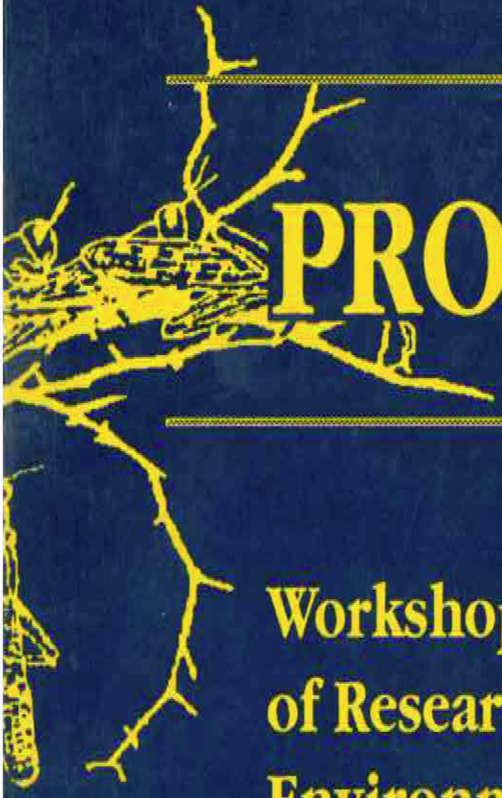

PROCEEDINGS

Workshop on Effective Networking of Research and Development on Environmentally Sustainable Locust Control Methods Among Locust-Affected Countries

Duduville, Nairobi, Kenya
16–18 September 1991

The International Centre of Insect Physiology and Ecology
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FOREWORD

PROF. S. EL BASHIR
Leader, Locust Research Programme
The International Centre of
Insect Physiology and Ecology (ICIPE)

The Locust Research Programme, the newest of the Centre's five research programmes was initiated in 1989. The long-term objective of this programme is to develop an alternative biorational and sustainable desert locust management and control strategy. The success of this endeavour depends on the ability to keep locusts permanently solitarious and to prevent the development of swarms.

However, in order to achieve this goal, intensive and carefully planned fundamental research of the source and nature of the signals mediating the processes of gregarisation, as well as the synchronised locust behaviour, leading to swarm formation, has to be undertaken. Certain behaviour modifying chemicals, semiochemicals, and in particular pheromones and plant kairomones are believed to be implicated. In addition, the role of biological control agents in regulating locust populations will also be investigated.

This is a long-term undertaking which involves laboratory and field research activities. However, during the initial stages, greater emphasis will be laid on laboratory investigations so that a sound basis for field research is provided.

This workshop is the first of its kind to be held since the inception of the Locust Research Programme. Its main objective is to lay a solid foundation for future collaboration between the ICIPE and the other partners dealing with locust research and control, especially in the locust-affected countries. There is no doubt that field research on locust is an extremely difficult undertaking, because of the mobile nature of the insect and the low numbers of the widely scattered recession populations which are encountered in harsh desert and semi-desert habitats.

Furthermore, there are few experienced field staff and very few researchers dealing with locusts. Hence it is important that resources are pooled and efforts coordinated so that progress towards effective, biorational and sustainble locust management strategy is made.

We wish to acknowledge the generous support provided to the Locust Research Programme by all donors who responded favourably to the recommedations of the Scientific Advisory Committee (SAC) of the Coordinating Group on Locust Research (CGLR). Special thanks are extended to the International Fund for Agricultural Development (IFAD) for supporting and funding this Workshop.

WELCOMING REMARKS

PROF. T. R. ODHIAMBO
Director, The International Centre of Insect Physiology and Ecology (ICIPE)

After four decades of spectacular campaigns of locust control by the aerial bombardment of locust swarms with synthetic insecticides, we have begun to realise that, however massive mortalities appear after each campaign event, we are far from achieving a sustainable conclusion regarding these recurrent and devastating locust plagues. Indeed, we have to remind ourselves that this insecticidal phase of attempted final solution of the locust problem was presaged by nearly a century of attempts at locust eradication by using general-purpose poisons such as cyanide and strychnine in baits sited in territory being crossed by marching bands of hoppers. Again, these early attempts at control were often spectacular but did not result in a long-term population effect. This protracted period of failure to attain the long-term goal of locust control, if not of eradication, has demonstrated the fact that we need to radically change our modern strategies for locust management if we wish to reach a sustainable measure of locust population control.

Part of this radical change is to switch our scientific focus from the eradication of the locust species *per se* from the face of the earth, and to concentrate our major effort instead, to preventing the development of locust swarms and their subsequent migration to new areas, when they ravage these as the historically feared marauding swarms. Such a radical switch would change our militaristic obsession with killing as a strategy for locust population eradication, to a more subtle knowledge-intensive strategy for locust population management. This latter strategy makes ecological sense, since the solitary-phase locust, which behaves more like the primeval grasshopper, is a selective browser in the savannahs, living a loosely elementary social life, keeping in touch through its modestly developed acoustic communication system. In this behavioural phase, the locust is an important converter of cellulose — perhaps just as important as the other major herbivores in the tropical savannahs, such as the mound-building termites, the dung beetles, and the ungulates. If the locusts could only be kept in this behavioural state on a permanent basis — without occasionally transforming themselves into the aggregating, swarming, migrating, and polyphagous destructive marauders — they would then remain a positive element in the ecology of the savannahs.

This unconventional approach being pioneered by the International Centre of Insect Physiology and Ecology (ICIPE) has no precedent in insect population management. It relies on two possible tactics:

- First, on minimisation of the normal solitaria- phase population in its usual breeding grounds, through the introduction of a low-level, endemic locust disease, either protozoan in origin or bacterial — not through a microbial insecticide.

- Second, on the modification of locust behaviour through the use of their own semiochemicals, so that the locust remains in its solitaria phase; remains non-aggregating, non-swarming, and non-migratory; and does not synchronise its sexual maturation or oviposition behaviour.

None of these two tactics are spectacular by themselves; but the results are crucial and long-lasting, as the locust populations will remain in their usual breeding habitat — never again organising themselves as recurrent marauding plagues.

This novel approach, as yet an uncharted territory, reminds one of what Snow (1979) had to say of Albert Einstein's unprecedented research on relativity:

> "This last paper [on the special theory of relativity] contains no references and quotes no authority ... They contain very little mathematics. There is a good deal of verbal commentary. The conclusions, the bizarre conclusions, emerge as though with the greatest ease: the reasoning is unbreakable. It looks as if he [Albert Einstein] had reached conclusions by pure thought unaided, without listening to the opinions of others. To a surprisingly large extent, that is precisely what he had done."

Yet, mission-oriented basic research that the ICIPE has already embarked upon will by itself not necessarily lead to the successful implementation of a new, long-term population management of the desert locust. The ICIPE needs to work interactively on a continuing basis with the scientific communities in the locust-affected countries, in at least three fields:

- First, in undertaking long-term ecological and behavioural studies of the desert locust within the breeding zones and locust-recession areas. Knowledge gathered in this fashion on the locust populations in respect of their semiochemical biology is an essential background to subsequent field experiments with natural or synthetic semiochemicals and locust pathogens.

- Second, we need to have access, country-by-country and in a comparative manner, to information on the behaviour of locusts during their recession phase. Very little is known about this phenomenon; and information exchange is an important component for effective scientific cooperation.

- Third, we require to develop the capacity of national scientists in the broad field of semiochemical scientific research and technological development (R&D), as a long-term measure in bringing to a realisation a sense of equal partnership in R&D cooperation.

It is ICIPE's sincere hope that the Workshop on Effective Networking of Research and Development on Environmentally Sustainable Locust Control Methods will succeed in laying down some guidelines for initiating such scientific cooperation in the near future.

We believe that the development of these guidelines is a vital step in the growth of an effective and productive partnership. The locust-affected countries have a national mandate individually and in regional groupings to control locusts. The ICIPE, on the other hand, has a mandate (in respect of locusts) to undertake mission-oriented basic research that would lead to the design of technologically efficacious, cost-effective, environmentally friendly, long-range locust management methodologies. The two parties are therefore complementary and have a synergistic relationship. The urgency for such a partnership is apparent, as our technological shelves are bare of creditable locust control technologies. Yet, we expect that the next locust outbreak will inevitably take place within the next few years, if the record of previous outbreaks is any pointer for the future. We need to be ready with a new approach, and new highly trained national scientific groups to carry through the novel knowledge-intensive technologies that will emerge from our behaviour-modifying semiochemicals R&D. This demand-driven process of consultation for the initiation of a long-lasting partnership is the very essence of this week's Workshop on Effective Networking.

We believe that capacity building must be an integral part of networking because the challenge of the new technologies is the rapidity with which they become obsolescent, and the need therefore to have the endogenous capability to keep up with the requirements for technological updating or even of its replacement. We are reminded so by a World Bank science policy specialist, Erik Thulstrup (1991):

> "Today scientific knowledge is among the most unevenly distributed assets in the world . . . while industrialized countries in 1985 on the average had 70 scientists and engineers per thousand population, African countries had only 3, and both Asia and Latin America had 12. Perhaps even more important than the quantitative gap is the qualitative one. Generally, the production of well trained S&T manpower in developing countries is limited by insufficient quality of the higher education teaching staff and laboratory facilities."

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CONTENTS

SESSION I:

LOCUST RESEARCH AT ICIPE

AN OVERVIEW OF THE RESEARCH AND POLICIES OF THE LOCUST RESEARCH PROGRAMME

S. EL BASHIR
Programme Leader, The Locust Research Programme, ICIPE

The Locust Research Programme whose research activities commenced in January 1990, is the newest of the five Programmes and five Research Units of the International Centre of Insect Physiology and Ecology (ICIPE). Preparations for its establishment began about three years earlier. So far, the target species is the desert locust (*Schistocerca gregaria* Forsk.), but other species of locusts and grasshoppers may also be included in the near future.

The long-term objective of the Locust Research Programme is to develop sound, environmentally friendly, biorational and sustainable locust control strategy. This approach received considerable support from both the scientific and donor communities, especially following the hard lessons learned during the last desert locust plague (1988–1989) in Sudan and other sub-Saharan countries. It is important to note that the last desert locust plague appeared at a time when field scouting activities were at their lowest, logistics were inadequate and pesticide stocks were depleted. Furthermore, the most effective and highly residual insecticides, which belong to the organochlorine group, were banned by most countries, especially the donor countries, and no substitutes were available. In addition to all this, there were serious knowledge gaps, particularly in the areas of locust behaviour, ecology and biology. There was thus pressing need for research to address some very basic issues in order to develop an alternative control strategy.

THE CURRENT CONTROL STRATEGY

The current locust control strategy is a fire-brigade strategy with short-term objectives. It is highly dependent on specific persistent pesticides which are applied on extremely fragile desert and semi-desert habitats. For its success, it requires constant surveillance of remote and inaccessible areas in order to discover gregarising locust populations and treat them before they form mobile swarms. In practice, survey activities are limited in scope and the strategy, therefore, transforms into the control of swarming populations; as such this strategy has never been successful in preventing plague development nor in containing it. In addition, it requires large quantities of pesticides, which are not only expensive to purchase and apply, but also contaminate the environment and cause drastic ecological effects.

AN ALTERNATIVE STRATEGY

This strategy aims at employing methods which are basically non-chemical, environmentally compatible and sustainable. Its main objective is to keep locust permanently solitarious since solitary locusts are harmless and may even have a beneficial role in the ecosystem. It envisages that, development of locust into the gregarious phase may be prevented by the disruption of the processes of multiplication and gregarisation.

THE RESEARCH APPROACH

To fulfil its objectives of developing an alternative biorational locust control strategy, the Locust Research Programme focuses on two broad research areas:

a. Research on Behaviour Modifying Chemicals (Semiochemicals)

These are chemical signals which stimulate and synchronise various vital processes associated with changes of phase status in locust. In particular, we are presently investigating pheromone systems triggering the processes of gregarisation/ solitarisation, maturation, oviposition and sex attraction. These are laboratory studies intended to demonstrate the occurrence of these pheromones, test their effect on locust behaviour and define their chemical characteristics. Investigations also include the role of plant kairomones in influencing host selection behaviour, especially among solitary individuals. However, since host selection behaviour is partly influenced by the shape and colour of the various host plants, some aspects of the biophysical behaviour of the desert locust is also being studied. This includes the visual responses of locusts to different colours and shapes.

For such detailed studies to be performed high quality laboratory-reared locusts of both crowded and solitary populations have to be supplied. Hence, there is a well-maintained locust rearing facility which is producing the required quality and quantity of locusts. However, because quality control and determination of phase status depend on morphometrics, which are rather unspecific parameters, we are now developing methods for quality control based on the biochemical characteristics of the different phases. This will be thoroughly tested, on both laboratory-reared and field populations, and it is hoped that a more dependable method will be developed.

b. Research on Biological Control

The primary objective of the biological control research is to look for indigenous pathogens which are present in the desert locust recession and breeding areas; develop methods for their colonisation and augmentation in the pre-gregarious locust populations. Since our targets are pre-swarming locust populations, which are difficult to locate and treat by conventional methods of pesticide application, we have to look for pathogens which can be transovarially transmitted. Hence, once the disease organism is released in a population it will continue to perpetuate and spread. However, the candidate pathogen should also be hardy enough to tolerate the harsh desert conditions, viz. high temperature, strong intensity of ultra violet light and low humidity. So far, our focus is on protozoa and viruses and there are interesting results already in hand.

FIELD INVESTIGATIONS

Laboratory research work is indispensable for generating the necessary information in order to develop an alternative strategy. However, this effort must also be accompanied by a strong field research component so that there is good understanding of the ecological parameters influencing population dynamics. There is also need for defining the most preferred solitary locust habitat which could be used as sites for testing the laboratory produced components of the locust chemical ecology.

However, field research should not be considered on seasonal basis, but it must be sustained throughout the year and for several years. Facilities must be made available for scientists to stay in the field for as much as is necessary so that generated technologies are based on proper field experience. This may require the setting up of field research bases with very definite programmes and work plans.

SEMIOCHEMICAL RESEARCH ON THE DESERT LOCUST *SCHISTOCERCA GREGARIA* (FORSK.) AT ICIPE: RATIONALE AND SCOPE

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Chemistry and Biochemistry Research Unit
The International Centre of Insect Physiology and Ecology (ICIPE)

RATIONALE

The most important feature of the desert locust is its ability to interconvert between two morphologically, physiologically and behaviourally distinct phases: the solitaria and the gregaria. Under endemic conditions in recession areas, which are characterised generally by dry and warm weather, the solitaria prevails. This phase lives as dispersed individuals in very low densities in scattered populations, feeding on a limited range of desert plants, and reproducing only when environmental conditions are sufficiently favourable. Under spells of dry weather maturation may be totally arrested, a condition which has been referred to as "reproductive diapause" (Norris 1964). When weather and vegetation conditions improve, maturation is resumed and breeding and rapid increase in numbers take place. Transformation to the gregarious phase is associated with dense concentrations of solitarious locusts, resulting from both immigration from neighbouring areas and breeding, the process going through a series of the so called transient forms (Roffey and Popov 1968). The gregarious phase is characterised by a highly cohesive behaviour, long-distance migratory aptitude, polyphagy, synchronous and accelerated maturation of males and females and mass egg-laying by gravid females at common sites (Steadman 1988). It is this remarkable set of characters of the gregarious phase that makes the desert locust such a devastating pest.

Major locust outbreaks are generally associated with improved rains and vegetation after a relatively long dry-weather spell. They begin with the migration of solitary-living locusts into areas where sufficient rain has recently fallen. Mating and egg-laying then occur. A sequence of appropriately timed rains in the winter and summer breeding areas, coinciding with the appearance of new locust generations,

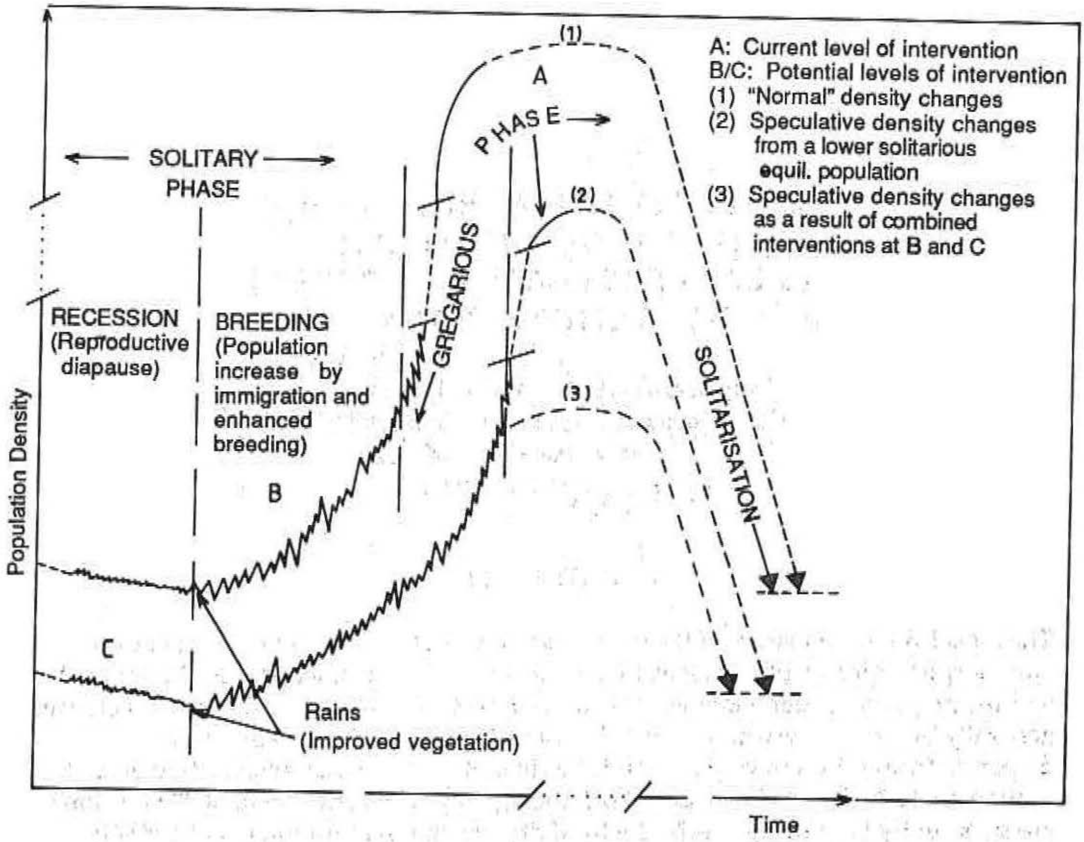

Fig. 1. Idealised representation of phase changes and current/potential levels of intervention

may lead to high concentrations and multiplication rates of the insect, which are then accompanied by gregarisation and swarming (Fig. 1). The current control method of the pest, based as it is on monitoring the development of swarms followed by large-scale application of synthetic pesticides, is curative in approach. It does not address the question of preventing the unfolding of the problem. Conceptually, at least two additional levels of intervention are possible which may prevent or pre-empt gregarisation and swarm formation (Fig. 1). The first involves the manipulation of population equilibrium of solitary locusts in order to lower it to levels less likely to lead to sustainable swarms. The second involves the disruption of the process of gregarisation, a key process in the assumption of a major pest status by the desert locust. Unfortunately, there are major gaps in our current knowledge of the desert locust which must be filled before viable approaches to interventions at these levels can be developed.

The ICIPE's desert locust semiochemicals project is designed to fill critical gaps in our knowledge of the chemical ecology of the insect. The objectives are (a) to understand the biochemical signals that mediate the behaviour and communication systems of the two phases and the way these signals regulate the life style and phase dynamics of the insect; (b) to develop semiochemical-based tools suitable for studying the ecology of the desert locust, particularly the solitaria and pre-gregarising populations; and (c) to exploit desert locust chemical ecology to develop new intervention strategies at levels indicated above. This paper and the accompanying complementary one by Dr. R. K. Saini give the scope of ICIPE's semiochemical research and the approaches employed.

SCOPE OF THE RESEARCH

Two groups of chemical cues have been implicated in the chemical ecology of the desert locusts:

- Interspecific signals synthesised and stored or emitted by host plants which may function as host location and recognition cues (kairomones), as defensive chemicals (allomones), or as cues that are of adaptive value to both the insect and host plants (synomones).
- Intraspecific signals (pheromones) produced by the locust themselves are important in regulating and sustaining the two respective phases.

The status of our current knowledge of these signals and the questions that need to be addressed are outlined below.

Interspecific Signals

Previous studies on host location and selection were confined to the gregarious phase. True to its polyphagous character, the gregarious desert locust responds to a wide range of phagostimulants (Bernays and Chapman 1974; Haskell *et al.* 1962; Rao 1982) and plants avoided have been associated with the presence of high levels of feeding deterrents (Hussain *et al.* 1946; Bernays and Chapman 1978; Rao and Mehrotra 1977). Since solitary desert locusts are, by and large, oligophagous and occur in low numbers in relatively low vegetation densities, we have postulated that a more specialised set of volatile kairomones may be involved in host plant location. Likewise, feeding may be regulated by specific combinations of allelochemics. Studies of these signals, therefore, form part of ICIPE's research programme.

Critical to our understanding of the phase dynamics of the desert locusts are factors which have been implicated in influencing or predisposing maturation (Carlisle *et al.* 1965) and change in phase characters (Jackson *et al.* 1978). Since rains change both the physiology (and therefore the chemistry) and the profile of desert plants available as food, there may be an intimate link between the physiological propensity of the insect to gregarise or to solitarise and allelochemicals and nutrients present in the host plants in the habitats of solitarious and pre-gregarising populations. These aspects of the research will be undertaken by Ph.D. scholars from the proposed networking countries.

Intraspecific Signals Relating to Gregarisation and the Gregarious Phase

The gregarious phase appears to be sustained by three sets of pheromone systems:

(a) gregarisation-cohesion pheromone

(b) maturation-mediating pheromone, and

(c) oviposition-aggregating pheromone

Both primer and releaser effects are involved.

The gregarisation-cohesion system elicits physiological transformation from solitarious to the gregarious phase as well as the cohesive behaviour of nymphal and adult stages (Nolte 1963; Gillett 1968; Nolte 1968; Gillett 1975; Nolte 1976; Gillett and Phillips 1977; Gillett 1983; Fuzeau-Braesch *et al.* 1988). Attempts to identify the components of the pheromone system have been described but the results were contradictory (Nolte 1976; Fuzeau-Braesch *et al.* 1988; Loher 1990); unfortunately, methods of isolation of candidate pheromone components used were inefficient and the researchers failed to deploy well-designed and sensitive assays that monitor, in parallel, physiological changes and behavioural responses of insects of both phases. Moreover, it has been assumed that the same set of compounds is involved in primer and releaser effects. The ICIPE Project seeks to carefully re-examine this multifaceted phenomenon.

Maturation in gregarious locusts is believed to be regulated by a two-set primer pheromone system: a maturation pheromone which has been shown to be associated with mature, male adults (Norris 1954; Loher 1960; Uvarov 1966) and an inhibition pheromone which has been hypothesised to be associated with fledglings and nymphs (Norris 1962). The former accelerates maturation in young male and female adults; the latter is believed to be responsible for apparent inhibitory effects observed on the maturation of adults when these are exposed to immature stages (Norris 1964; Norris and Pener 1965; Richards and El Mangoury 1968). It has been suggested that the combination of promotion and inhibition is responsible for synchronous maturation observed in gregarious adult populations (Norris 1962, 1964). Significantly, extracts of the maturation pheromone were not effective in accelerating maturation in solitarised locusts, suggesting that the gregarious state is a prerequisite for response to the pheromone (Amerasinghe 1978). One attempt to identify the maturation pheromone has been described, but the entrainment technique used was inefficient and no active compounds were isolated to allow any significant studies to be undertaken on the maturation process (Blight 1969).

