–30 November 1991.
K. S. Nokoe, D. M. Munyinyi

IFS-NAPRECA Workshop on Modern NMR Methods. Addis Ababa, Ethiopia, 9–15 December 1991.
W. Lwande

The 4th NAPRECA Symposium on Natural Products. Addis Ababa, Ethiopia, 16–21 December 1991.
W. Lwande, D. Nyarango

9th Tanzania Veterinary Association Scientific Conference: Arusha, Tanzania, 3–5 December 1991.
G. P. Kaaya

1991 Publications by ICIPE staff*

**The list does not include manuscripts in press and those submitted during 1991.*

Adegbehin J. O., Nwaighbo L. C. and Nokoe S. Resources of the mangrove with special reference to the coastal areas of Nigeria: Their utilisation and management perspectives. *Discovery and Innovation* 3, 37–45.

Adegbehin J. O., Nokoe S. and Okojie J. A. The versatility of the Gompertz and Logistic functions as growth models in forestry. *Discovery and Innovation* 3, 53–56.

Alghali A. M. Studies on cowpea farming practices in Nigeria, with emphasis on insect pest control. *Tropical Pest Management* 37, 71–74.

Asimeng E. J. Preliminary account of the phenology of some Nigerian savanna phlebotomine sandflies (Diptera:Psychodidae). *Journal of Medical Entomology* 28, 578–580.

Basimike M., Mutinga M. J. and Kumar R. Distribution of sandflies (Diptera: Psychodidae) in three vegetation habitats in the Marigat Area, Baringo District, Kenya. *Journal of Medical Entomology* 28, 330–333.

Bassir I. B. NGOs, women and community water. In *Preprints and proceedings of the 17th Annual Conference of the WEDC (Water, Engineering and Development Centre)*, Nairobi, Kenya, 19–23 August.

Brightwell R., Dransfield R. D. and Kyorku C. Development of a low-cost tsetse trap and odour baits for *Glossina pallidipes* and *G. longipennis* in Kenya. *Medical and Veterinary Entomology* 5, 153–164.

Brownbridge M. Native *Bacillus thuringiensis* isolates for the management of lepidopteran cereal pests. *Insect Science and its Application* 12, 57–61.

Broza M., Brownbridge M. and Sneh B. Monitoring secondary outbreaks of the African armyworm in Kenya using pheromone traps for timing of *Bacillus thuringiensis* application. *Crop Protection* 10, 229–233.

Broza M., Brownbridge M., Hamal M. and Sneh B. Control of the African armyworm *Spodoptera exempta* Walker (Lepidoptera:Noctuidae) in Kenyan fields with highly effective strains of *Bacillus thuringiensis* Berliner. *Biocontrol Science and Technology* 1, 127–135.

Chaudhury M. F. B. Evidence of hormonal control of sexual maturation, receptivity and mating in the male *Glossina pallidipes*. In *20th Meeting of the International Scientific Council for Trypanosomiasis Research and Control, Mombasa, Kenya, 10–14 April 1989*. No. 115, 205–209.

Chitere P. O. and Mutiso R. (Editors) *Working with Rural Communities: A Participatory Research Perspective*. University of Nairobi Press, Nairobi.

De Castro J. J. Influence of identification ear tags on the numbers of adult *Rhipicephalus appendiculatus* (Acari: Ixodidae) on the ears of the cattle. *Experimental and Applied Acarology* 12, 147–150.

De Castro J. J., Capstick P. B., Nokoe S., Kiara H., Rinkanya F., Slade R., Okello O. and Bennun L. Towards the selection of cattle for tick resistance in Africa. *Experimental and Applied Acarology* 12, 219–227.

Denlinger D. L. and Zdarek J. Intrapuparial development in the tsetse fly, *Glossina brevipalpis* (Diptera Glossinidae): behaviour associated with pupation. *Acta Entomologica Bohemoslovaca* 88, 353–358.

Denlinger D. L. and Zdarek J. Commitment to metamorphosis in tsetse (*Glossina morsitans centralis*) temporal, nutritional and hormonal aspects of the decision. *Journal of Insect Physiology* 37, 333–338.

Dipeolu O. O. and Ndungu J. N. Acaricidal activity of kupetaba, a ground mixture of natural products, against *Rhipicephalus appendiculatus*. *Veterinary Parasitology* 38, 327–338.

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1991 Personnel*

**as at 31 December 1991*

I. CORE RESEARCH AND TRAINING PROGRAMMES

CROP PESTS RESEARCH PROGRAMME (CPRP)

Prof. K. N. Saxena, *senior principal research scientist/ programme leader*
Mrs. H. A. Abade, *senior secretary*
Mrs. F. A. Okundi, *secretary*
Mrs. J. A. Ojijo, *secretary*

Plant Resistance to Insect Pests (PRIP) Section
MPFS-based
Prof. K. N. Saxena, *section head*
Dr. R. S. Pathak, *senior research scientist*
Dr. Z. R. Khan, *senior research scientist (leave of absence)*
Dr. H. Kumar, *research scientist*
Dr. A. E. M. Nour, *research associate*
Dr. S. O. Ajala, *research associate*
Dr. C. O. Omwega, *postdoctoral research fellow*
Dr. S. Oghiakhe, *scientific officer*
Mr. S. M. Othieno, *principal technician*
Mr. E. O. Nyangiri, *principal technician*
Mr. P. O. Ollimo, *principal technician*
Mr. J. N. Ngoya, *computer applications specialist (statistics)*
Mr. F. D. O. Odawa, *senior technician*
Mr. M. W. Obondi, *graphics technician*
Mr. C. O. Oloo, *technician*
Miss S. M. Muriithi, *technician*
Mr. P. M. Chiliswa, *technician*
Mr. J. O. Okello, *senior technician*
Mr. M. Kithokoi, *junior technician*
Mr. S. M. Otieno, *technical assistant*
Mr. G. O. Asino, *technical assistant*
Mr. J. A. Adero, *laboratory/field assistant*
Mr. P. O. Okello, *laboratory/field assistant*
Mr. P. O. Akello, *laboratory/field assistant*
Mr. P. O. Omolo, *laboratory/field assistant*
Mr. J. O. Ogoro, *laboratory/field assistant*
Mr. S. G. Ogechi, *senior driver*
Mr. W. Jayatileka, *driver*
Mr. R. O. Musa, *driver*

Biological Control (BC) Section
MPFS-based
Dr. M. O. Odindo, *senior research scientist/section head*
Dr. N. K. Maniania, *research scientist*
Dr. E. F. Dwumfour, *postdoctoral research fellow*
Mr. C. O. Omondi, *associate scientific officer*
Mr. Z. N. Otieno, *senior research assistant*
Mr. E. K. Ngugi, *senior technician*
Mr. R. O. Okello, *senior technician*
Mr. P. A. Amutalla, *technician*
Mr. J. O. Ochieng', *technical assistant*
Mr. R. O. Oluoch, *laboratory/field assistant*
Mr. P. B. O. Ogola, *laboratory/field assistant*
Mrs. T. A. Odero, *laboratory/field assistant*
Mrs. J. A. Okelo, *laboratory/field assistant*
Mr. M. Y. Oriwo, *laboratory/field assistant*
Mr. T. O. Onyango, *laboratory/field assistant*
Miss M. A. Andere, *laboratory/field assistant*
Mr. J. Mokaya, *driver*

Duduville-based
Dr. M. R. A. Mohamed, *postdoctoral research fellow*
Mr. M. T. Lusele, *junior technician*

Special Projects
(i) ICIPE/WAU Collaborative Project
Duduville-based
Dr. W. A. Overholt, *visiting research scientist*
Dr. J. B. O. Owuor, *senior scientific officer*
Mr. R. C. Odhiambo, *technician*
Mr. M. O. Odoyo, *laboratory/field assistant*
Mr. J. O. Awendo, *laboratory/field assistant*
Mr. J. A. Otieno, *laboratory/field assistant*
Mrs. B. M. Opiyo, *secretary*

MPFS-based
Dr. J. M. Chacko, *scientist-in-residence*
Mr. P. O. Agwaro, *technician*

Mtwapa-based
Mr. P. M. Lammers, *research associate*
Mr. K. Ogedah, *senior research assistant*
Mr. S. P. Ojwang', *laboratory/field* assistant

(ii) Cassava GSM Project (DANIDA)
(All MPFS-based)
Dr. M. O. Odindo, *coordinator*
Dr. J. Ogwang', *postdoctoral research fellow*
Mr. J. O. Obilo, *laboratory/field assistant*
Mrs. W. R. Adera, *laboratory/field assistant*
Mr. K. O. Onyango, *driver*

Cultural Control (CC) Section
(All MPFS-based)
Dr. K. V. Seshu Reddy, *principal research scientist/ section head*
Dr. K. Ampong-Nyarko, *postdoctoral research fellow*
Mrs. N. E. M. Smit, *graduate research scholar*
Miss R. A. Nyang'or, *senior research assistant*
Mr. K. S. Sum, *senior research assistant*
Mr. D. O. Nyagol, *technical assistant*
Mr. J. A. O. Mwanda, *laboratory/field assistant*
Mr. W. O. Owuor, *laboratory/field assistant*
Mr. I. O. Odhul, *laboratory/field assistant*
Mr. L. M. Origa, *laboratory/field assistant*

Special Project
(i) BMZ Banana Weevil Project
Tanzania-based
Dr. S. W. Waudo, *postdoctoral research fellow*

MPFS-based
Mr. P. R. Speijer, *graduate research scholar*
Mr. A. M. Koppenhofer, *graduate research scholar*
Mr. M. C. Lubega, *principal technician*
Mr. I. O. Mayoga, *laboratory/field assistant*
Mr. P. O. Ochanjo, *laboratory/field assistant*
Mr. D. O. Muok, *driver*

IPM and Population Biology (IPB) Section
(All MPFS-based)
Dr. R. C. Saxena, *senior principal research scientist/ section head*
Dr. S. A. Lux, *senior research scientist*
Mr. S. O. Paye, *senior technician*
Mr. E. L. Kidiavai, *technician*
Mr. J. O. Ondijo, *laboratory/field assistant*
Mr. P. A. Oreng, *laboratory/field assistant*
Mr. G. S. Odhiambo, *laboratory/field assistant*
Mr. D. A. Atieno, *laboratory/field assistant*

Special Project
(i) Upland Rice
Dr. Z. Harahap, *visiting research scientist*
Mr. J. C. Olela, *chief technician*

(ii) IPM R&D Project
Oyugis-based
Dr. E. O. Omolo, *senior research scientist/R&D field coordinator*
Dr. B. T. Nyambo, *senior scientific officer*
Mr. C. J. Simbi, *principal technician*
Mr. L. Ngode, *national project officer*
Mr. C. O. 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. A. Ondiek, *laboratory/field assistant*
Mr. J. M. Mwangangi, *driver*

(iii) Cypress Aphid
Chiromo-based
Dr. S. H. B. Okech, *senior scientific officer*

(iv) ARPPIS Research Projects
MPFS-based
Mr. J. O. Ngare, *laboratory/field assistant*
Mr. J. O. Obara, *laboratory/field assistant*
Mr. C. Oyugi, *laboratory/field assistant*

LIVESTOCK TICKS RESEARCH PROGRAMME (LTRP)
Duduville-based
Dr. G. P. Kaaya, *principal research scientist/ programme leader*
Dr. O. A. Mongi, *senior research scientist*
Dr. S. Essuman, *research scientist*
Dr. A. O. J. Amoo, *research scientist*
Dr. M. K. Limo, *research scientist*
Dr. A. N. Mohamed, *postdoctoral research fellow*
Dr. D. K. Puniyua, *senior scientific officer*
Dr. (Mrs) E. Mwangi, *associate scientific officer*
Mr. J. W. Chiera, *associate scientific officer*
Dr. I. G. Onyango, *research assistant*
Mr. W. A. Chapya, *chief technician*
Mr. J. G. Kabii, *principal technician*
Miss R. Chesang, *principal technician*
Mr. M. M. Malonza, *senior technician*
Mr. S. S. ole-Sipala, *senior technician*
Mr. J. G. Mugane, *technician*
Mr. J. N. Ndungu, *technician*
Mr. F. M. Thuo, *technician*
Mr. P. P. Muteria, *junior technician*
Mr. M. G. Kimondo, *junior technician*
Miss E. A. Ouna, *junior technician*
Mr. G. M. Hindi, *technical assistant*
Mr. G. K. O. Ochung', *technical assistant*
Mr. M. G. Kinyua, *laboratory/field assistant*
Mr. M. J. Khadiakala, *laboratory/field assistant*
Mr. P. S. Muchisu, *laboratory/field assistant*
Mr. J. K. Njuguna, *laboratory/field assistant*
Mr. R. K. Njonjo, *laboratory/field assistant*
Mr. J. N. Ndungu, *laboratory/field assistant*
Mr. E. N. Njamura, *laboratory/field assistant*
Mr. G. M. Kinyanjui, *driver*
Mr. A. H. A. Enana, *driver*
Mrs M. G. A. Odera, *secretary*