Aggregated oviposition behaviour of gravid females has been shown to be partly mediated by a chemical signal (Norris 1963, 1970). In a series of behavioural assays

(See Dr. R. K. Saini's paper), the signal has been shown to be remarkably effective in inducing group oviposition. The chemical nature of the compounds involved has not been investigated.

It is clear that maturation-mediating and oviposition-aggregating pheromone systems are critical to the gregarious phase. The former ensures that maturation and mating take place synchronously and the latter ensures that the nymphs are highly concentrated upon hatching. Thus the cohesiveness of the next generation, both temporal and spatial, is efficiently regulated. It follows also that these two processes may constitute potential targets for disrupting the gregarious phase. An intervention that leads to desynchronisation of maturation and/or to dispersed egg-laying could substantially affect the integrity of the gregarious phase and lead to degregarisation.

Intraspecific Signals Relating to Solitaria and Solitarisation

No specific chemical signals have been associated with the solitaria. However, a long-range sex communication system is clearly important in this low-density phase. We have speculated that this may well be pheromonal. Interestingly, there are hints of mediation of sex pheromones in a number of acridids (Whitman 1990) and two grasshopper species have been shown to use pheromones in mate location and recognition (Siddiqui and Khan 1981; Whitman 1982). A long-range sex pheromone in the solitaria would constitute a powerful tool for ecological studies of this phase and the ICIPE Project has accorded high priority to investigating the mediation of such a signal.

The eventual solitarisation of a gregarious population (Fig. 1), and indeed the remarkable periodicity of locust plagues, remains largely a mystery although a number of factors have been implicated (Michel 1980; Steadman 1988; Gillett 1988). The possibility of mediation of a physiologically modulated signal cannot be ruled out. In this regard the postulated existence of a solitarising pheromone in adult faeces is interesting (Gillett and Phillips 1977; Gillett 1988). In view of its possible implication in degregarising hoppers and gregarious adults, its existence needs to be verified.

APPROACH USED AT ICIPE

With the benefit of hindsight our approach to isolating and identifying desert locust semiochemicals is based on careful deployment of currently available micro-analytical techniques and on the use of appropriate bioassays to detect and monitor the presence of active compounds in each step of the process. Noteworthy points of the approach include:

(a) The search for reliable and quantifiable markers (cuticular components, haemolymph proteins etc.) to guide the identification of primer pheromones (gregarisation and maturation pheromones). Previous studies relied on slow-changing subjective effects such as colour or morphological changes. A number of such markers for differentiating between solitaria and gregaria or immature and mature locusts have been identified.

(b) The development of well-thought-out behavioural assays for monitoring releaser effects (See Dr. R. K. Saini's paper).

(c) Establishment of the nature of mediating semiochemicals (volatile/non-volatile, polar/non-polar) prior to selecting an analytical technique (gas chromatography or high performance liquid chromatography).

(d) Establishment of the efficacy of different trapping techniques and adsorption materials from volatile semiochemicals by chromatographic analysis and bioassays and the use of specially purified solvents of appropriate polarity for the extraction of non-volatile semiochemicals.

CONCLUDING REMARKS

Using the rigorous approach outlined above, the presence of a number of semiochemicals referred to earlier (maturation, host plant attractants, oviposition) has been confirmed and new features relating to the chemical nature of these pheromones have emerged. The identification of maturation associated molecular markers will provide a very convenient means of identifying the maturation-mediating pheromones. Likewise, phase-specific markers would make it possible to develop more sensitive measures of phase status that would be useful in the identification of the associated semiochemicals and in providing measures of gregarisation of field populations.

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BEHAVIOURAL RESEARCH ON THE DESERT LOCUST, *SCHISTOCERCA GREGARIA*

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ABSTRACT

Semiochemicals play an important role in mediating the behaviour of locusts and in their communication systems. In locusts, they also initiate specific physiological and behavioural transformations. In spite of several attempts to identify and characterise the pheromone systems in **Schistocerca gregaria,** ***the identity of the pheromones still remains unknown. In this presentation, ICIPE's approach to semiochemical-mediated behavioural research is discussed and an outline of the work on the maturation pheromone, oviposition-aggregating pheromone, mate finding by solitary locust, gregarisation pheromone, and host plant interactions is presented. It is hoped that knowledge gained from the above studies will assist in the manipulation of gregarisation and swarm formation behaviour.***

INTRODUCTION

Semiochemicals play an important role in regulating the behaviour of insects and in their communication systems. They can provide information about the location of food, hosts, mates or oviposition sites. They may control behaviour such as mating, aggregation, feeding and alarm; or they can initiate specific physiological and behavioural transformations in certain organisms.

In case of the life of the desert locust, *Schistocerca gregaria*, at least three categories of semiochemicals may mediate the different physiological and behavioural manifestations:

(i) A set of pheromone systems, crucial for initiating gregarisation and sustaining swarms, that gregarise nymphal stages, accelerate and synchronise sexual maturation and stimulate and concentrate egg laying within a small area;

(ii) A set of pheromones which appears to reverse some of the effects of the above swarm-promoting pheromones and which may play a role in degregarisation;

(iii) Kairomones from host plants, which act as feeding attractants or stimulants, and may also influence pre-swarm behaviour by helping to concentrate the adults in the breeding areas and by synchronising development of immature stages.

Several attempts to identify and characterise the above pheromone systems have been reported and yet the identity of these pheromones still remains unknown. In fact earlier work on locust pheromones is not only incomplete but also sometimes contradictory. Lack of reliable information concerning these pheromones and the behaviours they mediate, has so far not allowed semiochemical-based manipulation of gregarisation and swarm formation; the ultimate goal of the ICIPE's Locust Research Programme.

ICIPE's Approach to Semiochemical Mediated Behavioural Research

In order to develop behavioural manipulation strategies, a fundamental understanding of all the semiochemicals that are involved in phase polymorphism and in interactions with favoured host plants and habitats is hence critical. This basic knowledge is being obtained by the following approach:

(a) Observation of the phenomenon mediated by the semiochemical.

(b) Development of relevant bioassays as part of the methodology required for semiochemical isolation.

(c) Insight into the source of the pheromone, how and when it is transferred or released to other individuals, and the conditions necessary for response in order to develop the bioassay.

(d) Once a suitable bioassay is developed, and it can be shown, that isolates of the emitting insect or host plant have specific effects on the recipient, then chromatographic separation of the chemical blend can proceed.

(e) At every step of separation of the extracts into various components, behavioural and electrophysiological bioassays are crucial to locate the activity among the fractions.

(f) Synergism, where several compounds must be presented together to elicit maximal response must be investigated.

(g) Isolates of purified compounds must be released at known dose/rates in the behavioural bioassay or in electrophysiological recordings from the antenna or sensillum.

(h) Compounds identified from the laboratory investigations must be tested in large screen houses at release rates comparable to those expected from insects in nature before any large scale field testing.

All the above work is being undertaken in ICIPE's Locust Research Programme, Sensory Physiology Research Unit and Chemistry and Biochemistry Research Unit. Over here, all the basic facilities for this kind of work which includes behaviour, electrophysiology, chemical identification and synthesis of active compounds exist.

The techniques being used comprise of wind tunnel bioassays, olfactometers, gas chromatograph-linked to electroantennographic detector (GC-EAD), electroantennogram (EAG) investigations, gas chromatography (GC), high performance liquid chromatography (HPLC), gas chromatography-linked mass spectrometry (GC-MS) and where necessary, nuclear magnetic resonance (NMR).

RESEARCH PRIORITIES

Locust behaviour research at ICIPE focuses on semiochemicals that mediate:

(i) Maturation

(ii) Gregarisation

(iii) Oviposition

(iv) Host plant-solitary desert locust relationships

(v) Mate finding and selection in solitarious locusts.

Research in the above areas is being undertaken with the following objectives (for further details see also Professor A. Hassanali's paper).

i. Maturation Pheromone

Previous work undertaken indicates that a chemical factor, alleged to be secreted by epidermal glands of the sexually mature male accelerates the sexual maturation of immature male and female adults in gregarious populations (Norris 1954, 1962, 1963, 1964, 1968; Loher 1960). It was found that immature males change from pinkish-brown to uniformly yellow as they become sexually mature. Loher (1960) also claimed that sexual maturation, yellowing and pheromone production were under the control of corpora allata. Blight (1969) attempted to identify the maturation pheromones but their extracts failed to show any biological activity. In the present project, emphasis is on the development of appropriate bioassays to monitor the maturation accelerating effects. Different extracts and volatiles obtained by solvent extraction and cryogenic and adsorbent trapping will be tested for mediating maturation. The effective compounds will then be identified using behavioural and electrophysiological techniques, mass spectrometry (MS) and nuclear magnetic resonance spectroscopy (NMR).

ii. Gregarisation Pheromone

There seems to be little doubt that a gregarisation pheromone exists that mediates phase transformation towards the gregarious form and elicits aggregation behaviour (Nolte 1963, 1968; Nolte *et al.* 1970, 1973; Gillett 1968, 1975; Gillett and Phillips 1977 and Fuzeau-Braesch *et al.* 1988). The work of these authors also suggests that two sets of signals may be operational in mediating gregarisation.

(a) A primer pheromone associated with air surrounding crowded locust hoppers and shown to arise from the faeces of both gregarious and solitarious hoppers which functions by promoting grouping behaviour of hoppers and induces physiological changes associated with transformation of the solitarious to the gregarious phase; and

(b) An elicitor pheromone that may be associated with already gregarised locusts and may help to keep them together.

It is however, not clear, whether one compound or several participate in eliciting colour and morphometric changes, moulting synchronisation and cohesive behaviour. At ICIPE, a re-analysis of airborne volatiles from faeces as well as solitarious and gregarious locusts, using solvent-free techniques and a more sensitive and methodical set of assays of the identified compounds is in progress. The behavioural assays used by previous workers are also being improved in terms of quantification of the degree of grouping of test locust individuals.

iii. Oviposition-Aggregating Pheromone

Females of *S. gregaria* tend to deposit their egg pods in close proximity with other females (Popov 1958; Stower *et al.*, 1958; Uvarov 1966). Norris (1963) found that females oviposited more in sandy areas with living decoys than in areas without decoys indicating that visual cues may be important in aggregating females to common egg laying sites. However, immature or mature males as well as last instar hoppers can be used as decoys and they are functional even in total darkness. The suspicion that chemical stimuli may also be involved was confirmed when it was shown that paper decoys were ineffective unless the paper was taken from cultures of locusts. Norris (1970) showed that ether extracts of mature adults were effective in oviposition bioassays. Unfortunately, the chemical nature of the pheromone still remains unknown. Hence, how this mediates aggregation of gravid females and its potential as a trap cue in the pre-gregarisation phase still remains to be evaluated.

Work is in progress at ICIPE to confirm the presence of the oviposition aggregating pheromone and to determine its origin and chemical nature using behavioural and electrophysiological techniques.

iv. Host Plant-Solitary Desert Locust Relationships

In order to obtain a better understanding of the behaviour and biology of solitary populations, it is crucial to understand their interactions with host plants and their habitat. Kairomones are interspecific chemical cues which may mediate host plant seeking and host acceptance behaviour of locusts. They may also play a role in physiological disposing or predisposing solitarious locusts to the gregarious phase. Two groups of kairomones may influence the physiology and behaviour of locusts; volatile odours of host plants which may help in the location of food (Haskell *et al.* 1962; Kendall 1971, 1972) and non volatile allelochemics involved in food selection (Woodhead and Bernays 1978). However, no detailed studies on the volatile profiles of the atmosphere surrounding the breeding grounds or of the preferred hosts have been reported. Likewise, no study of the non-volatile feeding allelochemics, which may influence the feeding preference has been undertaken. At ICIPE, these plant derived attractants are being investigated and both desert plants preferred by solitarious locusts and plants growing in concentration/breeding areas are being studied in detail. In addition, the role of visual cues in host plant location is also being investigated.

v. Mate Finding by Solitary Locusts

Work is also in progress to determine how solitarious individuals find each other for the purpose of mating.

It is hoped that knowledge gained from all the above behavioural studies will open up new research avenues that will allow the development of strategies to interfere with the process of gregarisation and swarm formation of this important pest.

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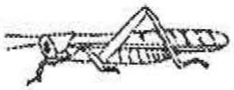

LOCUST BIOCONTROL RESEARCH AT ICIPE

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INTRODUCTION

The major aim of this research programme is to develop and demonstrate a strategy of desert locust management using sustainable biocontrol agents. Two groups of pathogens, viz., protozoa and viruses have demonstrated capability to perpetuate in the environment within the host by transmitting pathogenic stages transovarially from one generation to another (Nordin 1975; Canning *et al.* 1985; Entwistle *et al.* 1978; Raina *et al.* 1990). This is mandatory for a pest like desert locust which migrates from one field to another within a short time for which no ecologically sound direct hit method of control is available. Hence ICIPE has designed a long-term strategy for locust management by selecting chronic pathogens which affect the fecundity of the host and keep the pre-gregarious population at the sub-economic level thus preventing swarm formation.

Two protozoa, the Sarcomastigophora, *Malamoeba locustae* and the microsporidian, *Nosema locustae*, one viral family, poxviridae, entomopoxvirus of acridid group and the fungi, *Beauveria bassiana* strain have been selected for studies which are expected to develop these biopesticides and lead to the establishment of biocontrol agents in the field in Africa. This paper embodies the work accomplished with the protozoan *M. locustae*.

MATERIALS AND METHODS

The desert locust, *S. gregaria* were collected from the Red Sea Tokar Delta and mass reared at ICIPE mass rearing unit. The protozoa *M. locustae* were obtained from the infected laboratory-reared colonies and from the field collected specimens. These pathogens were isolated separately through centrifugation and used for further study. The pathogenesis and dose mortality of *M. locustae* in *S. gregaria* has been recorded by spraying different concentrations of *M. locustae* formulation on sorghum seedlings grass and allowing a batch of 3rd instars of locust to feed. The different degrees of mortality were observed with time. The route of infestation has been traced through histological examinations using haemotoxylene-eosin and Giemsa staining techniques (Humason 1962). These results were further confirmed by electron microscopy. Embryos and nymphs were fixed in Carnoy's and Bouin's fixatives, dehydrated in ethanol series, embedded at 60°C in paraplast, serially sectioned at 6 µm, stained in Erlich's hematoxylin and Eosin B stain to confirm the transmitted developmental stages. Several eggs, nymphs and embryos were also crushed and smear checked under phase contrast microscope for the presence of *M. locustae* stages. Haemocytic responses due to *M. locustae* infection in the haemolymph and some humoral components comprising lysozyme and the inducible antibacterial proteins have been worked out by methodology of Lackie (1981 a, b) and Lackie *et al.*, (1985).

The suitability of desert locust, for production of *M. locustae* have been tested. *M. locustae* cysts at concentration of 2×10^8 per ml of distilled water were used to inoculate 3rd instar nymphs individually. Locusts were starved for 24 hours before being fed 1 cm^2 piece of fresh lettuce on which a drop of solution having 2×10^8 conc. of cysts were placed. After 25–30 days, the adults, mostly dead and few alive were collected and homogenised with a tissue grinder. Five counts were made from each homogenate and the average of these counts were used in final calculation.

RESULTS

A. Incidence of the Protozoan *Malamoeba locustae* in the Field Population of the Desert Locust, *Schistocerca gregaria* in the Red Sea Coast of Sudan

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.

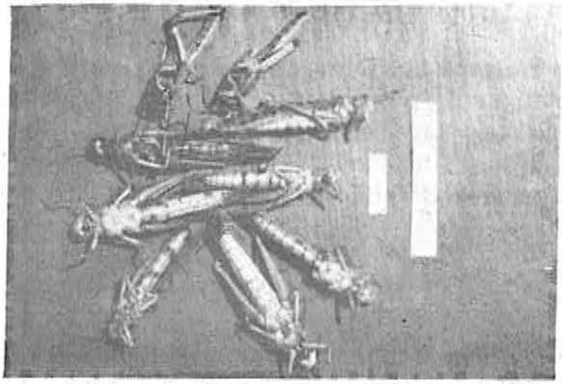

Fig. 1. **Locusts, *S. gregaria* infected with the protozoan *M. locustae* showing characteristic** irregular dark markings on the sterna (arrows)

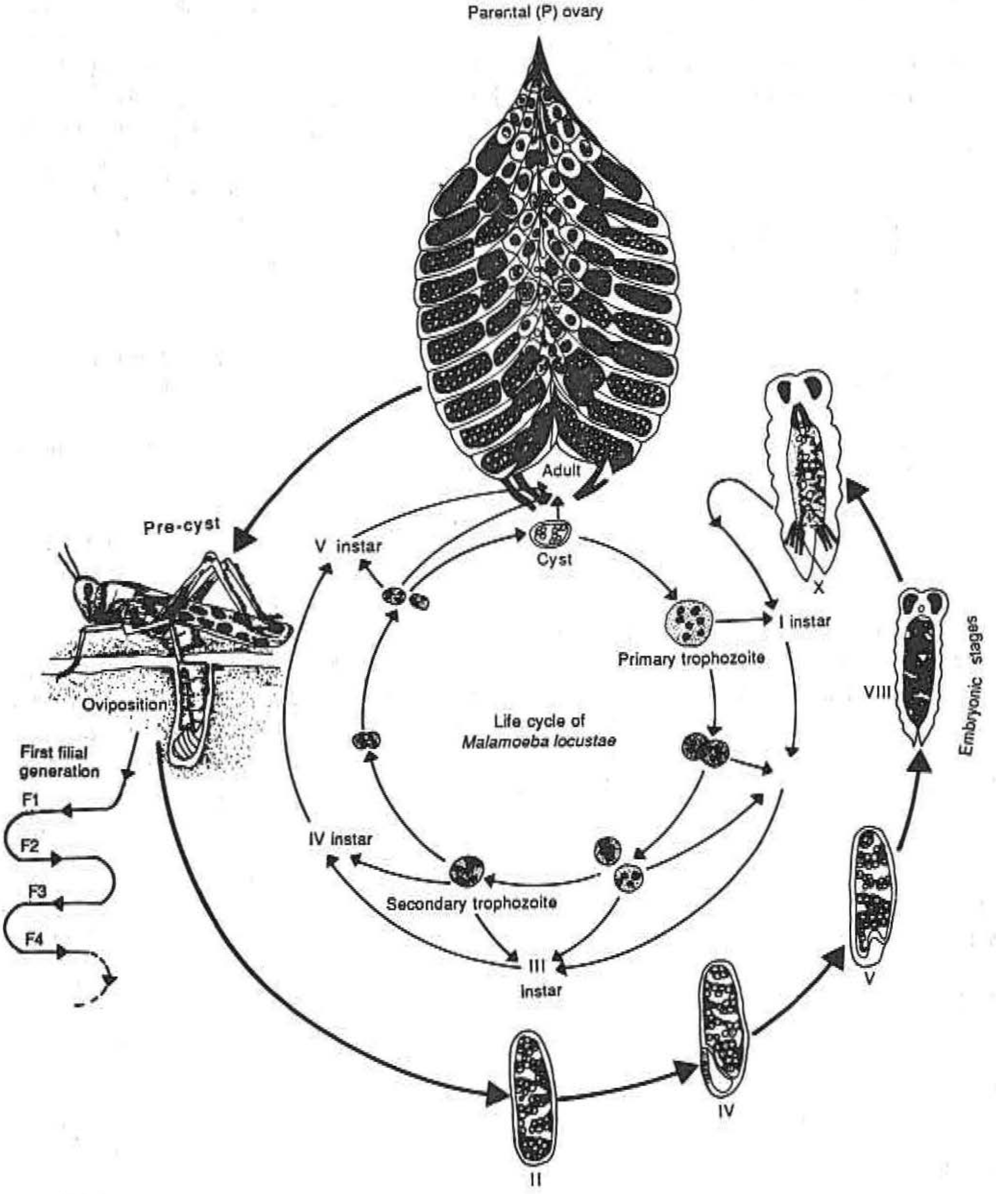

Fig. 2. Mechanism of transovarial transmission of *M. locustae* in generations of the locust, *S. gregaria*

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. In early January 1992, the population trend was drastically different, due to favourable conditions at the Red Sea coast, and the population density was high (600–700 locusts per hectare). 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 lower sternum and its joints (Fig. 1). It can be seen that 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 persistent under field conditions.

B. Transovarial Transmission of the Protozoan, *Malamoeba locustae* in the Desert Locust, *Schistocerca gregaria*

Batches of 150 third instar nymphs each were orally administered various dosages (2×10^7; 2×10^8 and 2×10^9 per ml) of *M. locustae* cysts using sorghum leaves. Different degrees of mortality were observed with time (Fig. 2). 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. 70 to 80% of the nymphs were infected and 25 to 57% died out during various

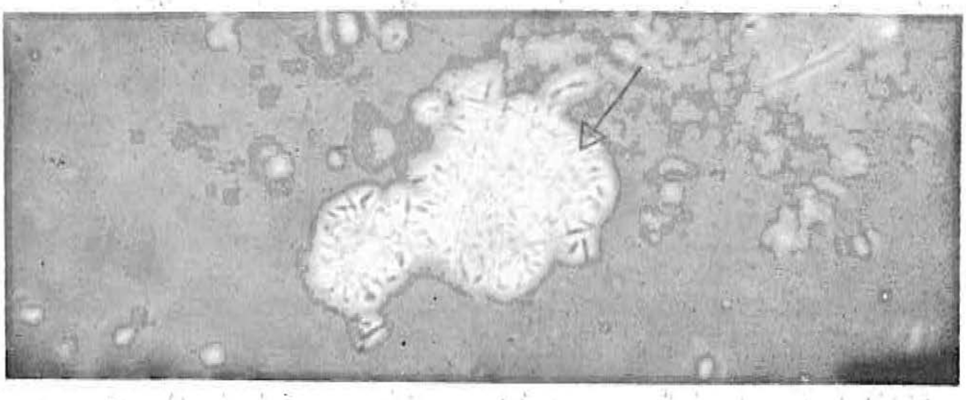

Fig. 3. Agglutination reaction of *L. major* with agglutinin-like factor in locust gut homogenate (arrow)

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. The subsequent generations (F_1–F_4) were observed and the mortality range remained at 60 to 70% in adults but decreased to 30% in nymphs.

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.

C. Identification of Some Humoral Factors in the Desert Locust, *Schistocerca gregaria* infected with the Protozoan *Malamoeba locustae*

When the fourth instar nymphs of locusts were fed with the protozoan *Malamoeba locustae* at the concentration of 1×10^9 per ml, 75–90% mortality was obtained. The survivors, however, carry the infection and even cross the maturity age. SDS Polyacrylamide Gel Electrophoresis technique was used to identify the haemolymph protein factors responsible for developing the resistance in surviving population.

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 24h.

Positive reactions were observed with *L. major* (agglutination) (Fig. 3) and *T. brucei* (lysis) but little with *M. locustae* cysts. This indicates the presence of some agglutinin-like factor(s) in the gut and the haemolymph which might play 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.

D. Potential of Desert Locust, *Schistocerca gregaria* for Production of the Protozoa, *Malamoeba locustae*

The chronic and debilitating nature of the protozoa, *M. locustae* in the desert locust, *Schistocerca gregaria* was reported last year. The pathogenicity, loss of fecundity caused by this pathogen in the locust and its transmission through ovaries into the next generations have been confirmed. *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.

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 10,000 rpm for 1 hour. Two layers were obtained, the lower containing *M. locustae* cysts was diluted with 5 ml of distilled water then the number of the protozoa was counted by means of a haemocytometer.

The results indicate that males can produce an average of 0.77×10^{10} cysts and females 1.50×10^{10} cysts.

Although the females produced more cysts per insect than the males it would be economical to produce *M. locustae* from males rather than females because the latter are used for egg production which is necessary for maintenance of the locust colony. A mass production prototype will be developed after appropriate strain selection which is in progress.