MPFS-based
Dr. S. M. Hassan, *research associate*
Dr. M. J. Wabomba, *associate scientific officer*
Mr. P. O. Ngoko, *senior technician*
Mr. J. N. Odhiambo, *technical assistant*
Mr. J. A. Arus, *laboratory/field assistant*
Mr. J. O. Odida, *laboratory/field assistant*

Kuja River-based
Mrs. A. A. Nyangwecha, *laboratory/field assistant*
Mr. H. M. P. Gesicho, *senior security guard*
Mr. H. M. Mugalo, *security guard*
Mr. J. M. Owili, *security guard*

Mariakani (Kilifi)-based
Mr. R. Ojowa, *senior technician*

MEDICAL VECTORS RESEARCH PROGRAMME (MVRP)
Duduville-based
Dr. M. J. Mutinga, *principal research scientist/ programme leader*
Dr. C. M. Mutero, *research scientist*
Dr. M. Basimike, *research scientist*
Dr. E. J. Asimeng, *postdoctoral research fellow*
Dr. A. E. P. Mnzava, *postdoctoral research fellow*

Mr. C. C. Kamau, *associate scientific officer*
Mr. B. N. Odero, *associate scientific officer*
Mr. F. A. Amimo, *senior research assistant*
Mr. M. P. Nyamori, *chief technician*
Mr. F. M. Masika, *scientific illustrator*
Mr. F. M. Kyai, *technician*
Mr. D. M. Omogo, *technician*
Mrs. E. M. Wahome, *junior technician*
Mr. R. M. Musyoki, *junior technician*
Mr. D. M. Mativo, *technical assistant*
Mr. M. M. Miti, *technical assistant*
Mr. J. M. Ndambuki, *laboratory/field assistant*
Mr. R. M. Mogaka, *driver*
Miss S. M. Kagondu, *senior administrative secretary*

Marigat (Baringo) West Pokot-based
Mr. D. K. Mbavu, *technical assistant/driver*
Mr. S. M. Mutua, *technical assistant*
Mr. P. K. Munguti, *technical assistant*
Mr. B. M. Muia, *technical assistant*
Mr. W. M. Kilonzo, *laboratory/field assistant*
Mr. S. M. Singi, *laboratory/field assistant*
Mr. P. B. Chepkoimet, *laboratory/field assistant*
Mr. K. J. Kisilu, *laboratory/field assistant*
Mr. P. O. Manyuanda, *laboratory/field assistant*
Mr. R. K. Leitich, *security guard*
Mr. J. N. Akeyo, *security guard*

Tseikuru (Kitui)-based
Mr. P. K. Wandei, *laboratory/field assistant*
Mr. R. K. Muoki, *laboratory/field assistant*

Special Project
(i) Biotechnology Project
Dr. M. Makayoto, *postdoctoral research fellow*
Mrs. M. A. Oketch, *scientific officer*
Mr. J. A. Nyawach, *laboratory/field assistant*

TSETSE RESEARCH PROGRAMME (TRP)

Duduville-based
Dr. L. H. Otieno, *principal research scientist/ programme leader*
Dr. S. Mihok, *senior research scientist*
Dr. L. C. Madubunyi, *senior research scientist*
Dr. K. Kuramochi, *visiting scientist*
Dr. J. K. Stiles, *postdoctoral research fellow*
Mr. J. O. Davies-Cole, *research associate*
Dr. E. K. Kangethe, *research associate*
Mrs. M. L. A. Owaga, *senior scientific officer*
Miss N. F. Darji, *principal research assistant*
Mr. S. M. Mwangi, *senior research assistant*
Mr. P. O. Agutu, *chief technician*
Mr. E. M. Ng'ongo, *senior technician*
Mr. E. Mpanga, *senior technician*
Mr. S. S. Wakape, *senior technician*
Mr. D. F. Uvyu, *senior technician*
Mr. A. M. Macharia, *senior technician*
Mr. M. O. Kotengo, *senior technician*
Mr. C. O. Machika, *technician*
Mr. P. M. Mwamisi, *technician*
Mr. J. K. Kiilu, *technician*
Mr. J. Likhanga, *technician/senior driver*
Mr. D. K. Mungai, *junior technician/driver*
Mr. M. W. Wangai, *junior technician/driver*
Mr. S. O. Maramba, *technical assistant*
Miss E. Afandi, *senior secretary*

MPFS-based
Dr. M. M. Mohamed-Ahmed, *postdoctoral research fellow*
Mr. J. M. Muchiri, *junior technician*
Mr. J. O. Abudi, *laboratory/field assistant*
Mr. S. E. Mokaya, *driver*

Nguruman (Kajiado)-based
Mr. J. N. Olekobai, *laboratory/field assistant*
Mr. T. Toroke, *laboratory/field assistant*
Mr. S. M. Pukare, *laboratory/field assistant*
Mr. S. T. Oseur, *laboratory/field assistant*
Mr. J. N. Tanchu, *laboratory/field assistant*
Mr. M. L. Parirong, *laboratory/field assistant*
Mr. J. ole Kobaai, *senior security guard*
Mr. D. S. Partari, *security guard*

Kwale/Muhaka-based
Mr. C. A. Kyorku, *research associate/postdoctoral research fellow*
Mr. J. Mwandandu, *technician/driver*
Mr. H. Simba, *laboratory/field assistant*

UNDP Kwale/Kilifi Special Project
Dr. I. M. I. Abu Zinid, *postdoctoral research fellow*
Ms I. J. M. de Groot, *research associate*

LOCUST RESEARCH PROGRAMME (LRP)

Duduville-based
Prof. S. El Bashir, *principal research scientist/ programme leader*
Dr. G. W. Oloo, *senior research scientist*
Dr. S. K. Raina, *senior research scientist*
Dr. C. Inayatullah, *senior research scientist*
Dr. B. Torto, *research scientist*
Dr. H. Mahamat, *postdoctoral research fellow*
Dr. D. Obeng-Ofori, *postdoctoral research fellow*
Mr. A. M. A. Malik, *research associate*
Dr. P. G. N. Njagi, *scientific officer*
Dr. M. M. Rai, *scientific officer*
Mr. S. M. Ndugo, *associate scientific officer*
Mr. H. Odongo, *research assistant*
Mr. D. O. Ojwang', *research assistant*
Mr. J. T. Kilori, *principal technician*
Miss J. R. Wawiye, *technician*
Mr. F. O. Odhare, *technician*
Mr. M. A. Mbeke, *driver/technical assistant*
Mr. J. M. Onyango, *laboratory/field assistant*
Mrs. K. Yaa, *secretary*

Sudan-based
Mr. H. El-Tigani Abdel-Rahman, *associate scientific officer*

INSTITUTIONAL BUILDING AND INTERACTIVE RESEARCH UNIT (IBIRU)

Prof. Z. T. Dabrowski, *acting head*
Miss I. K. Monyancha, *secretary*

Training: ARPPIS and Central Training Services
Prof. Z. T. Dabrowski, *training coordinator*
Miss R. Runo, *training assistant*
Miss V. K. Manene, *senior technician*
Mrs. G. N. Gathura, *secretary*

Mr. S. Rukungu, *senior driver*
Mr. D. Isoso, *driver*
Miss R. B. Bob-Manuel, *Ph.D. Scholar Year 3*
Mr. E. A. R. Ndhine, *Ph.D. Scholar Year 3*
Mr. A. H. Duale, *Ph.D. Scholar Year 3*
Mrs. D. D. S. Bawo, *Ph.D. Scholar Year 3*
Mr. F. E. Nwilene, *Ph.D. Scholar Year 3*
Mr. H. K. Kiara, *Ph.D. Scholar Year 3*
Mr. A. E. B. Ali, *Ph.D. Scholar Year 3*
Mr. B. E. M. A. Uronu, *Ph.D. Scholar Year 3*
Mr. A. S. S. Mbwana, *Ph.D. Scholar Year 3*
Mr. D. Dakouo, *Ph.D. Scholar Year 2*
Mr. S. Dossa, *Ph.D. Scholar Year 2*
Mr. S. Gebre, *Ph.D. Scholar Year 2*
Mr. J. Kayitare, *Ph.D. Scholar Year 2*
Mrs. E. U. Kenya, *Ph.D. Scholar Year 2*
Mr. S. K. Meressa, *Ph.D. Scholar Year 2*
Mr. A. S. Mohmed, *Ph.D. Scholar Year 2*
Mr. M. Mugunga, *Ph.D. Scholar Year 2*
Miss A. R. Mutambara, *Ph.D. Scholar Year 2*
Mr. L. O. Nwoke, *Ph.D. Scholar Year 2*
Mr. R. P. Uzakah, *Ph.D. Scholar Year 2*
Mr. D. O. Ogoyi, *Ph.D. Scholar Year 2*
Mr. K. K. Oyugi, *Ph.D. Scholar Year 2*
Mr. E. F. Rwekika, *Ph.D. Scholar Year 1*
Mr. A. O. Ahmed, *Ph.D. Scholar Year 1*
Mr. S. G. Mwangi, *Ph.D. Scholar Year 1*
Mr. S. I. Kamara, *Ph.D. Scholar Year 1*
Miss S. W. Kimani, *Ph.D. Scholar Year 1*
Mr. S. F. Kutua, *Ph.D. Scholar Year 1*
Mr. J. C. Mbapila, *Ph.D. Scholar Year 1*
Ms. A. J. Ngi-Song, *Ph.D. Scholar Year 1*
Mrs. J. A. Kongoro, *Ph.D. Scholar Year 1*
Mr. E. O. Omolo, *Ph.D. Scholar Year 1*
Mr. B. J Adgeh, *Ph.D. Scholar Year 1*

PESTNET
PESTNET Secretariat
Dr. E. O. Omolo, *PESTNET coordinator (out going)*
Mr. J. A. Lago, *senior technician (data-input)*
Mrs. S. M. A. Otieno, *secretary*

Country Resident Teams
PESTNET Kenya: Mtwapa-based
Dr. S. Kyamanywa, *PESTNET resident scientist*
Mr. A. M. Mzingirwa, *senior technician*
Mr. J. K. arap Mutai, *junior technician/driver*

PESTNET Somalia: Mogadishu-based
Mr. M. H. Mohamed, *research assistant*

PESTNET Zambia: Lusaka-based
Mrs. M. Taguma, *scientific officer*
Mr. C. Kazhila, *research assistant*

PESTNET Rwanda: Butare-based
Dr. S. K. Firempong, *scientific officer*

PESTNET Ethiopia: Addis Ababa-based
Mr. G. Tikubet, *scientific officer*

RANDMEN (All staff on secondment to the AAS)
Mrs. P. A. Ogada, *training officer*
Miss C. W. Mwangi, *secretary*

II RESEARCH SUPPORT UNITS

CHEMISTRY AND BIOCHEMISTRY RESEARCH UNIT (CBRU)
Prof. A. Hassanali, *principal research scientist/unit head*
Dr. W. Lwande, *senior research scientist*
Dr. E. O. Osir, *senior research scientist*
Dr. M. Imbuga, *postdoctoral research fellow*
Dr. (Mrs) R. M. W. Vundla, *senior scientific officer*
Mr. F. O. Oduol, *associate scientific officer*
Mr. B. O. K. Wanyama, *associate scientific officer*
Mr. N. K. Gikonyo, *associate scientific officer*
Mr. W. P. Ouma, *senior research assistant*
Mr. E. N. ole Sitayo, *principal technician*
Mr. E. Nyandat, *principal 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*

Special Project
(i) Banana Weevil Semiochemicals (Norway)
Dr. I. O. Ndiege, *postdoctoral research fellow*
Mr. D. O. Nyarango, *associate scientific officer*
Mr. D. O. Otieno, *senior technician*

CELL BIOLOGY RESEARCH UNIT (CRU)
Dr. N. N. Massamba, *senior research scientist/unit head*
Dr. E. D. Kokwaro, *research scientist*
Dr. W. G. Z. O. Jura, *research scientist*
Dr. V. Lutje, *postdoctoral research fellow*
Mr. M. M. B. Chimtawi, *research technologist*
Mr. P. Lisamulla, *chief technician*
Mrs. J. K. Muriithi, *chief technician*
Mr. J. O. Adino, *senior technician*
Mr. A. M. Ngei, *technician*
Mr. R. K. Rotich, *technical assistant*

SENSORY PHYSIOLOGY RESEARCH UNIT (SPRU)
Dr. R. K. Saini, *senior research scientist/unit head*
Dr. S. M. Waladde, *senior research scientist*
Dr. W. J. Budenberg, *postdoctoral research fellow*
Miss F. Karago, *research assistant*
Mr. H. M. Kahoro, *principal technician*
Mr. S. A. Ochieng', *principal technician*
Mr. J. A. Andoke, *senior technician*
Mr. P. O. Ahuya, *technician*
Mrs. P. N. Owitti, *senior secretary*