DISCUSSION

The protozoa have been subject to intense investigation as grasshopper pathogens (Bidochka and Kachaturians 1991). This included the sarcomastigophora *Malamoeba locustae* and the microspora *Nosema* sp. *M. locustae* has been found in natural populations of *Locustana pardalina* in South Africa (Lea 1958; Prinsloo 1960; Venter 1966) and North America (King and Taylor 1936). Henry (1968) has described the presence of this protozoa in laboratory colonies of grasshoppers. The pathological effects of *M. locustae* in *Melanoplus sanguinipes* have been described by Hinks and Ewen (1986) and Braun *et al.* (1988). The field survey conducted by ICIPE team in Red Sea coastal area of Sudan (Tokar Delta) has revealed the presence of *M. locustae* in the population of *S. gregaria* (El Bashir *et al.* 1992). In 1990 the incidence of this pathogen was less due to low population in the Tokar delta but in January 1992 when the locust population increased, the percentage of diseased individuals also increased. The disease was identified by light and electron microscopy as the protozoa sarcomastigophora, *M. locustae.* The route of infection in the desert locust was found to be the malpighian tubules which after infection burst open and release few cysts into the haemolymph and later infects fat body and the ovary or testis. In most cases particularly in males, death occurs before maturity of the adults. Characteristic melanin markings appear on the lower surface of the diseased locust which are more pronounced in males than the females. The prospects of biological control of locusts is more promising with the outcome of the study of transovarial transmission of *M. locustae* to its host *S. gregaria* resulting in higher mortality with the increasing generations. Kellen and Lindegren (1971) studied the mode of transmission of *Nosema plodiae* (K&L) in *Plodia interpunctella* (Hubner) and recorded that such infections reduce adult fecundity and about 27% of the progenies of diseased females paired with healthy males acquired infections transovarially. Nordin (1975) demonstrated that the *Nosema* sp. is transovarially transmitted and two phases in the infection process were noted in the pre- and post diapausing embryos. Wilson (1982) has observed that *N. fumiferanae* may be transmitted per-orally, transovarially or by injection to its host *C. fumiferanae.* Infected females, but not infected males, transmit the parasite to 90% of their offspring. Canning *et al.* (1985) have investigated the transmission mechanisms of microsporidian between generations of a geometrid moth, *Operophtera brumata*. Raina *et al.* (1988) recorded that *Nosema locustae* infection in *L. migratoria* continues uninterrupted up to F_8 generations and about 80% individuals of both sexes died in every generation leaving 20% survivors which carry over this disease transovarially into the subsequent generations. The crossing of infected males and females with healthy individuals revealed that females contribute better in transmitting infection than the males. Sectioned ovary, embryos and nymphs from the diseased females have demonstrated that in *S. gregaria* the protozoa *M. locustae* is transovarially transmitted up to F_5 generations (recorded to date) and it can perpetuate keeping the mortality rate upto 60% in every generation. The surviving population transmit the pathogen in the subsequent generations keeping the population of the host under check.

The surviving population have been checked in order to obtain some clues on the possibility of some immune factor. Lackie and Vasta (1988) reported that the humoral components comprises of lysozyme, lectins, phenoloxidase and some inducible antibacterial proteins. The concentration of antibacterial proteins within the haemolymph arises over a period of several days, the timing depending on the insect species. One of the induced proteins in *H. cecropia* P_4 itself appears able to induce synthesis of immune proteins (Anderson and Steiner 1987). Out of 15 different inducible proteins in *H. cecropia* two main groups comprise the cecropins and the attacins (Boman 1986). Molecules with similar characteristics to cecropins and attacins have now been found in many insect species (Hoffmann *et al.* 1981; Spies *et al.* 1986 a & b; Keppi *et al.* 1986 and Ando *et al.* 1987). These proteins appear to be absent from the cricket *Gryllus* (Schneider 1985) and *Locusta* (Hoffmann 1980). In *Locusta* and in *Rhodnius* antibacterial proteins of a different type are synthesised in response to infection (Lambert and Hoffmann 1985 and de Azambuja *et al.* 1986). In *S. gregaria,* following infection with *M. locustae* an extra band of protein has been located in the haemolymph of diseased individuals using SDS PAGE. Agglutination tests using protozoan parasites have revealed the presence of some agglutinin-like protein factor(s) in the gut and the haemolymph which might be playing a role in developing resistance against foreign bodies. Isolation and characterisation of these factors are being carried out using FPLC and SDS PAGE. In addition, the phenoloxidase system and its activation process are being investigated to establish its role in locust immune system.

Since *M. locustae* is an obligatory parasite of the host *S. gregaria* the cysts can be easily obtained by rearing large numbers of *S. gregaria* and infecting them with inoculum of *M. locustae* cysts. Henry and Oma (1981) obtained a greater yield of *Nosema locustae* in adults of grasshopper *Melanoplus bivittatus* using the fifth instar as a host.

In spruce budworm *Choristoneura fumiferana* can produce 1.36×10^8 spores of *Nosema fumigeranae* per larva (Wilson 1976). Raina et al. (1987) obtained 1.2×10^9 spores of *Nosema locustae* using *L. migratoria* as host. The mean cyst production of *M. locustae* per male locust *S. gregaria* was 0.77×10^{10} per ml and that of female was 1.50×10^{10} when each locust was individually fed 1.33×10^6 cysts on lettuce leaves. Although females' yield of cyst production was higher and considering the economics of production, males were preferred for mass production of the cysts of *M. locustae*.

Follow-up studies of the experimental plot in the field will reveal the persistence of this protozoan parasite on the desert locust population and confirm the transovarial transmission. It is hoped that further field trials with different formulations, cyst concentrations, and a sunlight protectant may be useful in establishing *M. locustae* as a long-term biological control agent.

SUMMARY

The incidence of *Malamoeba locustae* has been recorded in the field population of the desert locust *S. gregaria* in the Red Sea coast of Sudan in 1990 and 1992. The pathogenesis of *M. locustae* has been studied in *S. gregaria* through light and electron microscopy.

The dose-rate mortality and the transovarial transmission have been confirmed in filial generations. Some humoral factors in the haemolymph protein have been identified in the surviving populations of diseased desert locust; which may be building tolerance in the population. The potential of desert locust for the mass production of *M. locustae* has been examined to make them useful as a long-term biocontrol agent to minimise the incidence of locust outbreaks.

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A METHOD FOR REARING CROWDED (GREGARIOUS) AND ISOLATED (SOLITARY) LOCUSTS (ORTHOPTERA: ACRIDIDAE) IN THE LABORATORY

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ABSTRACT

A method for rearing isolated and crowded locusts exhibiting solitaria and gregaria phase characteristics, respectively, is described. The basic unit for rearing isolated locusts consists of banks of eight individual cages. Each unit has two bulbs suspended over the top of four cages for provision of light and heat. Gregarious locusts are reared in aluminium cuboid cages which are provided with a bulb in each cage for light and heat. Many generations of the desert locust **Schistocerca gregaria** ***(Forskal) have been successfully raised using these methods. A comparison of the morphometric-derived ratios of the laboratory-reared locusts with those of field collected locusts showed no differences between the two populations indicating the success of the method.***

INTRODUCTION

Locusts which are members of the family of short-horned grasshoppers (Orthoptera: Acrididae) differ from other grasshopper species by their ability to occur in various forms that differ in colour and physiology, occupy special ecological zones and show characteristic behavioural patterns (Uvarov 1928, 1966; Pener 1983). Phase polymorphism is density dependent in both the desert locust, *Schistocerca gregaria* (Forskal) and the African migratory locust, *Locusta migratoria migratoroides* (R&F). Under high density or in crowded populations, the locusts group together (Ellis 1953) become very active and are said to be in phase gregaria (see Uvarov 1966). Under low density or in isolated populations, the locusts live a solitary life and are therefore said to be in phase solitaria.

The recent locust plague in 1985–1989 (see Skaf, in press) has rekindled interest in locust research and locust phase polymorphism. Laboratory rearing of good quality of both isolated and crowded forms is crucial for research on endocrinology, phase transformation and chemical ecology. Phase gregaria-like locusts can be reproduced successfully in the laboratory with relative ease by rearing locusts in high density crowded conditions (Harvey 1990) using several methods and a variety of equipment (Albrecht 1953, 1973; Norris 1957; Hunter-Jones 1961; Dudley *et al.* 1962; Mulkern 1962; Loveridge 1966; Moriarty 1969; Mazuranich and Cowan 1966; Gangwere 1983; and Gardiner 1985).

The rearing of phase solitaria-like locusts is more difficult because many factors affect phase transformation or at least some phase characteristics. These include several categories of semio-chemicals (Loher 1990), tactile and auditory stimulation and vision. Environmental cues such as humidity, photoperiod and temperature may also be contributory factors. It is known that phase changes are transmitted to subsequent generations in a type of non-genetic maternal inheritance (Uvarov 1966; Harvey 1990); thus effects exerted on the parent generation affect phase characteristics of their progeny. Due to these difficulties only a few authors have reported success in maintaining true solitary locusts (Hunter-Jones 1961; Harvey 1990; S. Tobe, F. Hans-Jorg and S. Gillette, pers. comm.).

This paper reports a successful method for rearing both isolated and gregarious desert locusts, *S. gregaria*.

MATERIALS AND METHODS

The rearing of *S. gregaria* at the International Centre of Insect Physiology and Ecology (ICIPE) in Nairobi, Kenya, began in 1989.

Origin of the Locust Material

The colony of *S. gregaria* at the ICIPE was derived from the progeny of several generations of locusts collected from a swarm in Northern Ethiopia in 1973. The locusts had been reared in crowded conditions at the headquarters of the Desert Locust Control Organisation for Eastern Africa (DLCO-EA) in Addis Ababa, Ethiopia. Eight egg tubes from this colony were brought to Nairobi in 1989 (referred to as the Ex. Addis strain) and reared under crowded conditions for three consecutive generations. Offspring of the third generation was used to initiate the rearing of 64 isolated locusts for three generations (G_1–G_3).

True solitary *S. gregaria* locusts were collected from the Tokar Delta, Red Sea Coast of The Sudan (referred as Ex. Red Sea strain) in December 1990 and used for comparison with the laboratory reared solitary locusts.

Rearing Conditions

Three rooms (1.5 x 4.5 m) were used for rearing the locusts. A photoperiod of LD 12:12 was maintained by using an electric timer connected to the source of power. Temperature was maintained at 36 ± 1°C in the light phase (during the day) and 30 ± 1°C in the dark phase (during the night). The relative humidity was maintained at 40–50%. Air flow through the rooms was maintained at a negative pressure of about 10–15 air changes in an hour.

Rearing Equipment

(i) Isolated locusts

The isolated cages used were based on a prototype used in Israel for over two decades. The consideration made in the design was that each locust had to be reared in isolation, the locust must not be able to see any other locust or its own image and that the cages should allow for good air exchange. The material used in the fabrication of the cage had to be such as to allow for chemical and steam sterilisation.

The cages used were made of aluminium and came in banks of eight individual cages (Fig. 1). The cages were not stacked on top of each other. Each bank of eight cages had two bulbs, each suspended over the top of four cages to provide both light and heat. The height of the bulbs was adjustable for the regulation of cage

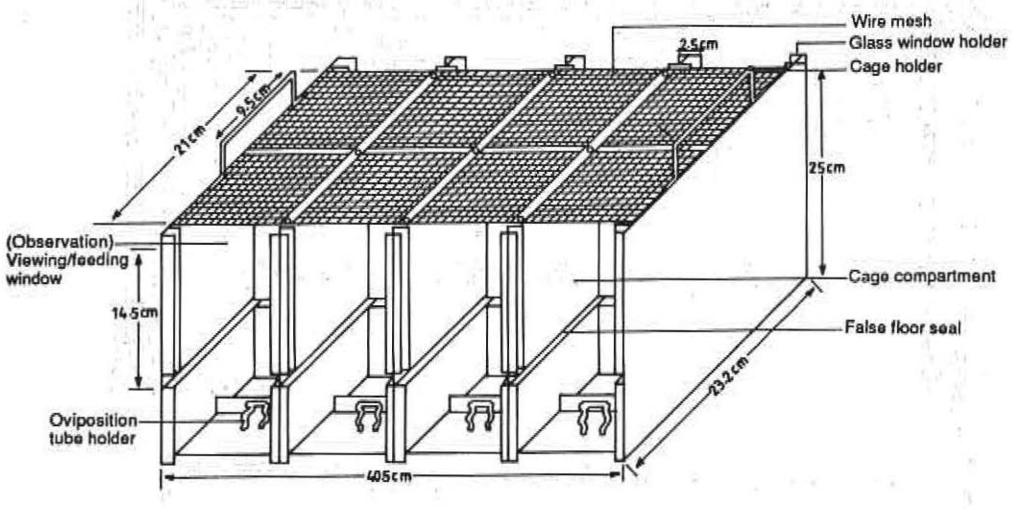


Fig. 1. Solitary locust cage

temperature. Two banks of cages (16 isolated cages) were held on trolleys. The cages were held at convenient height (eye level of a person sitting on an ordinary chair) for servicing (see Fig. 2).

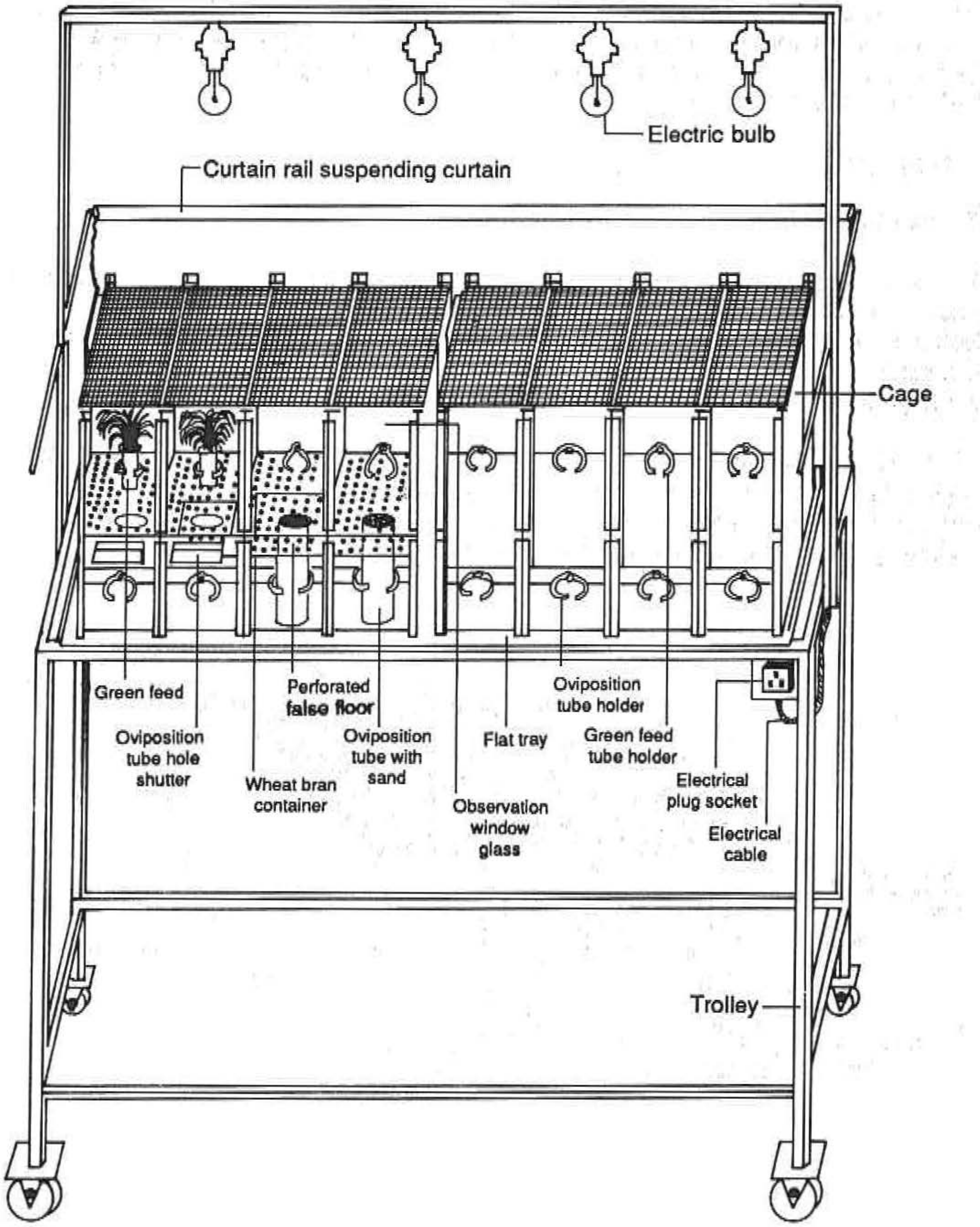
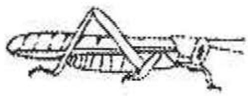


Fig. 2. Sixteen isolated cages held on a trolley



(ii) Crowded locusts

An aluminium cage of 50 x 50 x 50 cm was used for rearing crowded locusts (Fig. 3). The cages consisted of a removable front glass panel aiding observations, a fixed roof,

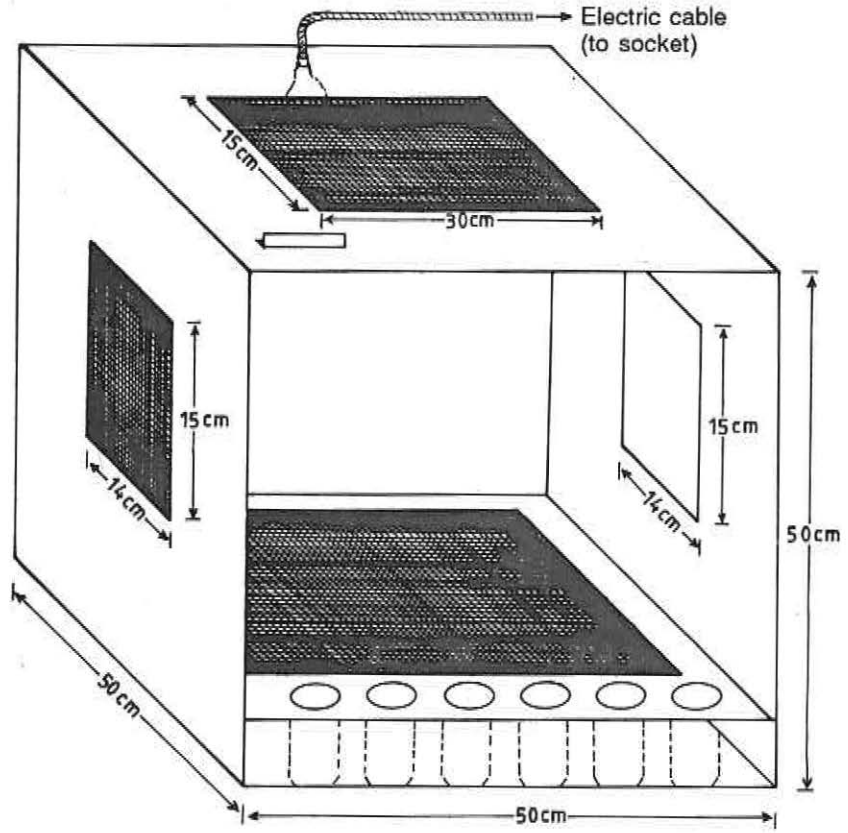


Fig. 3. Cage for rearing gregarious desert locust

a sliding door on the side of the cage and a well fitted false floor perforated to allow faecal matter to fall through. The floor had six holes of 3.5 cm diameter through which the females deposit their eggs into sand-filled aluminium tubes. The cage had a fitting to accommodate a light bulb inside, perforated ventilation panels in the sides and in the roof, a false bottom to catch the faeces falling through the false floor, and a hinged metal strip to cover egg oviposition holes when not in use. The cage was provided with a perch made of chicken mesh.

Each cage contains a maximum of 500 first instar nymphs and/or about 200 adults.

Feeds and Daily Management

For green feed, locusts were fed on fresh shoots of sorghum (Serena variety) which were cut and placed in a container containing water. In the rearing of first instar nymphs of isolated locusts the feed containers were blocked around the shoots with cotton wool to prevent the nymphs from drowning. The feed was changed every alternate day or when it had become dry for isolated locust and *ad libitum* for crowded locusts. The dry feed supplied was wheat bran held in small containers and was replenished whenever it was exhausted.

The cages were cleaned daily. Portable vacuum cleaners were used to remove faeces and plant debris from the floor of cages. Sterilisation was regularly done with a disinfectant (10% sodium hypochlorite solution). At the end of the rearing cycle, the cages were emersed in the disinfectant for 24 hrs.

All dead insects were removed immediately and submitted for pathological examination. The rearing rooms were swept often.

Mating, Egg Laying and Egg Incubation

(i) Isolated locusts

About 7–10 days after the final moult, male locusts were placed into female cages for mating. The male was removed after 24 hrs. Sand held in the egg oviposition tube was used as a medium for egg laying. Sand was sieved, sterilised in an oven at about 120°C for an hour. The sand was mixed at a ratio of 15:100 water to sand and filled into oviposition tubes leaving no air pockets. The oviposition tube was introduced after the removal of the male. The tubes were checked every day for the presence of egg pods. About 1 cm of sand was scooped from the top of tubes containing egg pods to leave room for the hatching nymphs. Females not laying within a period of about 4 days were re-mated.

The oviposition tubes were then covered with pieces of perforated polythene sheets held in place by a rubber band. The eggs were incubated at 30°C for 14–15 days. The sand was lightly moistened to prevent dessication of eggs. The emerging nymphs were negatively geotropic and collected on the top of the sand. The nymphs were separated every morning and reared in isolation.

(ii) Crowded locusts

In the crowded culture, locusts were allowed to mature, mate and oviposit. Egg tubes collected thereafter were treated as in the case of the isolated locusts. Cages were prepared with a water swab, green feed, wheat bran and care was taken to ensure that all the small openings in joints were covered with cotton wool. The tubes with hatching first instars were placed in the cages and the tube covers removed to release the young hoppers.

Morphometric Measurements

Morphometric measurements were made on mature locusts of every generation using an electronic Sylvac(T) caliper with a range of 0–150 mm and an accuracy of ± 0.03 mm. The parts measured were length of body, length of elytron, length of pronotum, length of anterior femur, length of middle femur, length of posterior femur, length of vertex between compound eyes, horizontal diameter of compound eye and maximum width of the head. Ratios between these measurements were calculated using the method described by Dirsh (1953).

RESULTS AND DISCUSSION

The desert locust is hemimetabolous and undergoes 5 nymphal instars after hatching from eggs to the time they become sexually immature adults. Each instar is separated by a moult after which the locust feeds and grows bigger before the next moult. In the solitary phase an extra moult might occur. The instar duration is influenced by a number of factors including temperature and feed availability. At higher temperatures the instar duration is reduced. At a constant temperature of 33°C (Chapman 1976) the instar durations are 5, 4, 4, 5 and 8 respectively. Also the hopper development period is 20 days and 45 days when they are reared at 24°C and 42°C respectively (Chapman 1976). Due to lack of diapause at any stage of the desert locust, it is possible to have 5, 7 or 8 generations per year at constant temperatures of 30°C, 36°C and 40°C respectively.

Mature locusts pair up and copulate. Fecund females drill holes in moist sand using their ovipositor valves and if conditions are right, eggs are deposited. The duration of egg incubation vary with soil temperature and can take between 10 and 70 days.

Under the rearing conditions described, eggs hatched 14–15 days after egg laying. The duration (days ± SE) of the larval instars was:
L_1=4.06 ± 0.04 and 4.09 ± 0.06; L_2= 3.67 ± 0.1 and 3.79 ± 0.07;L_3 =3.55 ± 0.11 and 3.55 ± 0.12; L_4= 3.71 ± 0.11 and 4.34 ± 0.08; L_5=5.4 ± 0.25 and 6.79 ± 0.10; for females and males, respectively of both crowded and isolated locusts. The extra nymphal instar in the isolated locusts (L_6) lasted about 7.7 ± 0.14 and 7.3 ± 0.14 for males and females, respectively (Fig. 4 and 5). The durations were not significantly different (P>0.05) in the three successive generations of rearing the Ex. Addis strain and did not differ with the Ex. Red Sea strain. There was a progressive increase in the number of isolated locusts exhibiting a sixth larval instar and an extra eye stripe from 0% in G_1, 65% and 3% in G_2, to 54% and 75% in G_3 for females and males, respectively. No extra eye stripe or instar was observed in the locusts reared under crowded conditions.

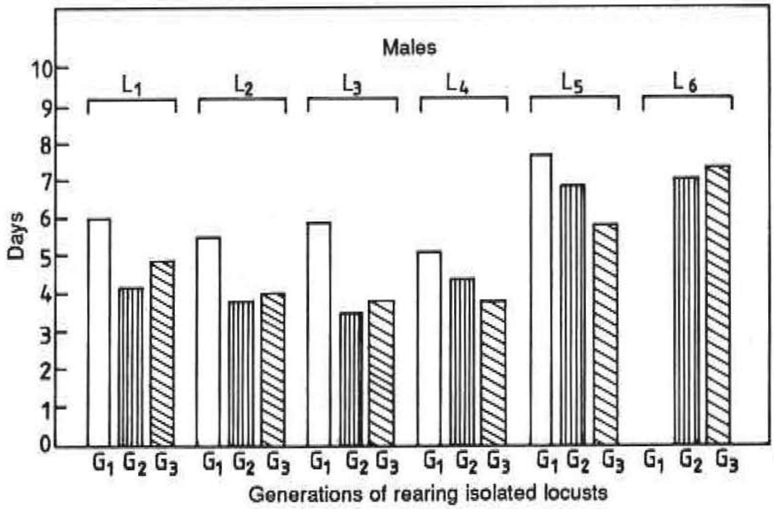


Fig. 4. Duration of the various instars of male isolated *S. gregaria* Ex. Addis in three successive generations of rearing

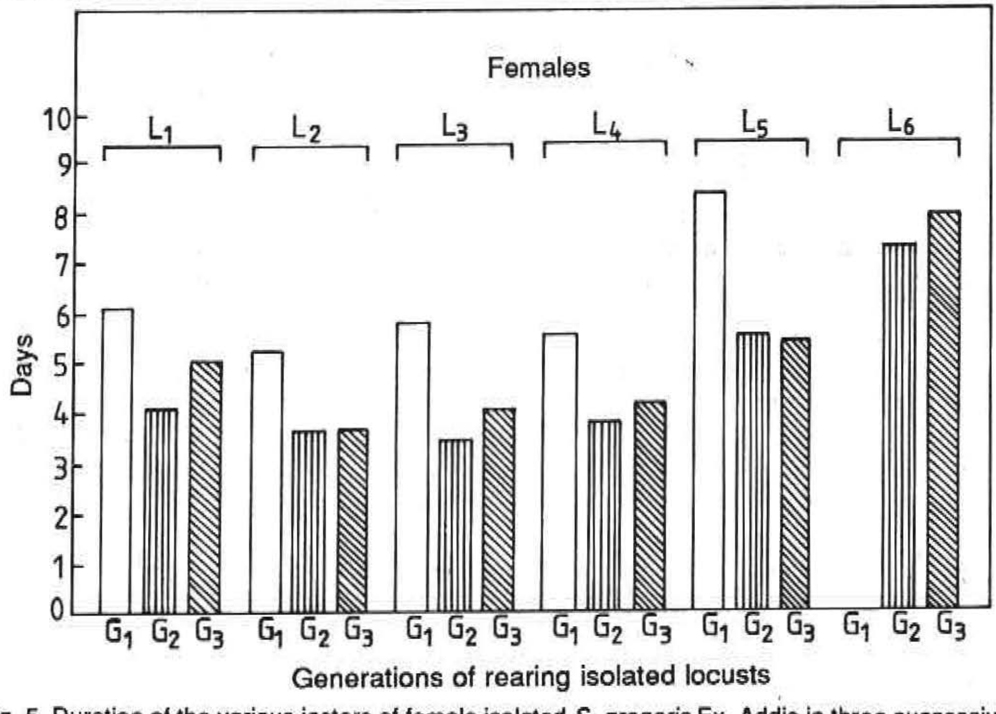


Fig. 5. Duration of the various instars of female isolated *S. gregaria* Ex. Addis in three successive generations of rearing

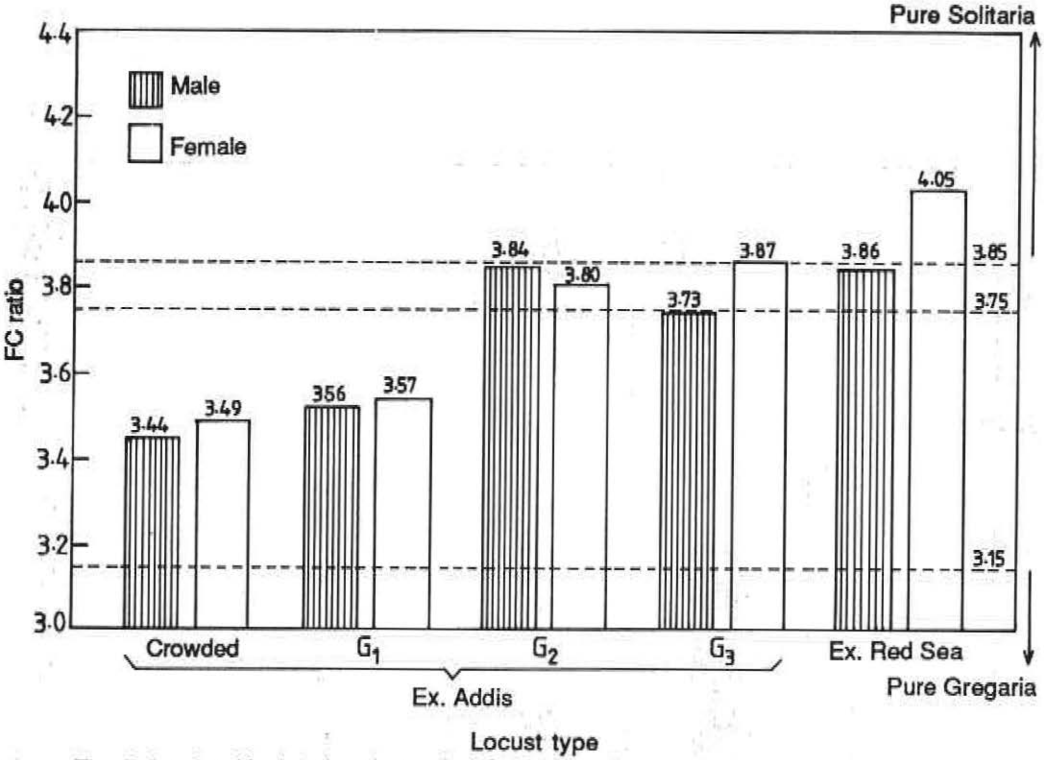


Fig. 6. The F/C ratio of isolated and crowded desert locusts

Figures 6 and 7 present the data of the morphometric studies. The F/C ratio (length of posterior femur/ maximum width of the head) increased progressively from those obtained from the crowded culture to approach the ratio of the Ex. Red Sea strain. The Ex. Red Sea strain had ratios well above those described as for true solitaria by Dirsh (1953). The E/F ratio (length of the elytron/length of posterior femur) showed no significant trends in the generations tested.

The coloration of the hoppers of the isolated locusts were mainly green while those of the crowded had black patterns on a yellow background which is in agreement with earlier reports (see review by Pener, 1983). Morphometrics have been considered as easy quantitative indicators of the phase polymorphism of the locusts (Dirsh 1951, 1953; Blackith 1972). Morphometrics are, however not absolute as they are influenced by non-density-dependent environmental factors such as temperature (Stower *et al.* 1960). Dirsh (1953) described the F/C ratio to be a more reliable indicator of phases. The F/C ratio is higher in the solitary than in the gregarious phase while the opposite is true for the E/F ratio. Locusts with F/C ratio of equal or less than 3.15 were considered as pure gregaria forms. Values above 3.75 and 3.85 for males and females, respectively, were considered as true solitaria.

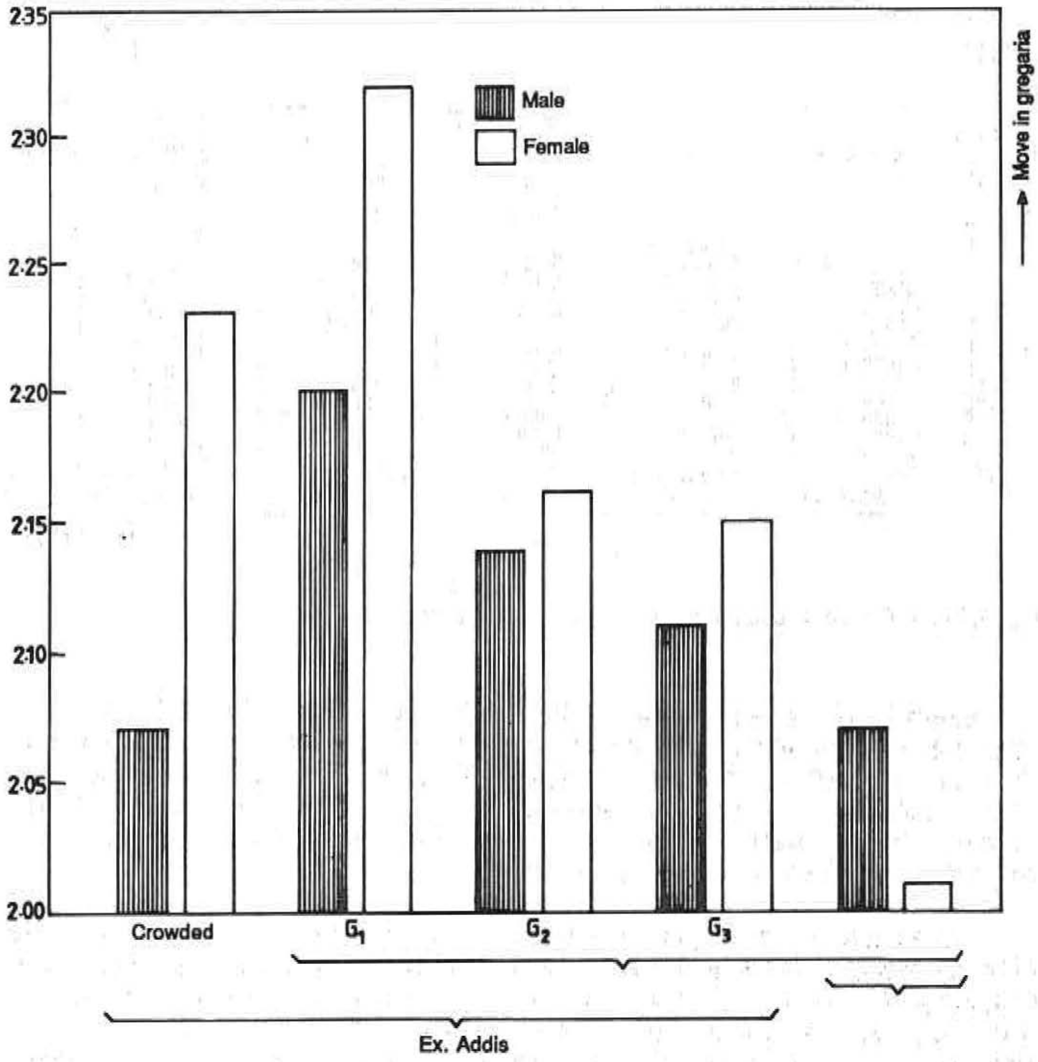


Fig.7. E/F ratio of desert locust types maintained at the ICIPE (E/F = Length of the elytron/length of posterior femur)

Our results indicate that the method of rearing described progressively shifts the F/C ratio towards those of the solitary populations. The fact that by the third generation of rearing Ex. Addis locusts were showing more instances of an extra nymphal instar and therefore an extra eye stripe is further proof of the success of the rearing method.

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SESSION II:

COUNTRY AND INSTITUTIONAL REPORTS

COUNTRY REPORT ON DESERT LOCUST CURRENT RESEARCH AND CONTROL ACTIVITIES IN EGYPT

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ABSTRACT

An intensive programme for locust control was built upon renewable indigenous resources in Egypt to improve control methods and diminish the environmental impact of insecticides. So far, the preliminary results showed that:

Although, juvenile hormones (JHs) are considered as a main physiological factor in locust phase transformation, their analogues and precocenes (Anti-JH) are not quite potent in the field due to their instability in nature.

The anti-chitin synthesis compounds; diflubenzuron, chlorfluazuron (IKI), and teflubenzuron (CME) as well as fenoxycarb and the JH-analogue, S-31183 exhibited anti-moulting action against locust nymphs during metamorphosis, while the reproductive potential of the female adults was reduced by IKI. In the near future these results will be validated in the field.

Under field conditions, powdered formulation of neem seeds, strongly reduced locusts on sprayed plants revealing that this compound could be used to displace locust cohorts to untreated areas or to toxic traps.

Preliminary surveys of plants revealed that some of them are untouched by locust. Our initial studies showed that these plants have powerful antifeedant effects against locusts and have toxic action against armyworms, aphids, beetles and cotton stainers.

During our routine surveys in February and May, 1991 we discovered a light infestation of locust solitary nymphs and adults in Marsa Alam and El-Shadhly areas on the Red Sea coast in Egypt. We began to classify the prevailing plant flora in the infested area to study their interaction with some biophysiological aspects of locust, especially gregarisation pheromone production by locust nymphs which mainly depends upon lignin in these plants.

Egypt was invaded by heavy swarms from Sudan during the last plague of desert locust (1986–1989). Control operations were undertaken using new heavy ULV sprayers, aircraft and dusters. The control of these swarms was quite satisfactory.

INTRODUCTION

The long-term research programme of Egypt is based on the internal and external regulators of locust physiology that control morphogenesis, development, reproduction, phase transformation and gregarisation. Juvenile hormone (JH), anti-JH, anti-moulting agents and fenoxycarb were found to disrupt all these developmental aspects.

A promising technology is the use of natural antifeedants to diminish locust herbivory on cultivated plants. We believe that the isolation and identification of antifeedants, toxicants and growth regulators from the wild plants will generate useful renewable methods for locust control.

RESULTS

Phase Differences in Relation to Juvenile Hormone (JH)

To study phase differences in the main metabolites of the haemolymph and fat body, a solitarious culture was established and maintained in the laboratory for 10 generations. Solitary females compared with gregarious ones displayed lower lipid content but higher carbohydrate and protein levels in the haemolymph and fat body of hoppers and adults.

The solitarious nymphs of the 4th and 5th stadia grew at a slower rate than gregarious ones, nonetheless attaining a lower mean body weight when their respiratory rates become low (Taha 1979). It is concluded that, the solitarious nymphs, in contrast to gregarious ones may expend more energy on growth during early stages compared to late developmental stages.

Administration of JH-C_{16}–C_{17} and C_{18} suppresses lipids but enhances protein and carbohydrate thus influencing energy production necessary for normal metamorphosis. The effect with C_{16} was more pronounced (El-Gammal 1979; Taha 1979).

Nymphal and imaginal colour characterising solitary locusts usually develop as a result of nymphal treatment with JH and CO_2 gas (El-Gammal 1979).

EFFECT OF JH-ANALOGUES

Fenoxycarb

Fenoxycarb at 15 µg/g (5th instar nymphs) induced 95% green solitarious colour and disrupted metamorphosis, while 8 µg/g resulted in about 98% adultiform. This compound increased haemolymph protein content in the treated 5th instar, whereas total lipid and cholesterol were decreased. This pattern of metabolic behaviour confirms that fenoxycarb has a pronounced juvenile hormone activity (El-Gammal *et al.* 1989).

JH-analogue—S-31183

A dose of 200 µg/g 5th instar nymphs of *S. gregaria* prevented their metamorphosis completely when administered to 1-day old 5th instar nymphs. The lower dose of 100 µg did not prevent metamorphosis, but induced 20% mortality during last ecdysis, 50% adultoids and 30% normal adults.

These results show that day-6 of the 5th stadium may be the sensitive period for ecdysone action on epidermal cells. Accordingly, treatment of 5th instar nymphs during the first 5 days blocks metamorphosis in *S. gregaria* (Taha and El-Gammal 1990).

EFFECT OF THE ANTI-JH, PRECOCENE II

Nymphal and Adult Stages

Precocene II, when topically applied on early instars of *S. gregaria* produced various types of abnormalities ranging from permanent nymphs to precocious adults. This compound also caused 100% adult mortality when applied at a dose of 100 µg/adult during the first day of the adult life. The second dose of 200 µg induced 100% sterility in adult females (El-Gammal 1983; El-Gammal *et al.* 1991c).

Embryogenesis

Different doses of precocene II (8, 4, 3, 2, 1, 0.8 and 0.4 µg) were topically applied to the eggs during three periods of their embryonic development. Precocene II induced high percentages of unhatched eggs ranging from 100 to 60% and produced 40% veriform nymphs when applied to 8–8.5 day old embryos. This period exhibited high sensitivity than the others which might indicate that the embryonic corpus allatum was more active and the level of JH was affected (El-Gammal *et al.* 1991a).

Effect of the Anti-Moulting Agents Under Laboratory Conditions

Diflubenzuron

A low concentration of diflubenzuron (10 ppm) resulted in greenish and fawn colour in the resulting 5th instar nymphs. The same dose produced permanent 4th instar nymphs when applied on the same instar. There was a negative correlation between concentration and effect (Gadallah *et al.* 1991).

Feeding 2-day old 4th instar nymphs of *S. gregaria* for 4 days on treated diet with 500, 200, 100, 50 and 10 ppm resulted in higher percentages of mortality compared with those fed for 1, 2 and 3 days during the next moult (El-Gammal and Taha 1984).

Teflubenzuron (CME)

The anti-chitin synthesis action of teflubenzuron (CME) was tested against the last nymphal instar of *S. gregaria* by leaf dipping technique. The treated diet with 200, 100, 50, 37.5, 25, 18.7., 12.5, 9.3, 4.6 and 2.3 ppm were offered to the 4th or 5th instar nymphs for one day. The treated stadium were prolonged and the failure in ecdysis to the next instars showed positive correlation with the concentrations (El-Gammal *et al.* 1991b).

Chlorfluazuron (IKI)

The other anti-moulting agent, chlorfluazuron (IKI) was tested in several concentrations against the last nymphal instar of *S. gregaria*. After feeding for 24 hrs the failure in ecdysis to the next instar increased from 37.8 to 62.2% in females and 6.7 to 95.6% in males (Gadallah *et al.* 1991).

Anti-Moulting Agents Against the Adult Stage

Immature female adults were fed on treated diet 100, 50 and 25 ppm of both chlorfluazuron (IKI) and teflubenzuron (CME). One hundred ppm of both compounds was the most effective concentration. This concentration reduced the mean number of eggs per pod, eggs laid and eggs hatched per female compared with the control (Metwally *et al.* 1991).

Evaluation of the Anti-Moulting Agent, Diflubenzuron Under Field Conditions

Groups of newly-moulted 4th nymphs of *S. gregaria* were fed on wheat leaves sprayed (Ultra Low Volume spraying technique) in field with diflubenzuron ODC-45 dispersible oil concentrate at the rates of 18.8 and 37.8 g a.i./feed.

The 4th instar duration was prolonged by feeding on the sprayed leaves at 18.8 g a.i./feed for 1, 2, and 3 days. Continuous feeding on leaves sprayed with the two concentrations for 6 days caused 93.8 and 100% mortality, respectively, compared with less than 40% when feeding did not exceed 4 days.

To study the residual effect of this compound, feeding was started 7 days after treatment with the two concentrations 18.8 and 37.8 g a.i./feed, that produced 70.3 and 100% mortality, respectively during ecdysis to 5th instar (El-Gammal 1991).

Studies on the Natural Products

The natural resources are the alternative approach to generate stable bioactive compounds that are highly insect specific and environmentally acceptable than currently used insecticides.

The antifeedant effects of the wild plants, *Argemon mexicana, Solanum dobium, Zygophyllum simplex, Calotropis procera, Withania somifera* and *Azidrachta indica* against *S. gregaria* were studied. All plant extracts in the solvents, pet. ether, diethyl ether, hexane, chloroform, 70% ethanol and distilled water inhibited the feeding activity of the adults of *S. gregaria* with various percentages ranging between 22.2 to 100% (El-Gammal *et al.* 1988).

In further study, the antifeedant and toxic actions of dichloromethane extract and its florisil fractions (Fs) against the 1st, 2nd and 5th instar nymphs of *S. gregaria* were investigated. The antifeeding effects of the florisil fractions of *Z. simplex* and *A. mexicana* were tested against the 5th instar. *A. mexicana* fractions, 2, 3, 4, 5 and 6 caused 61.4, 56.8, 59.1, 80.7 and 36.4% feeding reduction, respectively. The same fractions of *Z. simplex* stimulated feeding of 5th instars, their stimulation percentages were, 120, 110.2, 116.9, 114.6 and 134.8 respectively.

Some fractions of the two plants exhibited toxic action against the 1st and 2nd instar nymphs of *S. gregaria*. F_2 and F_3 were the most effective (El-Gammal *et al.* in preparation; El-Gammal 1990).

Antifeeding Trials under Field Conditions

Neem or Margosa tree has attracted much attention as an effective antifeeding agent against wide variety of insects. Locusts have received most of the preliminary trials with its powder or solvent extract, but little attention was given to neem formulations such as Azadirachtin and Margosan-O under field conditions.

Recently, we received about 7 grams of neem seed extract in form of a powder formulation. The antifeeding action at 0.1, 0.2 and 0.3% of neem diluted in water and sprayed by ULV machine inhibited feeding of immature adults after 24 and 48 hrs of spraying. Thus, this formulation could be used to displace locusts cohorts to untreated areas or to toxic traps.

Ecological Surveys

During May 1991, the survey along the Red Sea coast in the Eastern desert of Egypt revealed some individuals of solitary nymphs as well as adults. Most of the wild plants prevailing in the infested areas around Marsa Allam and El-Shadhly bases were collected and their botanical names were identified (16 plants). Further studies on the interaction between them and the biological aspects of locust are now being carried out.

Control Operation During Last Plague

During the last plague (1986–1989), Egypt was invaded by heavy swarms of locusts from the Sudan during October, 1988 to March, 1989.

During the last 5 years, we evaluated several tubes of ULV sprayers (18 double purpose sprayers, 40 ULV and 265 Knapsack sprayers and dusters) to select the most convenient for locust and grasshopper control. The double purpose and the ULV machines were mounted on vehicles.

Moreover, the locust control bases were provided with new and effective insecticides that proved promising against locust swarms.

Future Plans

1. The interaction among natural wild plants in the infested areas and some biological aspects of locust.

2. The studies on sites of gregarisation pheromone synthesis in locust with special reference to its limiting factors.

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LOCUST INVASIONS TO LIBYA FROM 1900 TO 1990 WITH SPECIAL REFERENCE TO THE 1988 INVASION

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ABSTRACT

From 1900 to 1990 Libya has been exposed to about 11 invasions of desert locust **Schistocerca gregaria*****, the last of which is the 1988 invasion. The recession between 1960 and 1988 was the longest to be seen in this century even though many control operations have been carried out against isolated groups in many parts of Libya.***

In 1988 swarms of desert locusts invaded Libya in two periods. The first started in March by swarms coming from Tunisia and Algeria. The control operation of these swarms continued up to August 1988. More than 100 thousand hectares of land infested by fledglings, mature adults and hopper bands were treated. Great quantities of poisoned baits, ULV and EC pesticides were used by air and the ground.

The second invasion was in November 1988 by swarms coming from Niger. The control operation lasted about one month in which about 35,000 hectares of fledglings were controlled. 135,000 kg of poisoned bait and 13 thousand litres of insecticides were used. In 1991 Libya has been considered to be free from desert locust.