BIOMATHEMATICS RESEARCH UNIT (BMRU)
Duduville-based
Dr. K. S. Nokoe, *senior research scientist/unit head*
Dr. J. O. Owino, *postdoctoral research fellow*
Mr. S. O. Essa, *senior computer engineer*
Mr. D. M. Munyinyi, *senior computer applications specialist*
Mr. J. M. Otedo, *computer programmer*
Mr. M. D. M. Gathoga, *computer technologist*
Mr. H. H. Meena, *computer applications specialist (GIS) (on training)*
Mr. O. O. Okello, *principal technician*
Mr. J. M. Mirangi, *senior technician*
Mr. A. O. Ojwang, *technician*
Mrs. A. K. Ogoti, *secretary*

MPFS-based
Dr. A. Odulaja, *senior computer applications specialist*
Mr. J. O. Omwa, *technician*

SOCIAL SCIENCE INTERFACE RESEARCH UNIT (SSIRU)
Duduville-based
Prof. F. G. Kiros, *principal research scientist/unit head*
Dr. G. T. Lako, *senior research scientist*
Dr. P. A. Chitere, *scientist-in-residence*
Prof. G. A. Schaefers, *visiting research scientist*
Dr. I. B. Bassir, *postdoctoral research fellow*
Dr. A. W. Oendo, *postdoctoral research fellow*
Mr. K. C. Chitala, *computer applications specialist*
Mrs. P. N. Kaweru, *secretary*
Mr. S. O. Mdimba, *driver*

MPFS-based
Dr. J. W. Ssennyonga, *senior research scientist*
Mr. P. G. Mungai, *technician*
Mr. S. O. Ambogo, *technical assistant*
Mr. R. O. Yogo, *technical assistant/enumerator*
Mr. J. O. Okomo, *technical assistant/enumerator*
Mr. N. O. Dibogo, *technical assistant/enumerator*
Mrs. M. A. Ayugi, *technical assistant/enumerator*
Mr. E. A. Kongere, *technical assistant/driver*

Oyugis-based
Miss M. M. Mwangi, *associate scientific officer*
Mr. B. A. Omollo, *senior technician*
Mr. G. O. Nengo, *technical assistant/enumerator*

Mariakani-based
Mr. O. J. Nyapela, *senior technician*
Mr. S. M. Jembe, *technical assistant/enumerator*

Kendu-Bay-based
Mr. J. S. Oluoch, *technical assistant/enumerator*

Nguruman-based
Mr. D. K. Kahuria, *technical assistant/enumerator*

Muhaka-based
Mr. O. K. Wambua, *technical assistant/enumerator*

Marigat-based
Mr. S. Kelwon, *technical assistant/enumerator*

III RESEARCH SUPPORT SERVICES

INSECT AND ANIMAL BREEDING UNIT (IABU)
Duduville-based
Dr. J. P. O. Odero, *senior scientific officer/unit head*
Mr. J. Wanyonje, *chief technician*
Mr. H. K. Banda, *chief technician*
Mr. J. M. Kagoiya, *principal technician*
Mr. A. K. Ikhunyalo, *senior technician*
Mr. P. E. W. Njoroge, *senior technician*
Mr. J. M. Ongudha, *technician*
Mr. E. O. Awuoche, *technician*
Mrs. K. G. G. Kariuki, *technician*
Mr. R. O. Agan, *technician*
Miss M. G. Wanjiru, *junior technician*
Mr. S. M. Mbugua, *junior technician*
Mr. G. M. Ng'ang'a, *junior technician*
Mr. S. A. Patya, *junior technician*
Mr. J. O. Oguk, *technical assistant*
Mr. N. Mwikya, *technical assistant*
Mr. A. Majanje, *laboratory/field assistant*
Mr. J. O. Kaleb, *laboratory/field assistant*

MPFS-based
Mr. F. O. Onyango, *associate scientific officer*
Mr. J. M. Okomo, *research assistant*
Mr. M. D. O. Bungu, *senior technician*
Mr. E. O. Amboga, *technician*
Mr. J. K. Gitegi, *junior technician*
Mr. J. A. Ojude, *junior technician*
Mr. P. A. Nyakwamba, *laboratory/field assistant*
Mr. W. I. O. Odhiambo, *laboratory/field assistant*
Mr. J. O. Maoro, *laboratory/field assistant*
Mr. J. O. Opere, *laboratory/field assistant*
Miss J. N. Kunyu, *laboratory/field assistant*
Mr. J. O. Osuri, *laboratory/field assistant*
Mr. W. O. Oganda, *laboratory/field assistant*
Mr. P. O. Wagara, *laboratory/field assistant*
Mr. A. G. Nyagwara, *laboratory/field assistant*
Mr. B. O. Owiyo, *laboratory/field assistant*
Mr. M. O. Chacha, *laboratory/field assistant*
Mr. D. J. O. Okode, *laboratory/field assistant*

WORKSHOPS AND LABORATORY SERVICE UNIT (WLSU)
Duduville-based
Mr. J. A. Mando, *principal controller for technical services/ unit head*
Mr. J. A. Mtei, *maintenance technologist*
Mr. J. O. Konyino, *electronics and instrumentation engineer*
Mr. D. Murali, *electronics and instrumentation engineer*
Mr. G. S. Kidunda, *electronics and instrument technologist*
Mr. A. R. S. Abdalla, *senior refrigeration technician*
Mr. P. O. Nyachieo, *chief technician*
Mr. J. M. Maina, *principal technician*
Mr. P. O. Auma, *maintenance foreman*
Mr. J. B. Omullo, *senior technician*
Mr. J. O. Ogalo, *senior technician*
Mr. P. A. Oluya, *senior technician*
Mr. K. Kinuthia, *technician*
Mr. A. M. Wanyama, *technician*
Mr. J. K. Gadonya, *junior technician*
Mr. J. O. Omondi, *junior technician*
Mr. M. O. Odada, *junior technician*
Mr. T. O. Ochieng', *junior technician*
Mr. M. M. O. Orwe, *workshops assistant*
Mrs. H. Githinji, *assistant secretary*
Mr. P. N. Muasa, *driver (on secondment)*

MBITA POINT FIELD STATION AND SATELLITE FIELD RESEARCH SITES
Station Management
Prof. K. N. Saxena, *manager for research policy and resources*
Mr. J. F. Omange, *station manager*
Mrs. R. A. Okoth, *senior secretary*

Administrative and Janitorial Services
Mr. E. O. Anyango, *administrative assistant*
Mr. C. A. Amolo, *gardener*
Mr. Z. O. Nyandere, *cleaner/messenger*
Mrs. M. A. Tindi, *cleaner/messenger*