BACKGROUND

Agriculture

Libya is a country of 1.75 million km^2 with a relatively small amount of rainfall which varies from (280–660 mm) per year in the extreme north to (0–200 mm) in the other parts of the country.

The total agricultural land in Libya is about 3,700,000 ha. 76% of them are located in western section, 21% in the eastern section and 1% in the southern section. This 1% includes the 40,000 ha of land set aside in the south recently for irrigated agricultural projects. The land under permanent crops is about 200,000 ha which represents about 6% of the total agricultural land. Orchards and vineyards are grown in compact plantations in the north. The number of scattered palm trees especially in the south is great.

The Climate

Temperature

Libya is located between (20°00′ and 33°00′N) (11°00′ and 26°00′E) and apart from the Mediterranean climate in the northern part of the country, the temperature in the South varies from 10–50°C depending on the season and time of day.

Rainfall

Rainfall in Libya occurs only from October to March. It ranges from 100–200 mm per annum in the coastal belts while in the mountain, the range varies from 200 to 700 mm per annum. The rainfall in the southern parts is limited and differs from one year to another giving an average of 70–75 mm per annum causing the existence of a considerable amount of water in the Wadis. This creates a very suitable environment for desert locust production.

DESERT LOCUST INVASIONS TO LIBYA

The invasion of desert locust *Schistocerca gregaria* to Libya is known to occur since the pre-Christian era. In this century there are observations of major invasions and control operations in the following years: 1906, 1926, 1927, 1928, 1930, 1932, 1944, 1945, 1954, 1955, 1957, 1958, 1959, 1960 and 1988. The infested areas are estimated to be in some years as follows: 400,000 ha in 1954, 150,000 ha in 1957, 200,000 ha in 1958 and 143,000 ha in 1988.

The previous records indicate that the north west parts of Libya are the most likely to be invaded. This is probably because it is the nearest part to Algeria and Tunisia from where most of the swarms come in February and March and probably because it is the most populated and cultivated area in Libya at that time (Fig. 1). The control operation takes place only in that area.

By referring to the above records we can see that the recession between 1960 and 1988 was the longest one. This, in fact gave an impression that locust invasion is no more a threat. But despite this long recession, the Desert Locust Department in Libya has managed several times in controlling various groups of scattered locust. The areas controlled vary from few to thousand hectares situated mainly in the south where warm climate, humidity and isolated areas are available.

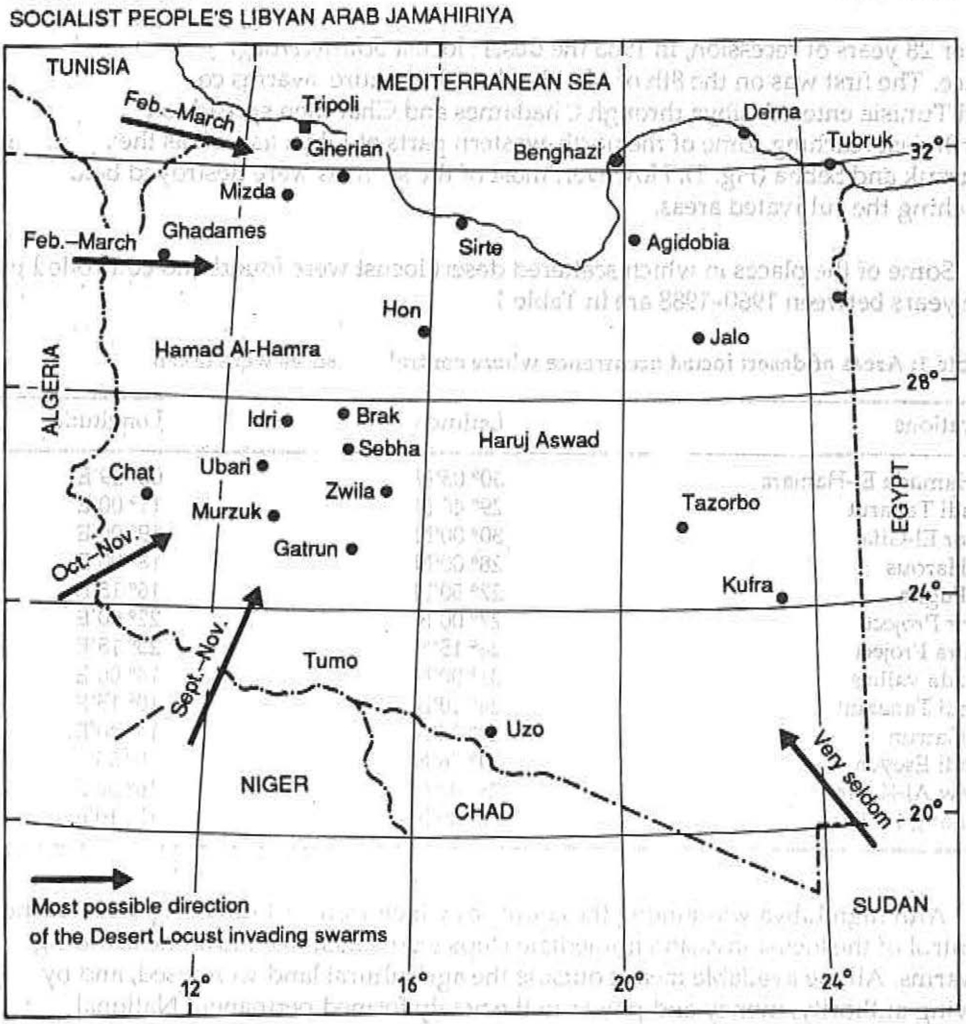

Fig. 1. Origins and direction (arrows) of desert locust invasion into Libya

In the past apart from some scattered oases planted with few palm trees, cereals and vegetables for local use, the southern section is a desert. Now the situation is different due to huge agricultural projects which have been established in that area. This is in addition to the creation of tens of agricultural settlements by land reclamation of more than 0.5 million hectares of land 20% of which are cultivated by permanent irrigation. Furthermore, thousands of farms have been created by farmers in the recent years. All these considerable changes in the Libyan Sahara have created new suitable environment for the desert locust development.

1988 Invasion

After 28 years of recession, in 1988 the desert locust *Schistocerca gregaria* invaded Libya twice. The first was on the 8th of March where immature swarms coming from Algeria and Tunisia entered Libya through Ghadames and Ghat then spread to the north and north-east reaching some of the north-western parts of Libya as well as the region of Murzuk and Sebha (Fig. 1). However, most of the swarms were destroyed before reaching the cultivated areas.

Some of the places in which scattered desert locust were found and controlled in the years between 1960–1988 are in Table 1.

Table 1: Areas of desert locust occurrence where control measures were taken

Locations	Latitude	Longitude
ElHamada El-Hamara	30° 05′N	06° 29′E
Wadi Tanarut	29° 40′N	11° 00′E
Chor El-Gifa	30° 00′N	19° 00′E
El-Harous	28° 00′N	18° 00′E
El-Fugha	27° 50′N	16° 15′E
Sarir Project	27° 00′N	22° 00′E
Kufra Project	24° 15′N	23° 15′E
Mizda vallies	31° 00′N	14° 00′E
Wadi Tanazuit	24° 10′N	10° 15′E
El-Gatrun	24° 58′N	14° 40′E
Wadi Eseyen	24° 26′N	9° 55′E
Waw Al-Kabir	24° 00′N	16° 30′E
Barjoug Project	26° 30′N	13° 10′E

Although Libya was among the countries which were not fully prepared for the control of the locust invasion immediate steps were taken to control the invading swarms. All the available means outside the agricultural land were used, and by giving authority, money and power to the newly formed permanent National Committee for Desert Locust Control, it started immediately to buy pesticides, equipment and training of personnel. Libya was also divided into 12 provinces to deal with the situation and each one was provided all the necessary means, such as vehicles, pesticides, spraying equipment and personnel.

The control measures continued from March to the second week of May, then they were limited only to the remaining pockets specially in the southern provinces, and against some of the hopper bands in some areas of the north-west and the south-west.

Egg laying took place only in the provinces which seem to have received the first swarms, namely Nikat El-Kams, Jabel El-Garbi, Wadi-Elhayat and Murzuk.

Damage

Due to the immediate and effective control measures which had been taken outside the agricultural land, no serious damage was reported due to this invasion except that on few leaves of palm trees in the south.

The second invasion to Libya in 1988 was on the 28th of November. The swarms came from the Niger through the border town of Tummo and possibly through Algeria and Ghat. The areas where locusts were controlled in the first campaign in different provinces (hectares) are in Table 2.

Table 2: Areas (ha) of locust (adults and hoppers) control in eight Provinces

Province	Area controlled		Total
	Adults	Hoppers	
Nikat El-Kams	18,359	3,567	21,926
Gebel El-Garbi	4,502	1,664	6,166
Sebha	6,623	-	6,623
Zawia	185	-	185
Tripoli	240	-	240
Kufra	2,450	-	2,450
Wadi El Hayat	25,360	3,660	29,020
Murzuk	39,016	2,634	41,650
Total	96,735	11,525	108,260

Some of these immature swarms spread to the north-east of the country reaching Ubari, Murzuk, Sebha and El-Haruj. Other swarms went to the east reaching El-Kufra, Saris, Tubrok and possibly the shores of Syria and Turkey through the Mediterranean Sea.

The control measures against these swarms continued until the end of December 1988. The area sprayed at this time was about 34,627 ha. During this invasion, the locusts did not lay eggs, possibly because of the low temperatures at the time. Some cohorts of locusts seem to have succeeded in remaining in the remote and difficult terrain of El-Haruj mountain and laid eggs. More than 3000 ha of hoppers were controlled in April and May 1989 in that area.

The equipment used in these campaigns are exhaust nozzle sprays, motorised sprayers and dusters and aircrafts equipped with Micronair 5000.

From June 1989 up to date Libya has remained free of desert locusts. Survey teams are keeping all the Libyan territories under close watch.

Areas (ha) where locusts were controlled in the second campaign in different provinces are in (Table 3).

Table 3: Area (Ha) of locust control during second campaign in seven Provinces

Province	Area controlled		Total
	Adults	Hoppers	
Kalig Sirt	4,885	-	4,885
Sebha	9,215	-	9,215
Wadi El Hayat	13,241	-	13,241
Murzuk	4,591	-	4,591
El-Kufra	450	-	450
Jebel El-Akdar	70	-	70
Butnan	2,175	-	2,175
Total	34,627		34,627

CONCLUSION

- Libya is considered to be one of the most desert locust-affected countries since the pre-Christian era and continues to be so.
- The area of the north west of Libya used to be the most affected by locust. The situation seems to be different now after huge agricultural projects were implemented in the south.
- The possible origins of the invading swarms remain to be the classical ones—Tunisia, Algeria, Niger, Chad and very seldom the Sudan.
- During the recession periods the Libyan Sahara can be a place of group gathering causing a threat to Libya and the neighbouring countries, therefore a continuous survey in the right time in these places is of great importance.
- Controlling locusts outside the agricultural areas proved to be effective and possibly more economical.
- The continuation of the locust invasions into the area since the pre-Christian era emphasises the great need of research on effective control strategies for this harmful insect.

PERSPECTIVE OF THE DESERT LOCUST PROBLEM IN SUDAN

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BACKGROUND

There are a number of acridoid species causing serious damage to crops in Sudan. Of these the desert locust (d.l.) *Schistocerca gregaria* (Forsk.) poses the greatest threat to the entire cultivated and wild flora of the Sudan. Catching sight of its huge swarms at the beginning of the breeding season is in itself a psychological deterrent discouraging the farmer not to further invest in agriculture, and start sending distress calls to the international community.

Special reference will be made to the summer campaign of 1988 and where relevant glimpses to the winter campaign of 1988/89, and the ensuing reaction of the Sudan Plant Protection Directorate (PPD).

THE DESERT LOCUST SITUATION IN 1988

In 1988, the Sudan witnessed the most serious plague ever since 1958. Over an area of 5 million ha was very likely the summer breeding terrain. However, the official report indicated only 3.7 M hectares. Although the warning.forecast was communicated in time, the PPD or the Locust Control Unit was caught distressingly unprepared. To avert the danger, a change of management strategy was seen as the main remedy for success. This was augmented by the quick response of the FAO and the International Community airlifting pesticides, spray equipment and other essential items, while Sudan Government beefed up the LCU with many basic requirements.

CONTROL STRATEGY

Faced with the enormous invasion, crop protection strategy rather than population reduction was adopted. Defence-lines along the White Nile, Blue Nile, The River Nile, el Fashir (13° 38'N/25° 21'E), el-Obeid (13° 15'N/30° 15'E), and a stretch of Wadi el-Milk in Kordufan had been very effective. Swarms trying to cross the White Nile (106) or succeeded to cross (104) and were within the triangle formed by the two rivers and their confluence at Khartoum 15° 36'N/32° 31'E were contained. The triangle was, indeed, the graveyard so that only a small portion of a swarm managed to fly eastwards and cross the Atbara River (Oct. 88). On the other hand, many swarms originating from the Sahara on either flank of the river Nile succeeded in flying east and NE to the Red Sea area and the Arabian Peninsula. Swarms bred in western portion of Darfur and the Sahara were claimed to have taken off to West and N. West Africa (for magnitude of plague; Appendix I–IV). The desert locust infestation and amount of pesticides used are in Table 1.

Table 1. The desert locust infestation and amount of chemicals used in the summer (S) and winter (W) campaigns in 1986–1989

Season	Infested area (ha)		Controlled area (ha)		Pesticides used (litres/kg)
	S	W	S	W	
1986/87	n.a.*	n.a	n.a	109,055	27,930/146,390
1987/88	n.a.	n.a	n.a	32,018	7,400/46,520
1988/89	3,700,000	300,000	900,000	110,000	583,823/508,592
1989/90	24,000	460	11,640	460	5,230/5,280
1990/91	The situation is calm during this season				

* : n.a. — not applicable

Remarks

- Concerted action is a basic necessity of any successful locust control campaign.
- Crop Protection strategy can be adopted rather than population reduction in case of a plague engulfing very huge area. This minimises dilution of limited resources in trying to protect the vast expanse of the Sahara and the uncultivated land.
- To elucidate and verify the migration patterns might be a lifelong discourse and perhaps an infinitive one.

IMPORTANCE OF THE DESERT LOCUST IN SUDAN

The Sudan by its geographical location lat. 4°N–22°N/long. 22°E–37°E is a fulcrum between the two almost identical ecological zones: the Near East/Horn of Africa and the West/NW Africa. Its recession area lies within 10°N–22°N whereas the invasion area covers the whole country and extends further to trespass East Africa.

In the summer of 1988 much of the migrating swarms were apparently originating from west and NW Africa more than coming from the conventional East flank. Likewise, much of the migrating swarms flew to the East/NE more than to the West/NW.

The Sudan is considered by many authorities as the main watershed and has the highest frequency in Africa and probably at the international scale. The desert locust summer-breeds in the vast plains of Sudan, concentrates and winter-breeds in the Red Sea Hill area almost incessantly throughout the year encompassing a vulnerable area larger than all the Eastern Africa countries combined.

Remark

Sudan is considered as a watershed for the desert locust. There are very large vulnerable areas with the highest frequency of solitary and gregarious locusts.

REPORTING SYSTEM

The recorded infested area for the summer of 1988 was 3.7 million ha, which we believe is far behind the truth, because of:

- from surprise visits to western Sudan, only one third of the reports at any time were channelled to the Headquarters.
- Still, most of the accessible areas were not detected because of management disarray and shortage of logistics at least up to the fledgling stage.
- Logistics cannot be diluted in the immense Sahara which needs especially equipped safari-convoys let alone the impossibility to cover to some extent the vulnerable areas, at a time the ITCZ reached the Aswan High Dam. No doubt, the Sahara had been invaded by large swarms of locusts, as caravans of camel riders and convoys of trucks coming from Libya to western Sudan, unanimously reported the locust activity at any noticeable greenery.

Remarks

- The infested area for the summer of 1988 was very likely above 5M ha.
- There is a need for improving the reporting system by appropriate management and logistics.
- Management is a science and art.

FORECASTING AND MODELLING

Reports sent by the FAO, and the greenness maps (every 15 days) by USAID, proved to be very instrumental. The vegetation index could direct the scout teams where to survey in spite of its late arrival. But it might not reflect the truth as it should be. It happens: I was in northern Kordufan in the second half of September 1988 transecting 552 km— along which was lush greenery with very high density of late-instars and fledglings. The flora was yellowish in the map while it was green on the ground, with high density of locusts.

Furthermore, to predict rainfall, might be a chance event. Cloudiness might signal a potential which might precipitate or dissipate sooner or later. I believe chronological events of rainfalls with the ongoing cloudiness, and sequential activity of the locust at the international arena will lend a strong clue of the locust potential outbreak.

Remarks

- Regional and international coordination and cooperation should be maintained.
- Can remote sensing be improved?
- Rainfall prediction, it seems, for durations less than a week is almost impossible.

DAMAGE ASSESSMENT

The controlled area was only 24% out of the recorded area of 3.7 M ha. But common sense dictates that the infestation was, more likely, above 5 M ha, and therefore the percentage of the control area will accordingly decrease in a comparative order. In other words, it is reasonable to assume about 90% had escaped the control operations, yet the damage was less than 1% for all field and horticultural crops (15 M ha) including cereals (11 M ha.). Damage to cereals was roughly estimated not more than 3%, while no guess was attempted to rangeland (100 M ha) or forests (35 M ha). It might be appropriate here to mention that desert locust plague may aggravate the problem of desertification, let alone the potential and psychological upheavals.

The damage being so low, might be attributable to:

- adopting the crop protection strategy.
- emigrating swarms (pink) were fat and sluggish.
- perhaps they were so nourished by the wild flora among which many annuals took a long time to grow and synchronously ripen with cereals.
- natural mortality factors may have been operating unnoticed.

Remarks

- damage assessment is just vague and subjective.
- reduction of damage to crops and wild flora should not consider the immediate gains spacially and temporarily at one locality, but should also consider the future gains for the whole country or a number of countries in time and space.
- is the wild flora more preferred than cereals, and what is the implication to desertification?
- perhaps 90% of the population had escaped the control operations, yet damage to crops was so low:
  - — locusts were too nourished?
  - — Natural mortality factors contributed for greater control than lethal control?
  - — crop protection strategy very effective?

PPD SET-UP

The PPD is probably the biggest organisation in Africa and the Near East. It is entrusted to reduce crop damage caused by various migrant pests or pests which are not the concern of one individual farmer. In general terms, its capabilities for 1988 were:

Personnel

Postgraduate	83
B.Sc.	161
Diploma	93
Field Officer (rankers)	655
Various jobs	400
Casual labour	5,000–10,000

Budget

Chapter I (personnel)	12,404,855
Chapter II (personnel)	5,463,660
Development	3,283,000

Almost 70% of all the budget was directed to the LCU in 1988, and indeed about 50% allotted to every fiscal year.

In 1988 an additional (emergency) budget was endorsed to the locust campaign:

operational	Ls 17 million*
pesticides	U$ 3 million
flying Hrs (33 planes)	U$ 3.5 million
55 vehicles	U$ 0.6 million
Commandeered vehicles	>100 vehicles

donors contributed:

In kind	U$ 13 million
In cash	Ls 21 million
flying Hrs (for the No. above)	U$ 1.5 million

* Ls = Sudanese pounds

Endeavours are fruitful to restructure an autonomous LCU under the umbrella of the PPD. Clear terms of reference are spelled out to ensure prompt reporting/action. The remaining units of the PPD can be mobilised during plagues. This kind of autonomy is now pipelined to other units of the PPD with due caution and consideration not to lose concerted action. Crop protection, I believe is not only an integrated and interactive discipline, but also is administratively so.

Remarks

- Improve management by:
  - motivation of the staff — the foremost priority
  - Utilisation of existing resources.
  - Mobilisation and discipline.
  - Prompt report/action.
  - Training.
- Foreign currency to purchase and finance:
  - pesticides
  - flying hrs
  - maintenance of vehicles and equipment.
- Sudan is the only country in Eastern Africa having a qualified and appropriate LCU to wage effective campaigns.
- Cooperation of the international community.
- Regional organisations as they exist now, and if they had mobilised all their strike power and staff could not have coped with even one province in Sudan in 1988.

- Regional organisations should only be a strike force for a short time till the weak National LCUs are well beefed up. They should have the future perception on how to coordinate effectively the efforts of the National LCUs, without having a strike power.

Future coordination centres only on:

- operational research
- feed-in and back the National efforts, including forecast and information exchange.
- training.

RESEARCH

To my knowledge, there has been no research activity in Sudan since the departure of the colonialists, except for few graduate trainees abroad. Currently an ICIPE/PPD joint programme has just taken off with the following activities:

- Establishment of a research station in Suakin on the Red Sea Coast.
- Ph.D. fellowship on the natural enemies of the desert locust.

It is felt that, though the desert locust research was once a pioneer and much of its science is still applied for many plant protection disciplines, it has lagged behind during the last three decades at a time methodology, data collection and interpretation has been tremendously improved for other plant protection disciplines.

Study of the physiology, behaviour and ecology of the desert locust, opens up an infinitive field which can take us as long as ever man lives upon earth. Let us draw clearly what we want. What questions to be answered at the immediate (1–3 years), mid (3–6 years) and long-term (6–15 years).

We believe, many questions of physiology — key subject to understand ecology, behaviour ... etc. can be smartly tackled—and perhaps more feasibly applied to reach our target abnormal physiology (toxicology). Obviously, during the research period, we have to use the existing toxic chemicals and perhaps very soon we will start to use the growth regulators and protozoa. Nevertheless, the application techniques for locusticides, are still clumsy and crude. This is an area where we can make tremendous improvement in no time. We believe, for example, we can reduce the present rate of fenitrothion 100% ULV of 0.3: 1 to 0.15: 1 . . . etc.

No doubt, the new trends of research open up a vast field. We are confident that during the foreseeable future, lethal or toxic chemicals will be kept in the archives and thereby avoid the curse of our generations.

Man calls this age, the space age. When we view our plants from the spaceship it is just like the tropical grapefruit. Let us preserve it, and we better call this age as the age of ecology, and ecology is manifested by physiology.

CONTROL OPERATIONS — SUMMER CAMPAIGN (ALL STAGES)

LOCATION	AREA OF APPLICATION (HA)			SUB-TOTAL
	Aerial	Ground	Mechanical	
DARFUR				
N. Darfur	70,300	18,065	76,910	165,275
S. Darfur	11,743	7,635	0	19,378
KORDUFAN				
N. Kordufan	129,898	66,722	0	196,620
S. Kordufan	3,700	400	0	4,100
WHITE NILE	57,132	9,817	0	66,949
KHARTOUM	55,376	14,554	0	69,930
GEZIRA	120,560	6,080	0	126,640
NORTHERN	98,132	45,233	0	143,365
KASSALA	46,071	2,500	0	48,571
RED SEA	37,660	16,600	0	54,260
GRAND TOTAL	630,572	187,606	76,910	895,088

APPENDIX II

IMMATURE SWARMS
SUMMER CAMPAIGN 1988

LOCATION	AREA INFESTED (HA)					GRAND TOTAL (HA)	AREA TREATED (HA)
	Immature Swarms						
	Sep.	Oct.	Nov.	Dec.	Jan.		
DARFUR							
(1) N. Darfur	65,710	9,650	29,400	2,000	0	106,760	29,787
(2) S. Darfur	0	3,300	800	0	0	4,100	800
KORDUFAN							
(1) N. Kor.	46,820	25,231	31,288	0	0	103,339	50,952
(2) S. Kor.	0	12,000	2,800	3,750	0	18,550	2,550
W. NILE	9,300	300	32,135	17,500	0	59,235	22,712
KHARTOUM	10,057	56,292	3,950	6,676	0	76,975	27,181
GEZIRA	1,800	37,177	63,131	45,090	0	147,198	96,080
NORTHERN	16,650	1,000	51,066	12,000	0	80,716	18,491
KASSALA	2,000	18,380	46,160	0	0	68,540	24,271
RED SEA	0	2,000	31,830	33,190	1,840	67,020	35,780
TOTAL						730,433	308,604

APPENDIX III

MATURE SWARMS
SUMMER CAMPAIGN 1988

LOCATION	AREA INFESTED (HA) Group adults and mature swarms							GRAND TOTAL (HA)	AREA TREATED (HA)
	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.		
Darfur									
(1) N. Darfur	127,560	2,120	18,213	17,865	6,200	0	0	171,958	25,048
(2) S. Darfur	0	0	2,400	887	0	0	0	3,287	3,287
KORDUFAN									
(1) N. Kordufan	168,500	2,040	8,792	15,100	0	0	0	194,432	34,499
(2) S. Kordufan	0	0	0	1,550	0	0	0	1,550	1,550
WHITE NILE	2,000	2,050	7,100	171,500	4,800	465	0	187,915	20,420
KHARTOUM	29,000	0	11,000	39,220	5,144	1,405	0	85,769	8,195
GEZIRA	0	0	0	63,600	4,695	12,490	0	80,785	30,560
NORTHERN	5,450	200	10,055	110,177	53,155	22,422	7,888	209,347	54,539
KASSALA	31,580	12,400	0	122,000	0	2,000	0	167,980	2,500
RED SEA	0	0	12,100	57,700	0	2,850	0	72,650	1,800
TOTAL								1,175,673	182,398

APPENDIX IV

HOPPER BANDS
SUMMER CAMPAIGN 1988

LOCATION	AREA INFESTED (HA) HOPPER BANDS						GRAND TOTAL (HA)	AREA TREATED (HA)
	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.		
DARFUR								
(1) N. Darfur	108,020	81,380	328,206	49,957	1,000	0	568,563	110,440
(2) S. Darfur	200	35,400	6,779	5,600	0	0	47,979	15,291
KORDUFAN								
(1) N. Kordufan	63,480	104,900	30,455	154,000	0	0	352,835	111,169
(2) S. Kordufan	0	0	0	0	0	0	0	0
WEST NILE	7,600	8,000	75,900	0	0	0	91,500	23,817
KHARTOUM	1,700	6,720	35,658	6,449	0	0	50,527	34,554
GEZIRA	0	0	0	0	0	0	0	0
NORTHERN	200	25,316	177,928	17,075	52,827	5,174	278,520	70,187
KASSALA	-	69,240	151,800	152,050	0	0	342,040	21,800
RED SEA	0	200	32,500	18,170	6,660	0	57,530	16,680
TOTAL	181,200	331,156	839,226	403,301	60,487	5,174	1,789,494	403,938

APPENDIX V

WINTER CAMPAIGN TOTALS (HA)

	BANDS/FLEDGLINGS		IMMATURE SWARMS		MATURE SWARMS		TOTALS	
	infested	control	infested	control	infested	control	infested	control
Campaign from 15/9/88	15,973	10,933	130,788	33,704	140,163	65,823	286,924	110,460

DLCO-EA RESEARCH PROGRAMME FOR LOCUST CONTROL

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DLCO-EA Department of Operational Research for Locust Control has two Units for that purpose, namely:

1. Insecticide Research Unit — at the Headquarter of the Organisation, in Addis Ababa.

   The Unit is manned by a Senior Research Officer and assisted by a Senior Laboratory Technician and a Laboratory Assistant.

2. Spray Technology Unit— at Nairobi Regional Office

The Unit works in collaboration with a DLCO-EA/UNDP/FAO Project for strengthening DLCO-EA in the control of migrant pests and also with a team of ODA (NRI) scientists.

INSECTICIDE RESEARCH UNIT

1.1 Determination of the Quality of Insecticides Stored at Various DLCO-EA Stores and Those Being Evaluated for Efficacy.

1.1.1 *Introduction*

Chemical and physical properties of insecticides are known to affect biological activity and efficacy. This exercise is intended to monitor the quality of insecticides stored in various DLCO-EA stores and those under efficacy testing.

1.1.2 *Objectives*

(a) To sample the insecticides stored in DLCO-EA stores within the Region at regular intervals, analyse them for chemical and physical properties and determine their suitability in migrant pest control activities.

(b) To sample and analyse the newer promising insecticides in order to determine the consistency of their quality and shelf life.

1.2 Alternative Insecticides for Locust Control

This is a continuous research activity to identify the most effective and safer insecticides as alternative to the organochlorines and the current standard fenitrothion used in the control of the desert locust.

1.2.1 *Laboratory toxicity tests*

New insecticides are tested in the laboratory on nymphs and adults of the desert locust in order to establish their relative toxicity. These toxicity evaluations are made by topical and stomach application techniques. Promising candidate insecticides are further investigated to examine their side effects against non-target organisms before any small and large scale evaluation is carried out in the field. Bendiocarb, carbosulfan, fluvalinate, propoxur, phoxim were found to be promising insecticides for further tests.

1.2.2 *Large scale field trials*

Field trials have been carried out to evaluate the effectiveness of the promising insecticides against natural populations of the desert locust and also to establish the application rate. The only limitation of this research activity is the absence of desert locust populations in the region in sufficient numbers for the trials.

1.3 Use of Methods Other than Insecticides for Locust Control

1.3.1 *Insect growth regulators (IGR) Nomolt (teflubenzuron), Dimilin (diflubenzuron)*

These compounds are of semi-insecticidal activity. Their mode of action is aimed at the inhibition of chitin deposition in target insects. They act primarily as stomach poison by interfering with chitin synthesis and the moulting process. Some insect growth regulators have also an ovicidal effect on fecundity.

Experiments are carried out in the laboratory on 3rd, 4th and 5th instar nymphs at two days after moulting. IGRs are mixed with wheat bran or sprayed onto wheat seedlings and then fed to nymphs.

1.3.2 (a) *Biological control of the desert locust by entomopathogens*

(b) *Laboratory and field evaluation of male aggregation pheromones*

These are joint projects between Institute for Biological Pest Control, Darmstadt, Germany for (a) The University of Hannover, Germany and (b) DLCO-EA. The duration of each Project is three years and is funded by EEC.

Aims of Project (a):

1. Surveys of the breeding areas of the Red Sea coast to establish the occurrence of the entomopathogens.

2. Collect naturally dead locusts and soil samples for isolation and identification of the pathogenic organisms.

3. Promising candidates will be screened and evaluated for their effectiveness under controlled conditions in the laboratory against nymphs and adults of the desert locust.

4. Suitable formulations will be investigated and tested.

5. Safety tests for possible hazards to non-target organisms will be carried out.

6. A mass production technique for the most promising candidate will be developed.

7. Field evaluation with natural populations of the desert locust will be carried out in selected areas.

Aims of Project (b):

1. Develop assay techniques for behaviour-modifying chemicals for screening male sex pheromone and aggregation pheromones against the desert locust in the laboratory.

2. Design a delivery system capable of releasing the pheromones at the desired concentrations to lure the desert locust to trap.

3. Assess the appropriate concentration levels of the pheromone for specific applications.

4. Investigate the biological activity of the pheromones, mode of action and evaluate the behavioural responses elicited by them.

5. Carry out field tests to evaluate the potential use of the pheromones for control and to optimise their delivery to the target to promote efficiency.

1.3.3. *Screening of potential natural/toxic compounds from plants for desert locust control*

The Project is a joint research undertaking between the Department of Chemistry, Addis Ababa University and DLCO-EA. The University will be involved in the extraction and chemistry of the active ingredient(s) while DLCO-EA will be involved in the laboratory screening for activity of extracts against nymphs and adults of the desert locust.

Initially extracts from the plants *Tephrosia vaglii* and *Millettia ferroginea* will be obtained at the University and samples of the crude extracts given to DLCO-EA. Desert locust adults and nymphs will then be exposed to varying quantities and dilutions of the extract. Rate of application and mortality will be assessed. An important objective will also be to isolate and identify the most effective active compound. Methods and techniques for application will be developed.

1.4 Investigation on the Fate of Pesticides and their Impact on the Environment

The objectives are:

(a) To investigate the fate of the earlier used HCH and dieldrin by obtaining samples of water, soil, vegetation and other biological materials from the areas previously treated with these products. These are analysed for residues and levels of persistence after application determined.

(b) To investigate persistence and direct effects on the environment after the application of fenitrothion and fenthion by obtaining samples and analysing them for residues, critical observations on the behavioural changes and mortality on targets and non-target animal populations.

(c) To evaluate the health hazards associated with the consumption of chemically killed *Quelea* birds. This would be achieved by analysing fenthion, and their metabolites in raw and traditionally cooked birds. Similar work can also be extended to locusts.

SPRAY TECHNOLOGY UNIT (STU)

2.1 Development of Pesticide Application Equipment

The three-year development work to replace the exhaust nozzle sprayer has been accomplished having developed the STU1 Sprayer. It is expected that a reputable firm will be identified to manufacture or order sufficient number of the STU1 sprayers for field evaluation. The role of the STU will be to monitor the quality and performance specifications of the finished products and make necessary improvements there-on.

2.2 **Development of Aerial Spray System**

There is an urgent need to precisely control pesticide application parameters to enhance coping up with increasing public concern for more effective management of the environment. The immediate areas requiring improvement include:

2.2.1 *Finer adjustment in pesticide flow rate in flight and improvement on accurate means of monitoring it.*

2.2.2 *Improvement on flow regulation systems in collaboration with manufacturers.* Presently, there is difficulty in maintaining equal output from both pods due to differences in VRU/pump performances.

2.2.3 *Introduction of computerised pesticide application systems.* To date, it is difficult to ascertain the accuracy and hence efficiency of a pest control operation in the absence of means to evaluate this. It is now possible to fit a computer onboard which is able to record most pertinent data in a given operation, namely: volume of pesticide used, dosage applied, area covered, accuracy of ground tracks etc.

THE SPECIFIC BIOMODEL OF THE DESERT LOCUST: PRINCIPLES AND APPLICATION

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All techniques for destroying locusts are fully efficient only when the control strategy is adequate, the targets are spatially and temporally pinpointed and the population size known. For various reasons, desert locust surveys have thus been very insufficient in all circumstances (regions being naturally remote or prohibited for security reasons, financial difficulties of the locust survey organisations, reduced motivation and vigilance after many years of recession in locust activity. . .).

Considering the problems and the need to improve preventive control, PRIFAS took on a desert locust biomodelling project some years ago. This project has been funded by the French Ministry of Cooperation and Development, the Commission of the European Communities and the Centre de Coopération Internationale en Recherche Agronomique pour le Devéloppement.

The use of biomodelling techniques to productively approach locust control strategy problems has recently been demonstrated (Launois and Lecoq 1990; Lecoq, 1988, 1990). Locust problems can now be fully dealt with on a real scale, over the entire distribution range of crop pest locusts. Operational locust survey biomodelling tools have been developed and are presently being used by crop protection services in six countries in the Sahel and by one regional organisation, CILSS/AGRHYMET.

For the desert locust, one main aim of the biomodelling project is to monitor locust population developments over the entire range of the species in real time and to forecast all potentially threatening situations and effectively guide locust survey and control teams in the field. Thus, improving on the efficiency of operations to control the most dangerous locust breeding centres.

The biomodel for the desert locust, *Schistocerca gregaria* (Forskal,1775) (called the SGR biomodel) is fundamentally synoptic and quantitative. It provides information for 10-day intervals on the level and developmental phase of desert locust populations over its entire habitat range on a square degree basis (Launois 1991).

This biomodel is based on the notion of ecological optimum and the definition of key factors of population dynamics. For 10-day periods, mean temperature, pluviometry, TEP, and phenological state of the vegetation are taken into consideration. Wind velocity at 880 mb (at 12:00 h local-time) and at 950 mb (21:00 h local-time) are monitored daily. These real-time data are provided by METEO FRANCE and the European Centre for Medium Range Weather Forecasts at Reading (UK). Survival and fecundity levels and development rates for different stages of the life cycle can be calculated along with immigration and emigration indices. Thus, the density and developmental phase of the desert locust population are estimated after redistribution of locusts in relation to the size and direction of the migration phenomena.

The SGR biomodel is now an operational, descriptive and predictive working tool that has been operative for several months. Test checks are currently underway. The relevance of different hypotheses upon which the biomodel is based and the resulting deductions are verified through these tests. Locust reports published by the FAO for the entire 1984 to 1991 period (including the last outbreak) are used as a reference.

A few specific applications of the SGR biomodel are already proposed, such as:

- to serve as a permanent locust watch
- to forecast crises
- to choose appropriate locust control strategies
- to serve as an information and training support

The SGR biomodel could eventually be integrated with a geographic information system so that ecological stratification of the desert locust habitat (this is currently being developed at PRIFAS) is taken into consideration. Moreover, meteorological data could be supplemented with remote sensing data and all other complementary data useful for forecasting current and potential locust situations could be managed.

This biomodelling project, begun in 1989, is in the final phase of prototype validation. The intellectual resources of 8 researchers and 3 technicians have been mobilised on a full and part-time basis. The success of the project can be attributed to the multidisciplinary teamwork and skilled management of locust, meteorological, ecological and computer data.

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DESCRIPTION OF THE LOCUST BIOTOPES IN ITS WESTERN ZONE HABITATS

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The uniqueness and scope of the desert locust biomodel, designed by PRIFAS, is based on interpreting the bioecological habitat potentiality relative to the actual environmental context and predicting main locust events through management of locust populations. It is essential, in terms of individual locusts, to take the surface area concerned and the size of the actual population into consideration to be able to account for phase development; the ecological nature, breeding and survival capacities being quite different for solitary and gregarious locusts.

The range of the desert locust is enormous (16 million km^2 during recessions and 29 million km^2 during outbreaks), hence this initially concerns the western part of the area of the African continent west of the Nile. Through this study it was possible to identify, characterise, delimit, classify and organise desert locust biotopes according to the locust's own perception of environments depending on individual requirements and developmental phase.

Eight years of study, which included compilation of published information on the desert locust and its environment and pooling of the field experience of an acridologist, an ecobotanist and a computer expert, resulted in the determination of ecologically homogenous territorial units (EHTU). The reference element is the desert locust biotope with higher order EHTUs being natural regions, ecological macroregions and ecoclimatic zones. The results of analyses provide a panoramic description of each typology, identification characteristics of the main habitat types, specifications on each biotope and distribution maps of the different macrofactor classes according to their biological values within each natural region.

It is now possible to temporally and spatially monitor the development of bioecological biotope values for survival, breeding, gregarisation as well as the surface areas concerned in the western zone of the desert locust range. This is a principal element for the SGR.biomodel. Moreover, the study (Popov *et al.* 1991) is a major contribution to knowledge on the Sahara and surrounding areas.

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VALIDATION OF INFORMATION GENERATED BY SATELLITE IN ORDER TO IDENTIFY THE POTENTIALLY FAVOURABLE ZONES TO THE DESERT LOCUST

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The strategy for the prevention of desert locust outbreaks is primarily based on surveys of the prevailing ecological conditions within the habitat range of solitary locusts, which essentially involves localisation of rain and green vegetation zones. This area is extremely vast and covers about 16 million km^2, thus satellite remote sensing is the only available tool which can monitor such a vast zone at reasonable cost (Roffey 1975).

Using NOAA satellites, having an AVHRR sensor with 1 and 4 km resolution, the dynamics of green vegetation in locust recession areas can be monitored (Tucker *et al.* 1985). The ARTEMIS system of the FAO and USAID have regularly, over the last few years, provided vegetation index maps that are used to locate potential habitats of the desert locust (Tappan *et al.* 1991). Data from the thermic infrared channel of the METEOSAT satellite are also used to locate the position of rain clouds. However, there is currently no completely operational early warning system for locust invasions which is entirely based on satellite remote sensing (US Congress 1990; FAO 1990). Presently, NOAA images of vegetation indices, in the absence of specific calibration, have been found to be relatively unuseful in desert zones (FAO 1990).

The GOELAN project is placed in this context (BDPA-CETAGRI, PRIFAS et SYSAME 1991). The scientific part of the project was carried out in late 1990–early 1991 by PRIFAS in the Tamesna desert zone of Niger with the financial support of the French Ministry of Cooperation and Development and the logistics support of the BDPA and the National Locust Control Centre of Agadez (Niger). Potential detection of small spots of green vegetation by the LANDSAT TM, SPOT and NOAA-AVHRR satellites was tested. The first results were encouraging and showed that extent of the green vegetation cover can be estimated for the Sahara Desert zone from the vegetation index data. The research is still underway to determine the minimum cover threshold for this evaluation. The focus is on the calibration of satellite data from field data.

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NETWORKING IN THE IIBC (INTERNATIONAL INSTITUTE OF BIOLOGICAL CONTROL)/IITA (INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE)/DFPV (DEPARTMENT FOR TRAINING IN CROP PROTECTION (DEPARTEMENT POUR LA FORMATION EN PROTECTION DES VEGETAUX) COLLABORATIVE PROGRAMME FOR RESEARCH ON THE BIOLOGICAL CONTROL OF LOCUSTS AND GRASSHOPPERS*

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INTRODUCTION

The programme is a joint venture with four donors and three implementing agencies. This makes for a rather complex structure, with a considerable overhead on internal administration and communications. The overall objective of the project is sharply focused to investigate the potential of fungi as mycopesticides to replace chemical pesticides in current control strategies. This is based on the finding of Dr. Prior (Prior *et al.* 1988), that fungal spores are very much more effective when formulated in oil than in water.

*Paper presented by Dr. M. Cock

So far, the project has demonstrated the effectiveness of oil-based formulations of a deuteromycete fungi against desert locust and *Zonocerus variegatus* in low humidities in the laboratory. Preliminary field demonstrations have been carried out at Cotonou, Benin, and will shortly be repeated in cages in Niamey.

We are also carrying out ecological studies on grasshoppers in Benin and Oman. In the course of these studies, several new field isolates of *Malamoeba* have been found, and these are being passed to ICIPE.

In order to have realistic field targets, the project is now turning towards grasshoppers until such time as field populations of locusts become available. Preliminary bioassays have shown that both *Zonocerus variegatus* and *Oedaleus senegalensis* are susceptible to strains of *Metarrhizium flavoviride*. *Hieroglyphus daganensis* and *Kraussaria angulifera* are under test at present and we hope to test *Eyprepocnemis plorans* and *Diabolocatantops axillaris* and other species in due course.

NETWORKING

This programme has two networking activities, which will become unified as the programme progresses. Firstly, a pathogen collecting network has been set up by Mr. Kooyman working out of DFPV in Niamey, Niger. Mr. Kooyman has visited most of the Sahelian countries which form part of CILSS (Comite Inter-Etats pour la Lutte contre la Secheresse dans le Sahel) to explain the project and identify collaborators. Where appropriate, a modest sum of money has been paid for fuel to allow collaborators to make field collections, and a cash reward for any useful isolates has been offered. Mr. Kooyman's exploration and collection activities are undertaken jointly with local plant protection services; in the course of these activities, the basic methods of collecting and preserving pathogens are discussed. To centralise the collection of samples and their transmission to DFPV, a national coordinator is nominated for pathogen monitoring in each national service for plant protection. A locust biocontrol meeting was held at IITA, Benin, in April this year to inform the national coordinators about the programme and potential of locust pathogens. Owing to the activities of DFPV and PRIFAS (Programme de Recherche Interdisciplinaire Francais pour l'Acridologie Sahelian) in Francophone West Africa, we find the existing human resource base of trained grasshopper personnel quite sound, although staff are often under-funded. A French-language booklet on pathogen collection is planned, which might fit in with the existing series of PRIFAS grasshopper and locust booklets.

At present, pathogens collected are passed back to IIBC in UK. IIBC forms part of the EEC network for the identification of locust and grasshopper pathogens, and specialises in fungi. Dr. Bergoin of St. Christol-les-Ales in France specialises in viruses, and Dr. Zelazny of Darmstadt specialises in bacteria and protozoa. In the long-term, as the insect pathology laboratory at IITA Benin develops, the network will feed into this laboratory.

The other network activity centered at IITA Cotonou is more concerned with training and research collaboration. As our research is still at an early stage, we are not yet in the position of being able to tell people how to control locusts with pathogens. Our goal is to involve local research programmes at an early stage, so that solutions developed will more likely be "appropriate". At present, we are hoping to invite qualified and practicing entomologists, particularly acridologists, to attend an insect pathology course early in 1992. The objective of the course will be to demonstrate a few practical skills in pathology, with a heavy emphasis on improvisation and use of existing facilities. This approach is to an extent imposed by the lack of specific funds available for networking. A scheme proposed by Montana State University would allow for provision of a microscope to course participants, but so far awaits funding.

We hope that course participants would then be able to return to their own organisations and carry on a research programme. We then intend to keep in touch with collaborators, and, where an active research programme was under way, attempt to coordinate trials in such a way that each country would be able to develop its own procedures while benefitting from one another's results.

QUARANTINE CONSIDERATIONS

We have been in touch with the Inter-African Phytosanitary Council (IAPSC) of the OAU. In general, the OAU is in favour of biological control and has undertaken to keep governments informed at a high level in order to avoid misunderstandings about the intentions of biological control organisations. The phytosanitary council is in favour of importing biocontrol agents where these have been appropriately quarantined and safety angles considered. In general, given the mobility of the desert locust, we would expect locust pathogens to be quite widely distributed; but it is project policy to avoid transporting pathogens between continents unless necessary. Our two best fungal strains are both *Metarrhizium flavoviride* from Africa, one for *Ornithacris cavroisi* from Niger, and one from *Zonocerus elegans* from Tanzania. We have virulent isolates from Australia under test in UK, but unless we can demonstrate a clear advantage over African isolates, we will hold this strain in reserve.

In the course of our surveys, we have also found other pathogens infecting grasshoppers, e.g. a strain of *Beauveria bassiana* from *Z. variegatus*, which is effective against *Zonocerus* spp. but not against locusts.

EXISTING RESOURCE BASE

One of the needs identified by a working group established at the Locust Biocontrol meeting in Cotonou in April was to prepare an inventory of the existing resource base in insect pathology. We are preparing a questionnaire for this purpose, but would welcome any comments from this meeting.

In our experience, most locust-affected countries do not carry out much research on locusts. Certainly in West Africa, it would be appropriate for any organisation charged with locust research to carry out work on grasshoppers while locusts are in recession; we see this as essential justification for maintaining personnel and facilities which would otherwise be under-used. One of the advantages of attempting to develop a research base in insect pathology is that such laboratories could tackle a range of problems, not just locusts and grasshoppers.

Ideally, we would like to see some donor funds set aside which countries could apply for to participate in the collaborative programme. We would assist in developing proposals where necessary, but hope that, in general, countries would provide their own impetus.

There is a clear need for donor funds to be available for countries to participate in such a framework. We would prefer to see countries applying for and administering their own projects than for a single agency carrying out research and dispersing funds.

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FAO REPORT FOR THE ICIPE WORKSHOP ON EFFECTIVE NETWORKING AND DEVELOPMENT

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Over the past 60 years an international network has developed, covering all aspects of anti-locust activities including information, survey, reporting and forecasting, control, research and development, and training. This involves all of the 55 countries affected by the desert locust, many donor governments and institutions, international agencies and research and development institutions. The network is coordinated by FAO as the lead agency in the UN system and essentially operates at three levels: international, regional and national. Thus, while responsibility for survey and control operations basically rests with the national plant protection services, most of the affected countries are also members of one of five regional commissions or organisations:

DLCO-EA: Member States: Djibouti, Ethiopia, Kenya, Somalia, Sudan, Tanzania, Uganda.

OCLALAV: Member States: Benin, Burkina Faso, Cameroon, Chad, Ivory Coast, Gambia, Mali, Mauritania, Niger, Senegal.

FAO Near East Commission: Member States: Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Sudan, Syria, United Arab Emirates, Yemen.

FAO North-West Africa Commission: Member States: Algeria, Libya, Mauritania, Morocco, Tunisia.

FAO South-West Asia Commission: Member States: Afghanistan, India, Iran and Pakistan and virtually all are members of the FAO Desert Locust Control Committee (DLCC).