Mrs. M. O. Walter, *janitorial/gardening assistant*
Mr. G. O. Ogero, *janitorial/gardening assistant*
Mr. T. A. Owiti, *janitorial/gardening assistant*
Mr. S. M. Mkamba, *janitorial/gardening assistant*
Mr. V. O. Nyangute, *janitorial/gardening assistant*
Mr. T. K. Adwar, *janitorial/gardening assistant*
Mr. M. O. Omollo, *janitorial/gardening assistant*
Mr. J. D. Orimbo, *janitorial/gardening assistant*
Mr. R. Y. Owawa, *janitorial/gardening assistant*
Mrs. Z. P. Mmbone, *janitorial/gardening assistant*
Mr. B. O. Yana, *janitorial/gardening assistant*
Mr. A. A. Awich, *janitorial/gardening assistant*
Miss F. B. Esalako, *senior secretary*
Miss D. A. Achieng', *assistant secretary*
Mr. G. K. Khisa, *telephonist/receptionist*
Miss M. A. Okoth, *telephonist/receptionist/typist*
Mr. R. R. Nyaridi, *clerical assistant*

Accounts and Supplies Section
Mr. F. K. Ongola, *accountant*
Mr. M. N. E. Asudi, *assistant accountant*
Mr. E. O. D. Odhiambo, *accounts assistant*
Mr. M. T. Kanyara, *accounts assistant*
Mr. J. O. Gombe, *assistant supplies officer*
Mr. E. O. Jasor, *stores clerk*

Security Section
Mrs. P. A. Oriwa, *senior security officer*
Mr. J. C. Wanga, *security officer*
Mr. J. K. N. Birir, *security supervisor*
Mr. J. Omogi, *security supervisor*
Mr. J. N. Kavemba, *security guard*
Mr. J. O. Musingo, *security guard*
Mr. O. K. Kamau, *security guard*
Mr. M. O. Omom, *security guard*
Mr. P. N. Bise, *security guard*
Mr. N. Kibicho, *security guard*
Mr. N. N. Omurumba, *security guard*
Mr. E. P. Achenya, *security guard*
Mr. E. O. Raringo, *security guard*
Mr. D. R. M. Njeru, *security guard*
Mr. G. M. Kinyuah, *security guard*
Mr. J. T. Rege, *security guard*
Mr. G. O. Aunga, *security guard*
Mr. N. Odhiambo, *security guard*
Mr. S. O. Mboga, *security guard*
Mr. N. O. Mbija, *security guard*

Farm Services
Mr. P. Nyongesa, *farm supervisor*
Mr. P. O. Ouma, *senior farm assistant*
Mr. E. O. Ogutu, *tractor driver*
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*
Mr H. O. Abongo, *farm assistant*
Mr. W. J. O. Odhiambo, *farm assistant*
Mr. P. C. K. Wanyonyi, *farm assistant*

Library Section
Miss D. Achieng, *librarian*
Mr. E. A. Sonye, *clerical assistant*

Workshops and Laboratory Service Unit (MPFS Branch)
Workshops and Maintenance
Mr. P. K. Kimani, *maintenance engineer*
Mr. J. K. Alwala, *electronics and instrumentation engineer*
Mr. M. S. Nakitare, *electronics and instrument technologist*
Mr. P. M. Alianda, *senior technician (water works)*
Mr. P. M. Okwanyo, *senior technician (carpentry)*
Mr. T. L. Ngutu, *senior technician (metal works and machines)*
Mr. K. G. Ogweno, *senior technician (power supply)*
Mr. M. S. Likhanga, *senior technician (refrigeration)*
Mr. E. E. Okello, *technician (electronics)*
Mr. J. O. A. Wasinda, *technician (electrical)*
Mr. R. M. Nzioka, *technician (plumbing)*
Mr. S. M. Karanja, *technician (general maintenance)*
Mr. J. O. Okech, *junior technician (masonry)*
Mr. D. O. Wanjara, *junior technician (carpentry)*
Mr. W. O. Omonge, *junior technician (welding)*
Mr. P. O. Gati, *technical assistant (oxidation ponds)*
Mr. C. A. Otuta, *workshops assistant*
Mr. N. O. Otengo, *workshops assistant*

Ungoye-based
Mr. Z. B. Ooko, *janitorial/technical assistant*

Transport
Mr. J. N. Asanyo, *automobile foreman*
Mr. C. O. Ojoo, *transport assistant*
Mr. J. H. Ohato, *senior driver/mechanic*
Mr. W. N. Omino, *coxswain*
Mr. P. O. Mbuya, *senior driver*
Mr. L. O. Odongo, *driver*
Mr. J. O. Otunge, *driver*
Mr. E. O. Ndiao, *mechanic assistant*
Mr. S. O. Haira, *mechanic assistant*

Oyugis Sub-Station
Dr. E. O. Omolo, *(in charge)*
Mrs. D. T. Ongondo, *typist*

Farm Services
Mr. P. L. Rakwach, *tractor driver/mechanic*
Mr. J. O. Ojunga, *farm assistant*

Security
Mr. B. W. Okello, *security supervisor*
Mr. A. O. Omondi, *security guard*
Mr. J. M. Chacha, *security guard*
Mr. O. Ohwanda, *security guard*

Ungoye Field Station
Farm Services
Mr. E. G. Kabiru, *farm foreman*
Mr. D. O. Oyoo, *senior farm assistant*

Security
Mr. S. M. Abaya, *security supervisor*
Mr. P. O. Juma, *senior security guard*
Mr. P. O. Opinde, *security guard*
Mr. W. K. Makori, *security guard*

Mr. P. O. Okech, *security guard*
Mr. J. M. Motari, *security guard*
Mr. P. O. Kisaria, *security guard*
Mr. P. R. Manga, *security guard*
Mr. A. O. Agugo, *security guard*

Kuja River Field Station

* Security Staff listed under LTRP

MUHAKA FIELD STATION
Mr. B. S. Masyanga, *farm development officer*
Mr. S. Abdalla, *security guard*

LIBRARY, INFORMATION AND DOCUMENTATION SERVICES DEPARTMENT
Miss R. A. Washika, *principal communication officer*
Mr. N. S. M. Nsubuga, *senior librarian*
Mrs. R. P. Ortega, *senior communication officer*
Miss D. W. Barasa, *documentalist*
Mrs. R. A. Oyoko, *librarian*
Miss E. N. Kahuhu, *library assistant*
Mr. F. J. Utanje, *travel officer*
Miss M. K. Kingori, *secretary*
Miss N. N. Zani, *secretary*
Mr. A. Shisoka, *clerical assistant*