Historically, regional organisations have played an important role in locust control. Preventive control organisations were set up to monitor and undertake preventive control operations against the African migratory locust and the red locust after the end of the last plagues in the 1940s and in the Middle East and Eastern Africa. In recent years, however, the successors to these organisations have become seriously weakened or even dissolved because of lack of financial support from their member states. FAO's current policy with respect to the regional locust organisations is, in cooperation with their member states, the organisations themselves and donors, to identify sustainable programmes of work, focusing on activities where a regional approach is more appropriate than a national one e.g. support for national surveys, research and development, training. Regional information services may be highly appropriate activities, e.g. for armyworm but less so for the more highly mobile desert locust, for which an international reporting and forecasting service has been in existence for nearly 50 years.

The current strategy, adopted by the DLCC in 1969, by which FAO and its Member States seek to implement the policy is through **prevention control** which in essence consists of monitoring desert locusts in their seasonal breeding areas and undertaking control measures against any populations considered large enough and starting to gregarise.

FAO's policy on the preventive control strategy is to build up national desert locust units to the level where they can effectively monitor the seasonal breeding areas and to seek external funding when this is deemed necessary. A project to support preventive control in the four front line states in West Africa is being prepared and should this approach prove successful, consideration will be given to making similar arrangements in the countries around the Red Sea and Gulf of Aden.

The onset of a new desert locust plague in 1986, the ban on the use of dieldrin and the consequent need to apply over 10 million litres of pesticides led to a resurgence of interest in improving existing methods of locust control and on the need for developing alternative methods of control which are environmentally safer than current chemical methods. FAO supports both approaches and has taken a number of initiatives:

- convened a meeting on desert locust research: defining future research priorities;
- convened panels of experts on pesticide application, evaluating pesticides for locust control, environmental side-effects of desert locust control, desert locust forecasting and population dynamics, desert locust biology and behaviour;
- in collaboration with UNDP, it has formed a Scientific Advisory Committee to review desert locust research project submitted to UNDP for funding;
- prepared a Desert Locust Research and Development Register and set up a Pesticide Trials referee panel to establish recommended dosages for locust control.

In all these activities FAO, through The Locusts, Other Migratory Pests and Emergency Operations Group, have emphasised the need for close collaboration between field and laboratory workers, industry and plant protection services and between the plant protection services themselves. The desert locust plague and the Sahelian grasshopper outbreaks facilitated such collaboration and every opportunity to expand this is being and will be taken in conjunction with the research being funded by UNDP and other donors.

THE STRUCTURE OF INTERNATIONAL COORDINATION MAJOR ACTIVITIES

The major activities under the FAO Locust Programme are coordination of anti-locust activities at international, regional and national levels, reporting and forecasting, coordination of field services, project formulation, operation and technical support, provision of equipment and supplies, and personnel training. In recent years, activities have been expanded to deal with other locust species, as well as the desert locust, grasshoppers, other migratory pests, and emergency operations.

Coordination of Anti-Locust Activities at International, Regional and National Levels

The FAO Desert Locust Control Committee meets biennially. Membership is open to all countries affected by the desert locust and other interested governments. The Committee reviews all aspects of anti-locust activities and makes recommendations for future activities. It provides the main policy guidelines to the Locust Programme. In addition, there are regular meetings of the three FAO Regional Locust Commissions where regional aspects of coordination are reviewed, and of the Regional Organisations at which operational activities are also considered.

Ongoing FAO Research Activities in Eastern/Central and Southern Africa

In collaboration with Desert Locust Control Organisation of Eastern Africa, through a UNDP/FAO project RAF/88/033 "Strengthening DLCO-EA in the control of migrant pests" the following activities were carried out which resulted in the improved efficiency, effectiveness and safety of aerial and ground application of pesticides under East African conditions, improved pest target identification, and extensive training for crop protection officers in the region.

Main Activities:

I. Training

- Regional training courses for crop protection officers from DLCO-EA member countries and from other countries affected by migrant pests.

- In-service training on pesticide application techniques and remote sensing.

II. Remote sensing and mapping

- Using historical data of traditional breeding sites, *Quelea* habitats were mapped using aerial and ground survey and satellite imagery. The maps, inserted into a data bank, can be periodically updated to guide survey teams more efficiently to locate potential targets. This activity will be extended to the desert locust.

III. Pest management

- Development of suitable ground and aerial spray equipment.

- Study of droplet behaviour in relation to weather conditions.

- Study of formulations, improvement in the mode of entry and testing of existing and improved pesticides and formulations.

This research resulted in reducing the application rate of pesticides thereby reducing hazards to the environment. It also improved the effectiveness of pesticides in their impaction and mode of entry.

Similar programmes have been carried with the IRLCO-CSA and, at national level, with countries like Botswana, Zimbabwe, Mozambique, Swaziland, Lesotho and Madagascar.

Future Needs

Research is necessary to refine certain aspects of locust survey and control, for example, better definition of breeding and gregarisation areas using historical, geomorphological and ecological data, improved interpretation of remote sensing imagery and improved aerial and ground control techniques to reduce insecticide dosages and to minimise environmental contamination. There is a continuing need to strengthen telecommunications at national, regional and international levels.

Environment

Proposals have been made to assess the environmental effects of locust control through:

- assessment of environmental impact of pesticides used for locust control for a range of representative habitats;

- development of field evaluation methods to assess non-target impact; and

- assess the impact of new products for locust control as these become available.

Mapping, Forecasting and Monitoring

A project proposal includes improved detection and early warning of locust through:

- mapping of desert locust habitats in the traditional winter/spring breeding areas of Sudan, Ethiopia and Somalia;
- strengthening the current desert locust information and forecasting service by application of remote sensing technology;
- development of an integrated early warning/surveillance system for desert locust which includes strengthening the capabilities of national PPS in desert locust monitoring.

Application Techniques

- Development of suitable ground and aerial spray equipment.
- Testing of formulations of and application techniques for growth regulators and bioagents.
- Assessment of available ground/aerial spray equipment in their suitability for the application of growth regulators/bioagents.
- Study impact efficiency of pesticide/growth regulators, bioagents on ground and in flight and physical stress leading to low application rates.

Training

Further intensified regional and national training programmes are envisaged to cover the fields of expertise mentioned above.

Future project proposals include the following M.Sc. fellowships:

- environmental monitoring and evaluation and ectoxicological screening;
- remote sensing; and
- pest management.

Short, specialist courses, will also be offered and video films and publications produced and disseminated.

Since locust control is essentially a national responsibility or the responsibility of groups of countries working in coordination, FAO's overall strategy will be to build up national plant protection and locust control services through training, and the provision of equipment and supplies to enable individual countries to control local locust outbreaks and outbreaks of other migratory pests.

Lastly, FAO also encourages close cooperation with reputable international institutions such as ICIPE. However, particular emphasis should be laid on liaison in the preparation of work programmes for field research to avoid duplication of objectives.

RED LOCUST (*NOMADACRIS SEPTEMFASCIATA* SERV.) CONTROL AND RESEARCH ACTIVITIES BY THE INTERNATIONAL RED LOCUST CONTROL ORGANISATION FOR CENTRAL AND SOUTHERN AFRICA

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INTRODUCTION

The International Red Locust Control Organisation for Central and Southern Africa (IRLCO-CSA) was formed in 1970 as a successor to the International Red Locust Control Service. The latter had been formed in 1949 by the Governments of Great Britain, Belgium, Portugal and South Africa soon after the 1930–1944 red locust plague (Fig.1).

The mandate of IRLCO-CSA was, originally, primarily for the survey of red locust, *Nomadacris septemfasciata* Serville in its recognised outbreak areas (Fig. 2). This strategy was aimed at facilitating control and preventing the occurrence of further plagues of *N. septemfasciata* in the region. The mandate also stipulated that IRLCO-CSA should reinforce and coordinate the activities of plant protection service units in its member countries in combating red locust outbreaks. The mandate of the Organisation was expanded in 1985 to include the control of red locust, the survey of other locust species such as African migratory locust (*Locusta migratoria migratorioides* R&F) and brown locust (*Locustana pardalina* Walker), armyworm (*Spodoptera exempta* Walker) and grain eating birds (*Quelea* spp.).

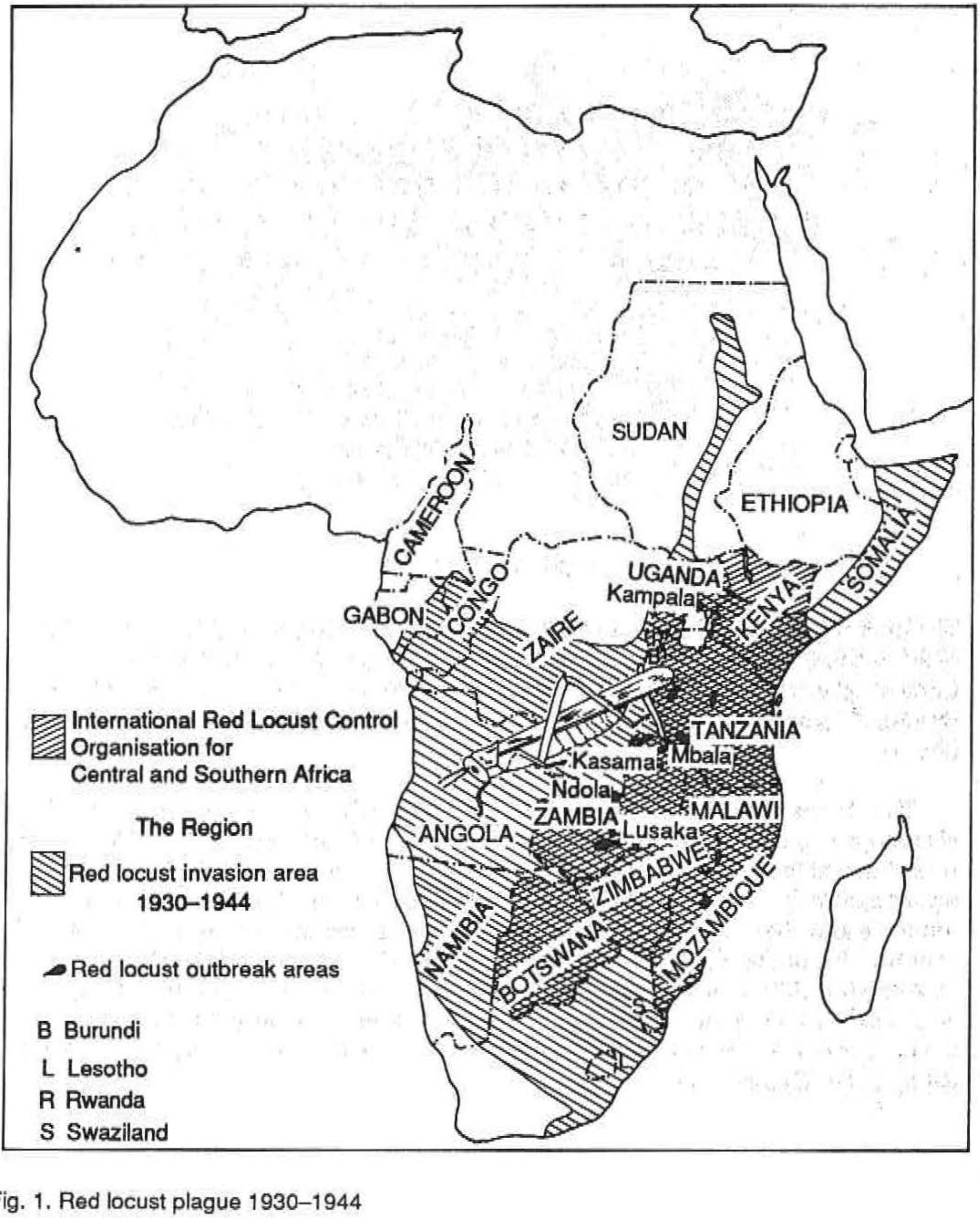
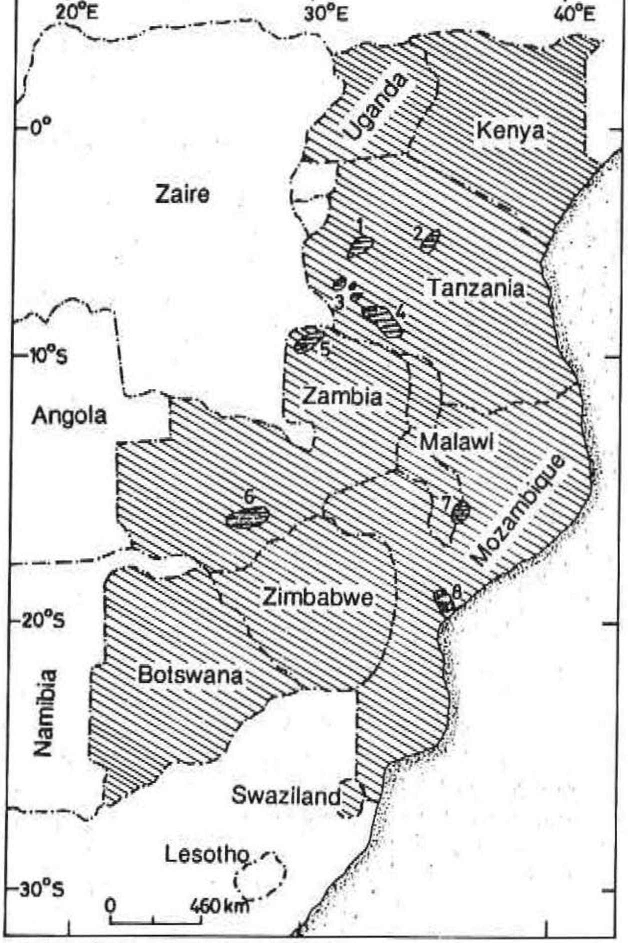


Fig. 1. Red locust plague 1930–1944



Member countries of IRLCO-CSA
Outbreak areas of Red Locust

1. Malagarasi basin
2. Wembere steppe
3. Iku and Katavi plains
4. Rukwa valley
5. Mweru-wa-Ntipa
6. Kafue flats
7. Lake Chilwa plains
8. Buzi-Gorogosa plains

Fig. 2. The recognised red locust outbreak areas in IRLCO-CSA region

MEMBERSHIP OF THE ORGANISATION

The Organisation currently has nine member states which are Botswana, Kenya, Malawi, Mozambique, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe. Recognised outbreak areas of *N. septemfasciata* are in Malawi, Mozambique, Tanzania and Zambia (Fig. 2). These areas are characterised by impeded drainage and/or periodic flooding and are generally flat grasslands.

RED LOCUST INCIDENCE AND CONTROL

The red locust situation was generally calm during the period 1980 to 1982 except for a localised outbreak in Swaziland and Tanzania (Table 1). There were widespread outbreaks of the red locust in same member countries from 1983 to 1984 (Table 2). These outbreaks were controlled by the Organisation and national plant protection units using mainly fenitrothion, dinitro-o-cresol, and dieldrin.

INCIDENCE OF OTHER LOCUSTS AND GRASSHOPPERS

The IRLCO-CSA region is vulnerable to invasions by *Locusta migratoria migratorioides* and *Locustana pardalina*. Outbreaks of these locust species occurred in some member countries (Table 1). Green grasshoppers *Rusporia differens* Serville attacked crops in Botswana, Malawi, Mozambique and Zambia (Table 2). Outbreaks of the locusts and green grasshoppers were controlled by the Organisation and national plant protection units.

PAST RESEARCH ON RED LOCUST

It was realised that for effective prevention of plague of the red locust *N. septemfasciata*, good knowledge on the demarcation and geography of recognised outbreak areas had to be obtained (Michelmore 1949; Gunn 1960b; Carnegie 1961; Albrecht 1964; Vessey-Fitzgerald 1970; Symmons 1978). The biology of the red locust, hopper and adult behaviour, and ecological factors which affect its population dynamics were also studied (Rainey *et al.* 1957; Robertson 1958b; Scheepers *et al.* 1958; Symmons and Carnegie 1959; Yule and Lloyd 1959; Vessey-Fitzgerald 1959; Gunn 1960a; Yule 1960; Dean 1967a,b; Stortenbecker 1967). The modification of vegetation in the outbreak areas and the use of pesticides for the control of red locust have been tried (Robertson 1958a; Yule 1960; Gunn 1979). Biological control agents for red locust have also been observed especially during plagues (Chapman and Robertson 1958; Sweeney 1963; Dean 1964).

Ecology and Behaviour

It was observed that each developmental stage of *N. septemfasciata* Serv. has its ecological niche (Vessey-Fitzgerald 1964). The study of the biology of *N. septemfasciata* has shown that the requirements vary at different times of the year (Robertson and Chapman 1962). Robertson and Chapman (1962) reported a considerable redistribution of the population of *N. septemfasciata* at the beginning of the breeding season. Red locust females move into the ringing woodland where they lay eggs. Thus, *N. septemfasciata* is only found in woodlands during the breeding season, except when the population is very high resulting in swarms. *N. septemfasciata* was reported to prefer *Echinochloa* (Robertson and Chapman 1962). They showed that 74.5% of specimens in the grasslands were collected from *Echinochloa*, 14.5% from *Diplachne*, 7.5% from *Sporobolus*, and 0.5% from *Hyparrhenia*. This observation showed that the *Echinochloa* habitat was the most suitable for swarm formation, hence the one to be monitored more closely. They also reported that although the *Diplachne* habitat was second in

Table 1: Incidence of and control measures of locusts and grasshoppers 1983 – 1989

Period	Country	Location	Pest	Insecticide* used (Litres)	Area sprayed (Ha)
Sept. 1983	Malawi	Kuselikumvenji Estates	RL	–	–
Sept. 1983	Tanzania	Wembere Plains	RL	495	800
Jan. 1984	Zimbabwe	Chiredzi	AML	N/A	N/A
June 1984	Zambia	Kafue flats	RL	100	330
Aug. 1984	Zambia	Kafue flats	RL	275	896
Sep. 1984	Tanzania	Wembere Plains	RL	617 540 DNOC	1,190
Sep. 1984	Zambia	Nakambala	RL	530	476
Nov. 1984	Zambia	Nakambala	AML	875	N/A
Mar. 1985	Tanzania	Wembere Plains	RL	N/A	200
2nd Qtr. 1985	Botswana	Barolong Farms	AML	288	360
Aug.–Sep. 1985	Tanzania	Wembere Plains	RL	40	80
2nd Qtr. 1985	Mozambique	Tete Province	RL	N/A	N/A
Jan.–Mar. 1986	Tanzania	Wembere Plains	RL	1980 Dieldrin	N/A
May 1986	Botswana	Chobe District	RL AML	18 N/A	N/A N/A
Feb.–Oct. 1986	Botswana	Kgalagadi District Southern District Kweneng District Ghanzi District	BL	40,000 500 (Alphcypermethrin)	N/A N/A N/A
May–Sep. 1986	Tanzania	Wembere Plains	RL	3,066	N/A
May, June and Oct. 1986	Tanzania	Iku Katavi	RL	5,958 421	N/A N/A
May–June 1986	Tanzania	Southern Rukwa Valley	RL	1,100	N/A
Aug.–Sep. 1986	Zambia	Kafue Flats		750	N/A
April 1987	Malawi	Mchinji	RL	180	360
Aug.–Sep. 1987	Tanzania	Wembere	RL	1,250	2,500
Aug.–Sep. 1987	Tanzania	Iku/Katavi	RL	4,800	9,600
March 1987	Zambia	Kafue Flats	RL	1,400	5,740
Aug. 1987	Zambia	Kafue Flats	RL	1,377	2,754
Sep. 1988	Zambia	Sesheke	AML	20	40
May–June 1988	Zambia	Kafue Flats	RL	1,000	2,000
June 1988	Zambia	–	AML	2,095	4,190
June 1988	Zambia	–	AML	9,045	7,236
June 1988	Zambia	–	AML	400	480
Jan.–Mar. 1988	Zimbabwe	S.E. Lowveld	AML	1,000	2,000
Sep.–Oct. 1988	Zimbabwe	S.E. Lowveld Beitbridge Mashonland West	AML	N/A	N/A
May 1988	Botswana	Satau Pandamatenga	AML RL	23,420 N/A	46,840 N/A
			AML	22,178	44,356
Oct. 1989	Zambia	Kafue Flats	RL	200	400

* Insecticide used was fenitrothion or as stated.

KEY

RL : Red locust; AML : African migratory locust; BL : Brown locust; N/A : Data not available.

Table 2: Incidence and control of grasshoppers in IRLCO-CSA Member Countries for the period 1985 to 1989

Year	Country	Location	Type of grasshopper	Insecticide (Litres)*	Area sprayed (Ha)
1985	Malawi	Mangochi District	Armoured G/H	340	350
1988	Botswana	Chobe District	Green G/H	N/A	N/A
		Ngamiland	"	"	"
		Central District	"	"	"
1988	Malawi	Chikwawa District	Green G/H	"	"
		Nsanje District	"	"	"
1988	Mozambique	Tete Province	Green G/H	"	"
		Manica Province	"	"	"
		Zambezi Province	"	"	"
1988	Tanzania	Pemba Islands	Green G/H	"	"
		Kisarawe	"	"	"
1988	Zambia	Kalabo	Green G/H	"	"
		Senanga	"	"	"
		Mongu	"	"	"
		Gwembe District	"	"	"
1988	Zimbabwe	–	N/A	"	"
1989	Uganda	Rakai District	Elegant G/H	"	"
		Masaka District	Elegant G/H	"	7,500

NOTE:

* N/A = Data not available

importance, most of the specimens collected were nymphs. They showed that adult locusts tended to move out of *Diplachne* patches. This observation led to the conclusion that the *Diplachne* habitat should also be closely watched as it could produce high parental populations for the following season.

It was shown that the colour of the *Nomadacris* hoppers varied from the typical solitary phase green through yellow to red and black which is characteristic of the gregarious phase (Robertson and Chapman 1962; Anonymous 1982). The proportion of hoppers that had the gregarious phase coloration (brown) is in Table 3 (Robertson and Chapman 1962). Data presented in Table 3 confirms that *Echinochloa* is the most dangerous habitat and that in *Diplachne* a large proportion of hopper population actively moves out as soon as the adults emerge. They usually move to the *Echinochloa*

Table 3: The percentage of different hopper phases of *Nomadacris septemfasciata* caught in various habitats

Habitat	% Greenhoppers	% Brown hoppers	Total no. examined
Diplachne	7	93	153
Echinochloa	5	95	757
Hyparrhenia	60	40	10
Sporobolus	73	8	98
Woodland	92	8	49

habitat. The majority of hoppers in the other habitats were green (solitary) showing that these habitats are less likely to act as primary concentration zones (Table 3).

Robertson (1958a) observed that ovaries of females of *N. septemfasciata* started developing from November and the development continued through to January (Table 4). It was reported that the number of ovaries per specimen was as high as 164. This was higher than the average number of 92 eggs per pod suggested by Robertson (1954) but was within the range given by Chapman and Robertson (1958). The average number per pod was considerably lower than the total number of ovarioles because some of ovarioles did not develop normally. Robertson and Chapman (1962) reported that 5.2 to 16.6% of the ovarioles did not contain well developed eggs.

Table 4: Development of ovaries of *Nomadacris septemfasciata*

Month	No. of ovaries examined	% showing development
October	894	0
November	2,580	4
December	1,790	85
January	126	85

These observations showed that *N. septemfasciata* had one generation per year and a short oviposition period which extended from November to January. Robertson and Chapman (1962) demonstrated that *N. septemfasciata* were present from March to January and hoppers were caught from January to March. They also showed that adult *N. septemfasciata* survived through the dry season.

Survey

Decisions on whether locust populations in outbreak areas should be sprayed or not depend on systematic estimates of the population sizes and densities. This assessment includes the extent of multiplication during the breeding season in the recognised outbreak areas. Many of the outbreak areas are vast flat grasslands in which the red locust populations are not homogeneously distributed. Thus, population assessment is difficult due to the size of the areas and the presence of dense tall grasses. Although there are these inherent problems in the outbreak areas survey studies have been conducted.