ICIPE SCIENCE PRESS DEPARTMENT
Mr. L. Okola, *head of department*
Dr. M. F. B. Chaudhury, *principal science editor*
Dr. A. Ng'eny Mengech, *senior science editor*
Mrs. W. A. Oyuko, *production officer (graphics)*
Mrs. S. W. Mwanycky, *senior scientific editor*
Mr. N. M. Komeri, *senior scientific illustrator*
Mrs. D. O. Odhiambo, *proof reader*
Miss I. A. Ogendo, *graphic artist*
Mr. G. K. N. Suka, *printing and offset machine operator*
Miss D. M. Munene, *senior phototypesetter*
Mrs. J. Odallo, *desktop typesetter*
Mrs. J. J. Gombe, *senior secretary*
Mrs. Y. Obiero, *senior secretary*
Mr. N. Okumbe, *cleaner/messenger*
Mr. J. M. Kisini, *cleaner/messenger*

IV AMENITIES AND SOCIAL SERVICES

INTERNATIONAL GUEST CENTRE SYSTEM
Duduville International Guest Centre
Mr. J. A. Achilla, *senior business and catering controller*
Mr. J. C. Wanzala, *accountant*
Mr. W. O. Matundura, *catering officer*
Mr. G. J. Rugendo, *assistant accountant*
Mr. C. B. Oyieyo, *foods and beverages supervisor*
Mr. A. Lweya, *assistant head cook*
Mr. G. Gichuru, *cook*
Mr. J. M. Mwakisha, *cook*
Mr. E. M. Aosa, *assistant storekeeper*
Mr. P. A. Omollo, *senior barman/waiter*
Mr. L. M. Mulae, *room steward*
Mrs. P. A. Ochola, *assistant housekeeper*
Mr. H. M. Kibisu, *senior launder*
Mr. J. O. Mukhobi, *janitorial assistant*
Mr. S. Obondo, *janitorial assistant*
Mr. K. K. Omari, *janitorial assistant*
Mr. G. S. O. Omondi, *kitchen assistant*
Mr. J. N. Chege, *kitchen assistant*
Mr. G. O. Odero, *housekeeping assistant*
Miss A. M. Mwangi, *waiter*
Mr. W. O. Odera, *waiter*
Mrs. J. A. Awich, *laundry assistant*
Mr. J. N. Kipserem, *laundry assistant*
Miss J. W. Weru, *laundry assistant*
Mrs. P. M. Wekesa, *senior telephonist/receptionist/cashier*
Miss J. A. Misaki, *receptionist/cashier*
Mr. A. O. Were, *messenger/waiter/cleaner*
Mrs. T. A. Ogongo, *room steward*
Mr. D. K. Mahiuha, *driver*
Mr. W. M. Ngatia, *kitchen assistant*
Mr. J. W. Mburu, *kitchen assistant*
Mr. P. Mungithya, *waiter*
Mr. C. M. Omondi, *stores clerk*
Mr. G. O. Oketch, *waiter*
Mr. D. O. Resa, *front office assistant*
Mrs. G. O. Obwanda, *secretary*

MPFS International Guest Centre
Mr. J. A. Kooro, *assistant business and catering controller*
Mr. S. Nyangi, *general assistant*
Mr. H. O. Onyango, *barman/waiter*
Mr. S. A. Alos, *assistant barman*
Mr. P. O. Odote, *chef*
Mr. J. O. Koyaa, *stores clerk*
Mr. A. O. Nyarimah, *kitchen assistant*
Mr. F. O. Orwa, *kitchen assistant*
Mr. E. J. Odero, *gardening assistant*
Mr. C. O. Nyagaya, *housekeeping assistant*
Mr. H. O. Omala, *housekeeping assistant*
Miss M. A. Nalo, *housekeeping assistant*
Mr. F. N. Omutsembi, *laundry assistant*
Mrs. H. A. Ouma, *laundry assistant*
Miss L. A. Olack, *front office assistant*

IGCS Staff based in Field Research Sites
Ungoye Guest House
Mrs. R. Osuna, *guest house attendant*
Mr. S. O. Odhako, *guest house attendant*

Oyugis Guest House
Mr. J. A. Oloo, *guest house attendant*
Mr. H. O. Wara, *guest house attendant*

Nguruman Guest House
Mr. W. M. Esirenyi, *guest house attendant*
Mr. L. M. Maki, *guest house attendant*

Marigat Guest House
Miss S. J. Cheboiywo, *guest house attendant*

Muhaka Guest House
Mr. S. O. Ojwang', *guest house attendant*
Miss N. Ifire, *guest house attendant*

MEDICAL AND CLINICAL SERVICES UNIT
St. Luke's Clinic — Duduville
Dr. R. W. Kimokoti, *medical officer*
Mrs. F. P. Mbogo, *senior 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*
Mr. J. M. Asitiba, *janitorial assistant*

St. Jude's Clinic — MPFS
Dr. E. C. Achieng', *medical officer*
Mr. J. H. Odoyo, *senior clinical officer*
Mrs. S. A. L. Chybire, *public health nurse*
Mrs. A. A. Miruka, *enrolled community nurse*
Mr. C. O. Nyanjom, *pharmaceutical technologist*
Mrs. F. K. W. Mukoko, *clerical assistant*
Mr. A. O. Olwoko, *senior driver*
Mrs. L. A. Abuya, *clinical attendant*
Mrs. C. A. Abonyo, *janitorial assistant*

MBITA POINT INTERNATIONAL SCHOOL
Mr. D. B. E. Okongo, *principal*
Mr. F. O. Omolo, *deputy principal*
Mr. Y. M. Koko, *teacher*
Mrs. C. O. M. Ndiege, *teacher*
Mr. P. W. Mburu, *teacher*
Mr. P. W. Mitugo, *teacher*
Mrs. L. G. Chacha, *teacher*
Mr. J. B. A. Sune, *teacher*
Mrs. M. N. Okach, *assistant secretary*
Miss S. A. Omune, *school attendant*
Mrs. O. A. Ojwang', *school attendant/cleaner*

V MANAGEMENT AND GENERAL OPERATIONS

OFFICE OF THE DIRECTOR
Prof. T. R. Odhiambo, *director*
Dr. P. B. Capstick, *deputy director*
Mrs. R. A. Odingo, *chief planning officer*
Dr. W. A. Otieno, *principal research and development planning officer*
Mr. V. S. Mutisya, *principal internal auditor*
Mrs. D. W. Njoroge, *senior internal auditor*
Miss M. H. Bugembe, *senior planning officer (on training)*
Mrs. G. M. A. Ochola, *personal assistant to the director*
Mr. J. R. Kapkirwok, *planning officer*
Mrs. E. A. Akidiva, *senior secretary*
Mrs. L. A. Were, *secretary*
Mrs. S. A. O. Madowo, *secretary*
Miss I. N. Nzuve, *secretary*
Mrs. H. A. Masibo, *secretary*
Miss H. A. Oketch, *assistant secretary*
Mr. D. O. Aoko, *clerical assistant*
Mr. J. K. Kibor, *principal driver*
Mr. O. Ogello, *driver*
Mr. S. O. Okiri, *driver*
Mr. J. O. Aroko, *driver*
Mr. F. O. Ujiji, *driver*
Mr. J. M. Mutunga, *driver*
Mr. D. J. M. Mwawasi, *driver*
Mr. J. L. Mwangai, *messenger/clerk*
Mr. H. O. Agonyo, *messenger/clerk*
Mr. P. H. Deche, *cleaner/messenger*

ADMINISTRATION AND INFORMATION DIVISION
Mr. L. Okola, *manager for administration and information*

Human Resources
Dr. V. O. Musewe, *head, human resources*
Mr. M. M. Moinde, *principal administrative officer*
Mr. S. M. Kimaita, *principal administrative officer*
Mrs. A. M. Mulei, *administrative officer*
Mrs. M. R. Opande, *office management supervisor*
Mrs. G. A. Kwanya, *senior administrative secretary*
Mrs. S. N. Govedi, *secretary*
Mrs. M. M. Onyach, *secretary (pool)*
Ms. R. A. Okoth, *data input clerk*
Mr. J. M. Mwendar, *clerical assistant*
Mr. E. E. O. Obuya, *clerical assistant*

Central Administrative Services and Utilities
Mr. L. Okola, *(in charge)*
Mr. W. W. Wapakala, *principal administrative officer*

Utilities Section
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, *mail clerk*
Mr. L. Kisutia, *machine operator*

Janitorial Section
Mr. C. F. O. Onoka, *janitorial supervisor*
Mr. E. Asami, *cleaner/messenger*
Mr. D. Chege, *cleaner/messenger*
Mr. L. L. Ayekha, *gardening assistant*
Mr. W. O. Adhiambo, *cleaner/messenger*
Miss P. Siva, *cleaner/messenger*
Mr. R. M. Masaka, *cleaner/messenger*
Mr. D. M. Muthama, *cleaner/messenger*
Mr. E. Ondeyo, *cleaner/messenger*
Miss E. J. Tirop, *cleaner/messenger*
Mr. T. O. Adongo, *cleaner/messenger*
Miss L. W. Mwaura, *cleaner/messenger*
Mr. B. M. Oketch, *cleaner/messenger*
Mr. W. Ambaka, *cleaner/messenger*
Mr. G. S. K. Kariuki, *cleaner/messenger*
Mrs. S. A. Otila, *cleaner/messenger*
Mrs. M. A. Ochanda, *cleaner/messenger*
Mrs. S. Onyango, *cleaner/messenger*
Miss T. D. Makero, *cleaner/messenger*
Miss L. W. Kabiru, *cleaner/messenger*
Mr. F. O. Athula, *cleaner/messenger*

Security Section
Mr. M. P. Arrumm, *chief of security and protocol*
Mr. A. M. Bwana, *senior security officer*
Mr. G. O. Abong'o, *security officer*
Mr. J. M. Mwitta, *security supervisor*
Mr. A. M. Ouma, *security supervisor*
Mr. M. M. Kinguu, *senior security guard*
Mr. T. S. Ekisa, *security guard*
Mr. A. M. Muhindi, *security guard*
Mr. C. K. Mulela, *security guard*
Mr. J. D. Nyawalo, *security guard*
Mr. E. H. Otieno, *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. P. O. Apodo, *security guard*
Mr. Z. Otieno, *security guard*
Mrs. M. N. Muiruri, *security guard*

Mr. M. O. Otiende, *security guard*
Mr. D. O. Aloo, *security guard*
Mr. J. N. Aburi, *security guard*
Mr. G. O. Omondi, *security guard*
Mr. B. N. Kimunya, *security guard*

Transport Section
Mr. V. O. Odhiambo, *transport assistant*
Mr. J. O. Madero, *data in-put clerk*
Mr. J. O. Oduol, *automobile foreman*
Mr. A. J. Ombija, *senior mechanic*
Mr. R. M. Kiboi, *driver/mechanic*
Mr. M. O. Ombech, *senior driver*
Mr. P. N. Mahogo, *senior driver*
Mr. P. O. Owuor, *senior driver*
Mr. P. Otiende, *driver*
Mr. E. N. Kiio, *driver*
Mr. P. T. Litaba, *driver*
Mr. A. Kathoka, *driver*
Mr. H. N. Njuchi, *driver*
Mr. A. Mwangi, *driver*

FINANCE DIVISION
Miss F. Ojode, *senior administrative secretary*

Accounting Services (Duduville-based)
Mr. R. M. P. Okura, *chief accountant*
Mr. G. W. Kanza, *principal accountant*
Mr. R. Otieno, *senior accountant*
Mrs. W. N. K. Ssebunnya, *senior systems analyst*
Mr. V. M. Kamanyi, *accountant*
Mr. A. A. M. Oguda, *accountant*
Mr. M. Kawaka, *accountant*
Mrs. L. W. Kimani, *accountant*
Mr. P. O. Ngugi, *accountant*
Mrs. L. W. Muchene, *assistant accountant*
Mr. S. M. Aritho, *assistant accountant*
Mr. P. O. Okune, *assistant accountant*
Mr. J. R. Okello, *accounts assistant*
Mr. C. T. Maingi, *accounts assistant*
Mr. N. K. Mulwa, *accounts assistant*
Miss M. L. Mwangemi, *data processing assistant*
Mr. J. O. Madiwia, *clerical assistant*
Mrs. M. M. Butali, *secretary*
Mr. J. B. Oyondi, *senior driver/messenger*
Mr. A. Bubusi, *senior cleaner/messenger*

Stores and Supplies (Duduville-based)
Mr. C. M. Oloo, *controller for supplies and stores*
Mr. C. N. Keli, *assistant supplies officer*
Mr. P. N. K. Kathenya, *supplies assistant*
Mr. D. O. Olalo, *storekeeper*
Mr. D. K. Yaem, *assistant storekeeper*
Mr. A. O. Kirimba, *driver*
Miss S. M. Matiku, *assistant secretary*