(a) Ground survey

Ground surveys were conducted by walking and motor vehicle (Lloyd 1959). Surveys by walking during rainy season were ruled out because of high flood waters and thick vegetation (Lloyd 1959). Amphibious vehicles (swamp skippers) were tried and found not robust enough and were costly. Land Rovers were found ideal for ground surveys during the dry season although their versatility was restricted to where vegetation and topography allowed. Thus, accessibility of swampy outbreak areas is limited during ground surveys (Lloyd 1959). Motor vehicles are, however, vital for ferrying staff, insecticides, supplies and other requirements during operations.

(b) Aerial survey

Crosse-Upcott (1978) stated that fixed-wing aircrafts were ideal for locust survey. Aircraft were first deployed for locust survey in the Rukwa Valley in Tanzania. Subsequently, the organisation adopted aircraft as a major tool for red locust survey and control (Dean 1968). Observations made in the field showed that fixed-wing aircraft surveys could only locate up to 25% of the hopper bands present in an area as established by ground surveys.

It was realised that red locust surveys by helicopter were better at detecting hopper bands than fixed-wing aircraft since the helicopter could be flown low and could hover and/or land for closer inspection to be made (Symmons 1966). As a result of this the Organisation procured a helicopter in 1964.

Control Methods

Various control methods have been developed against the red locust with different degrees of success (Materu 1984). These include ecological, chemical and biological control.

(a) Ecological control methods

The objective of ecological control is to make it difficult for red locusts in outbreak areas to enter the gregarious phase. A number of strategies have been investigated in order to modify the ecological conditions in the breeding areas.

Gunn (1960a) attempted to modify the ecology of the Rukwa Valley and Mweru-wa-Ntipa by flooding. Afforestation was suggested by Robertson

(1958a) as a means of turning the grasslands into wooded expanses of land. Ranching and fire prevention were also recommended for habitat modification (Gunn 1958). None of these methods was found appropriate for suppression of red locust populations in the outbreak areas.

(b) Chemical control methods

Since methods that altered the ecology of the outbreak areas were found inappropriate for the detriment of red locust population upsurges, quick control methods were deemed necessary. Preemptive red locust control in outbreak areas was required if plagues were to be prevented. Hence the use of pesticides was looked into (Gunn 1960a).

Various pesticides have been tried for the control of both hoppers and adults of red locust (Michelmore 1947; Gunn 1960a; Yule 1960; Whellan 1964). Gunn (1955, 1958) and Yule (1960) reported that benzene hexachloride (BHC), dieldrin dinitro-ortho-cresol (DNOC) and arsenic compounds were used for the control of hoppers and adults. Dieldrin was found effective for the control of red locust hoppers when applied in lattices by aircraft (Yule 1960). It was observed that dieldrin was active against hoppers for three weeks when applied in ultra low volume doses to the vegetation. Initially, pesticide baits of arsenic compounds and BHC were used for the control of red locusts. Through careful research these chemicals were found to be persistent hence had adverse effects to non-target organisms. Eventually these pesticides were replaced by synthetic organic pesticides such as fenitrothion. Adult red locusts are controlled using fenitrothion which is used as a standard. With the advent of synthetic pyrethroids, their combinations with the organic pesticides have been evaluated. These potential combinations will be validated when more data are collected and analysed.

(c) Biological control

Natural biological control agents of *Nomadacris septemfasciata* have been reported to cause considerable mortality to different developmental stages of this insect (Lewin 1939; Smee 1940, 1941; Sweeney 1963; Dean 1964; Stortenbecker 1967). These included *Entomophthora grylli* Fres., bush crickets (*Acanthoplus speiser* Branc.), reduviid bug (*Rhinocoris violentus* Germ.), asilid flies (*Promachus scalaris* Loew., *Ommatius vasiabilis* Engel and *Philodecus nigripes* Ricardo), dragon fly (*Anisoptera* sp) and tachinid parasites on hoppers; *Metarrhizium anisopliae* Metschn., *E. grylli* and many species of birds on adults; and rats especially *Mystomys natalensis*, the hymenopteran *Scelio howardi* Crawford, beetles (*Chlaenius obesus* Laferte, *Epicauta brevipennis* Haag, *E. velata* Gerst, *Mylabris dicincta* Bert, and *M. pertinax* Per.), and several species of mites on eggs. The effect of natural enemies on egg mortality was considered insignificant (Materu 1984).

FUTURE RESEARCH PLANS

Ecological methods of red locust control have not been applied because they would be more costly than pesticide control (Gunn 1960a). Although many pesticides have been used for locust control more research is required to test the efficacy of more novel compounds being introduced. Hence IRLCO-CSA has planned to embark on research programmes to test several pesticides for the control of red locust. The Organisation is also planning to conduct research on alternative control methods for the red locust including the use of some known biological control agents such as *Entomophthora grylli* and other pathogens and parasitoids.

On the testing of pesticides, the organisation will look into the use of ultra low volume (ULV) techniques of application in order to reduce quantities of pesticides used. The use of pathogens, parasitoids and predators will also be investigated. Some of the biological control agents will be collected from the field, identified and hopefully propagated and tested under laboratory and field conditions.

A lot remains to be refined in terms of red locust control and understanding the reasons for the non-occurrence of red locust plagues in some years. The latter entails the analysis of past occurrences of red locust outbreaks in relation to weather patterns and flooding of outbreak areas.

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RESEARCH COLLABORATION

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INTRODUCTION

Locust is a migratory pest which crosses geopolitical boundaries and has a very wide range of distribution. It is not confined to a specific field or region of a country, hence research on locust requires collaboration on regional level, if not on international scale. Locust plagues do not occur annually, indeed sometimes a decade will pass without a record of a serious upsurge. Furthermore, locust research is an expensive undertaking, especially, the field component, since it requires many inputs and logistics. For these reasons it is not a priority in most of the resource-limited locust-affected countries.

STATUS QUO OF RESEARCH IN THE LOCUST-AFFECTED COUNTRIES

Very few countries have active programmes on locust research, and most of those are either laboratory-oriented, with insignificant practical impact, or mainly field trials for screening of pesticides and testing of application equipment. The modest research effort that is carried out, which is usually insufficiently funded, is conducted during upsurges and plagues. However, during recession times, interest in research declines and support dwindles.

Consequently, there is generally a lack of new information and initiatives. This is clearly demonstrated by the lack of innovative strategies and control methods since the methods used now were those developed several decades ago. There is also serious shortage of trained and motivated research scientists in this field. Hence there are wide knowledge gaps especially in the area of locust behaviour and ecology.

THE FUTURE

To rectify this situation and prepare for the future, collaboration between all concerned especially those in the locust-affected countries has to be fostered. At the ICIPE, we see many possibilities for collaboration and in more than one area. However, the most obvious is that of capacity development. In this regard short-term training of technical staff on various aspects of locust rearing, handling and laboratory techniques can be implemented almost immediately. There are also possibilities for long-term training for young scientists to obtain Ph.D. qualifications in insect science. Candidates for such training may be nominated by their countries and if sufficiently qualified, they may be selected to join the ARPPIS Programme. There are also provisions for research scientists from the locust-affected countries to join the research group at the ICIPE, to work for short periods (3–6 months) on problems of their choice but related to the on-going programmes. Scientists from the ICIPE may also visit laboratories in the region and work with national researchers in those laboratories.

Collaboration may also be effected in the form of methodology workshops and in research management meetings. In such workshops and meetings it will be possible to avoid duplication of efforts, to set out priorities and maintain smooth flow of information. Joint research programmes may also be developed with effective sharing of experience and better utilisation of available resources.

The ICIPE has no predetermined model for such collaboration but is willing to offer its experience in other areas such as PESTNET and ARPPIS and it is for the participants to discuss and agree on the model of their choice.

SESSION III

ICIPE'S EXPERIENCE IN COLLABORATIVE RESEARCH AND NETWORKING

CAPACITY BUILDING AND NETWORKING: ICIPE'S EXPERIENCE

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The present African science and technology human capital is relatively small. There are estimated to be some 20,000 research and development (R&D) specialists manning about 250 R&D institutions in Africa south of the Sahara, and approximately 32,000 R&D specialists in about 300 R&D institutions if North Africa is included. This leaves a huge science and technology gap — a dangerous human resource weakness which threatens any mission-oriented R&D programme for national development. Therefore, the rapid intensification of high level training at the advanced degree and postdoctoral levels relying solely on the universities is presently unrealistic.

Recent reports of the World Bank, UNESCO, UNDP, the Third World Academy of Sciences and the Association of African Universities all confirmed that most of sub-Saharan Africa is going through a period of grave economic crisis which particularly adversely affects the universities. At the same time, a great potential of research institutions in advanced training is not fully utilised. In contrast, in other regions of the third world (India, Brazil, Venezuela etc.) and other countries such as Soviet Union, Israel, Spain, etc., the centres of excellence make major contributions through research and advanced Ph.D. training (including awarding own Ph.D. degrees) towards the evolution of self-sustaining industries and in agriculture.

As a Centre of Excellence, ICIPE contributes to the development effort in Africa in two ways: (a) carrying out research relevant to crop and livestock insect pests, as well as insect vectors of tropical diseases crucial to rural health, with a view to developing sustainable pest management technologies; and (b) developing human resource capacities in insect science and its application through education and training. The following are current training titles: (i) leadership training through the African Regional Postgraduate Programme in Insect Science (ARPPIS); (ii) group training courses in Insect Science; (iii) Postdoctoral Research Fellowship Scheme, and (iv) Research Associate Scheme. A new ICIPE initiative in developing, coordinating and further improving graduate education and training through establishment of the ICIPE Graduate School in Insect Science and pest management in tropical developing countries is presented in details.

In the beginning of 1980s the ICIPE realised that, impetus for creating a science and technology (S&T) network in Africa is the immense science- and -technology gap that the continent is experiencing. In addition, there was an urgent need for stimulating and implementing a technology-led development with a small, fragile and shrinking, indigenous scientific community (Odhiambo, 1988, Intern, Conf. on Networking of African Scientific Organisations, Nairobi).

The ICIPE together with various partners in African Universities, Research and Development National Systems, Policy makers and Administrators of African governmental institutions have facilitated establishment of four networks:

(i) THE AFRICAN REGIONAL POSTGRADUATE PROGRAMME IN INSECT SCIENCE (ARPPIS) in 1983;

Presently including 18 universities and 5 others seeking approval from the ARPPIS Academic Board. ARPPIS harnesses together the need of the universities to have high calibre insect scientists with the experience and resources of the ICIPE in producing well-trained, highly motivated African scientists able to tackle the pressing problems of insect pests in tropical Africa.

The ARPPIS is advised on policy matters by an Academic Board. The Academic Coordinator is responsible for the day-to-day administration of the programme, assisted by a fifteen-member Board of Studies. 86 Ph.D. students from 18 African countries have now registered with ARPPIS; and 48 graduates from the programme have been awarded Ph.D. degrees by different registering universities. All ARPPIS graduates are working in Africa.

(ii) THE ARPPIS SCIENTIFIC NETWORK

The first follow-up international conference on the ARPPIS Graduates under the theme "Capacity Building in Insect Science in Africa": Field Experience and Evaluation of the Impact of ARPPIS, 3rd–6th December 1990 recognised that there was persistent brain drain of the best young scientists from research in Africa, and that self-confidence, stimulation and effectiveness of a scientist depended on contact and exchange with his or her peers. The participants recommended that the ARPPIS postdoctoral network be formally instituted.

ARPPIS accepted the responsibility to provide further career support and integration mechanism for its graduates so as to sustain their creativity and commitment to research and training. ARPPIS tries to prevent drain of scientists from active research in the national programmes of Africa by developing new systems providing its graduates throughout by: (a) joint approaches to donors; (b) PESTNET supporting small research grants; (c) ICIPE Research Association Fellowships.

(iii) THE PEST MANAGEMENT RESEARCH AND DEVELOPMENT NETWORK (PESTNET) was initiated in 1985 on recognition by African countries that individual country's resources of trained manpower and funds are equal to the task of combating losses due to crop and livestock pests. A programme of work for PESTNET was endorsed in June 1986 by representatives of 9 member governments. There are four ICIPE-PESTNET scientists resident in: Zambia, Kenya, Rwanda and Ethiopia (Somalia withdrew in December 1990); and there are plans to fund similar teams to other African countries, including Senegal and Côte d'Ivoire.

ICIPE provides the secretariat and coordinates the activities of PESTNET on behalf of the participating countries and research institutes. The ICIPE is assisted by an advisory Steering Committee, while a Scientific Coordinator provides management expertise to the Programme. In addition, there are National Coordinators in each member country, and Zonal Coordinators for each of five planned zones of Africa.

Recent recommendations on establishing a PESTNET GOVERNING COUNCIL as the highest authority of the Network should further integrate IPM scientists and practitioners both from the ICIPE and national programmes with decision-makers of participating governments.

(iv) THE FINANCIAL AND ADMINISTRATIVE MANAGEMENT OF RESEARCH PROJECTS IN EASTERN AND SOUTHERN AFRICA (FAMESA) was initiated to improve research management skills and performance of managers of national scientific R&D institutions. FAMESA develops research management training at the regional and national levels, and established R&D management, information, documentation and advisory services.

Based on the ICIPE's nearly ten years' experience in networking, we wish to make the following recommendations on establishing a new network:

1. The objectives of the network must be compelling, and then be translated into a set of well defined and sharply focused programme activities.

2. The core programme cannot simply be a conglomeration of priority projects of the individual partners in the Network. The Network has to transcend the individual objectives and components of needs into a common set of goals and an agreed programme strategy for implementation.

3. The partners of the Network must be committed to the networking concept and have basic minimum institutional strength and experience to possess the capacity to function as **equal** partners in the Network.

4. The institutional partners must deliberately establish a policy and coordinating system to steer the networking activities and "oil" its operation.

5. Adequate financial resources must be available for policy and coordinating system as well as programme activities that the latter supports.

6. Bringing scientists/technologists and decision makers together.

7. The principal weakness of the practice of networking is the inherently complex management of such a loosely knit entity; which requires continual consultation on priority setting and implementation mechanisms, while too strong a coordination of these could conceivably attract negative whisperings of "being brother" inclinations.

PEST MANAGEMENT DOCUMENTATION AND INFORMATION SYSTEM AND SERVICE (PMDISS)

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GOAL

The major goal of the Pest Management Documentation and Information System and Service (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.

OBJECTIVES

The specific objectives of PMDISS are:

(a) To establish a centre of insect pest and vector management documentation and information to serve the information needs of PESTNET and other users in the tropical developing countries.

(b) To promote in the development and strengthening of an efficient information exchange and document delivery capacity between the relevant national institutions and the centre.

(c) To develop a computerised database and an extensive collection of hard copies of literature which will form the nucleus of the insect pest and vector management information network with special emphasis on grey literature.

(d) To collaborate and cooperate with other organisations in the exchange of information.

FUNCTIONAL ORGANISATION

The PMDISS Centre

PMDISS Centre is hosted in Nairobi, Kenya at the Secretariat of PESTNET. PMDISS is an integrated part of PESTNET and has the following functions:

Functions of the Regional Centre

(a) Planning and coordinating the development of the information network.

(b) Preparation and distribution of standard operating procedures.

(c) Training and technical support for the national participating centres in documentation processing techniques.

(d) Preparation and distribution of standard operating procedures.

(e) Production of indexes and other current awareness products.

(f) Organisation of a document delivery system.

(g) Developing collaborative networks with other relevant regional and global information systems.

(h) Promotion of the network.

(i) Facilitates acquisition of funding by the secretariat for the development of the network at the national and regional levels.

National Programme Participation

Participation is effected through appointed National Coordinating Centres.

Functions of the National Coordinating Centres

(a) Identifying, selecting and obtaining documents relevant to the goals of the network.

(b) Preparing and forwarding input sheets for the selected documents.

(c) Disseminating the products and services of the network to the local users.

(d) Providing copies of documents from the national programmes on request.

In addition, functions of coordination and intercommunication may be added for selected centres especially in those countries with multiple centres.

Networking and Collaborative Strategy

The old tradition of interlibrary cooperation may make it easier for the information network to spread faster into the various countries than the R&D network. This has the advantage that all information within the region will be available to our users. Information and documentation may therefore turn out to be the pioneering activity for PESTNET in some countries.

Due to the specialist nature of information and documentation operations, only PMDISS administrative and protocol issues will be channeled through zonal offices. Services and other professional matters will be dealt with directly with the National Coordinating Centres or the users. This will reduce the turn around time of answers to queries of professional nature.

It should therefore cultivate appropriate relationships with such systems for mutual benefit. Part of the strategy will be to go out and identify relevant networks and form links with them.

DISSEMINATION SERVICES AND PRODUCTS

The ultimate goal for all PMDISS activities is to make the retrieval of information on Pest Management quick and easily available to users. It is, therefore, imperative that the products of the database that act as search tools be as efficient and as fast as possible. In addition to providing information requested by users, enquiries are normally directed to other alternative sources of information.

Current Awareness Services

Individuals with a continuing interest in a clearly defined field need to remain currently informed about what is presently being published. This is achieved through periodically reviewing the latest issues of the relevant journals, examining the table of contents of current journals, and reviewing relevant indexing and abstracting journal.

With limited resources, this need is met by using Selective Dissemination of Information (SDI) whereby interest profiles are prepared for individuals or groups of individuals to represent their subject area of interest.

PMDISS achieves this by:

- Periodical bulletins: a current awareness publication listing new materials in the database.

- Cumulative printed indexes by subject, species, author and other bibliographic features.

- Databases searches on request.

- Bibliographies produced from time to time on subjects of tropical interest.

- Records of specialists, institutions and projects majoring in Pest Management.

Retrospective Searches

In addition to current literature, there is need for retrospective literature searching. This is normally done on request to enable users to know what has been published in the past on a particular subject of interest.

Document Delivery Services

A good current awareness service generates an increased demand for copies of the actual publications. PMDISS is therefore putting a lot of emphasis on document delivery. Every effort is made to acquire a copy of every document described in the database.

Question and Answer Service

Certain questions on Pest Management problems cannot be answered satisfactorily by sending references. This calls for more specialist attention than the documentation centre can give. Such questions cannot be answered or handled by an information worker directly and are re-directed to specialists within the PESTNET Network.

ACHIEVEMENTS

For some time, ground work has been going on for the implementation of PMDISS. The following are some of the major preparations that have been made.

(a) A planning workshop was held in November 1989 to enable potential participants in the network to contribute to the blue print of the PMDISS. In addition, several briefing sessions at PESTNET methodology workshops were organised.

(b) All relevant documentary material received at the PMDISS Regional centre is being analysed and entered into the database. Scanning of all relevant sources of information is an on-going process.

(c) Collection of publications and grey literature on insect pest management, especially that of crop borers.

(d) An Information Training Workshop was held in Entebbe, Uganda on 4th–8th August 1991 to train representatives of the National Coordinating Centres on the PMDISS methodology and to evaluate the PMDISS tools. This included the input sheets and a manual for information processing.

(e) Appropriate computer hardware and software for setting up the database has been acquired, installed and tested at the regional centre.

(f) Microfiching equipment and reader/printers have been installed at the regional centre.

(g) A documentalist and data entry technician have been appointed.

(h) Initial links have been made with the following centres to start operating as PMDISS National Coordinating Centres.

  (i) The Documentation and Information Centre of the Ministry of Agriculture (CDA), in Mozambique.

  (ii) Mt. Makulu Central Research Station Library in Zambia.

  (iii) The National Agricultural Documentation and Information Centre (NADIC), Ministry of Agriculture, Animal Industry and Fisheries, in Uganda.

In the near future, the Information Centre of the Institut des Sciences Agronomiques du Rwanda (ISAR) in Rwanda, may well become the National Coordinating Centre for Rwanda.

The above centres have received some publications from the PMDISS Regional Centre as reference material and will be receiving all current awareness material in the future. They are also to assist in the collection of information of interest to PMDISS from their respective countries.

For the National Coordinating Centres to function well, PMDISS is assisting them in the following ways:

(a) A small operational budget is provided for the centres to improve their capabilities in procuring documents from individuals and institutions.

(b) Equipment: Microfiche reader-printers have been recommended particularly to ease the problem of document delivery.

(c) Training of staff in documentation work especially on PMDISS methodology and to improve dissemination of information to potential users in all the countries concerned.

FUTURE PLANS

The following are the planned activities of PMDISS for the next three to four years:

(a) Follow-up Workshops and visits to the National Coordinating Centres.

(b) Provision of expanded facilities to facilitate the publication of PMDISS products.

(c) Installation of an on-line facility at the PMDISS headquarters to enable initiation of work on putting the PMDISS database on CD-ROM.

(d) Carrying out a user survey to determine the PESTNET information needs and to develop a profile for SDI services.

(e) Continue to expand and strengthen linkages with other networks, e.g. INIBAP, SACCAR and PADIS; and thereby begin to participate in the International Information System for the Agricultural Sciences and Technology (AGRIS).

(f) Human resource development.

(g) Instal microfiche reader/printers in the 4 pilot countries in which PMDISS will be operating, and initiate operation in countries where PESTNET is starting operations.

ICIPE'S EXPERIENCE IN COLLABORATIVE RESEARCH AND NETWORKING: MOBILISATION OF RESOURCES FOR R&D NETWORKING

R.A. ODINGO
Planning and Development Unit,
The International Centre of Insect Physiology and Ecology (ICIPE)

STRATEGIC PLANNING

A common ground is being reached by the international development community. In the World Bank report on Africa released in November 1989, this common and high ground is seen as "human-centred development" while UNDP and ECA's latest concern is for democratising development and therefore also making development people-oriented. The ICIPE recognised the need for mission-oriented research and capacity building, and therefore, people-oriented development from its very inception twenty-one years ago. People involvement is part of ICIPE's mandate and is its very fabric of operation. It permeates its governance, management, scientists, donors, and the people it seeks to serve. The latter includes even the pastoral community participating in making tsetse traps or the farmers in the rural areas who share their knowledge base as part of the scientific team developing technology for managing crop borers. Better still, every year, ten to fifteen Ph.D. scholars graduate from the African Regional Postgraduate Programme in Insect Science (ARPPIS) at the ICIPE and return to their countries in Africa to provide the much needed leadership in research and education, and for strengthening institutions. Such new-style leadership can transform the key management constraints impending development.

The Brundtland Commission on Environment and Development defines "sustainable development" as development that meets the needs of the present generation without compromising the ability of the future generations to meet their own needs. The major objective of development is the satisfaction of human needs and aspirations.

How are these needs identified? A process of strategic planning can assist in identifying the needs and priorities.

The ICIPE is managed within three-year cycles of strategic plans. The Directors' Forum which brought together Directors of Agriculture, Livestock, Health, and Research, from several African countries, in early September 1991, endorsed ICIPE's Vision and Strategic Framework for the 1990s. This Forum has brought a new dimension into ICIPE's strategic planning process and strengthened its partnership with national programmes.

Choices have to be made in the process of strategic planning. The needs of the constituency in the context of the environment should drive the national development planning (Fig. 1).

This people-oriented ideal requires an effective planning and coordination mechanism. The ICIPE established a Planning and Development Unit (PDU) in 1981. Figure 1 shows the points at which the PDU interfaces with the Management and the scientists in the process of planning and the implementation of the approved programmes.

The PDU has responsibility for:

Planning

- Strategic planning
- Project planning and monitoring
- Management audits

Resource Mobilisation and Budgeting

- Project proposals
- Project reports to donors
- Institutional programme and budget

Development

- Development of products and services from research and development results
- Capital development

Through the strategic planning process, the mandate is translated into mission and policies, which are approved by the Governing Council. In approving the scientific policy, the Governing Council is advised by its Programme Committee comprising eminent scientists in relevant disciplines; while the Executive Board comprising eminent science administrators and economists, advise the Council on resource allocation. From these policies, the Management evolves strategic goals in the context

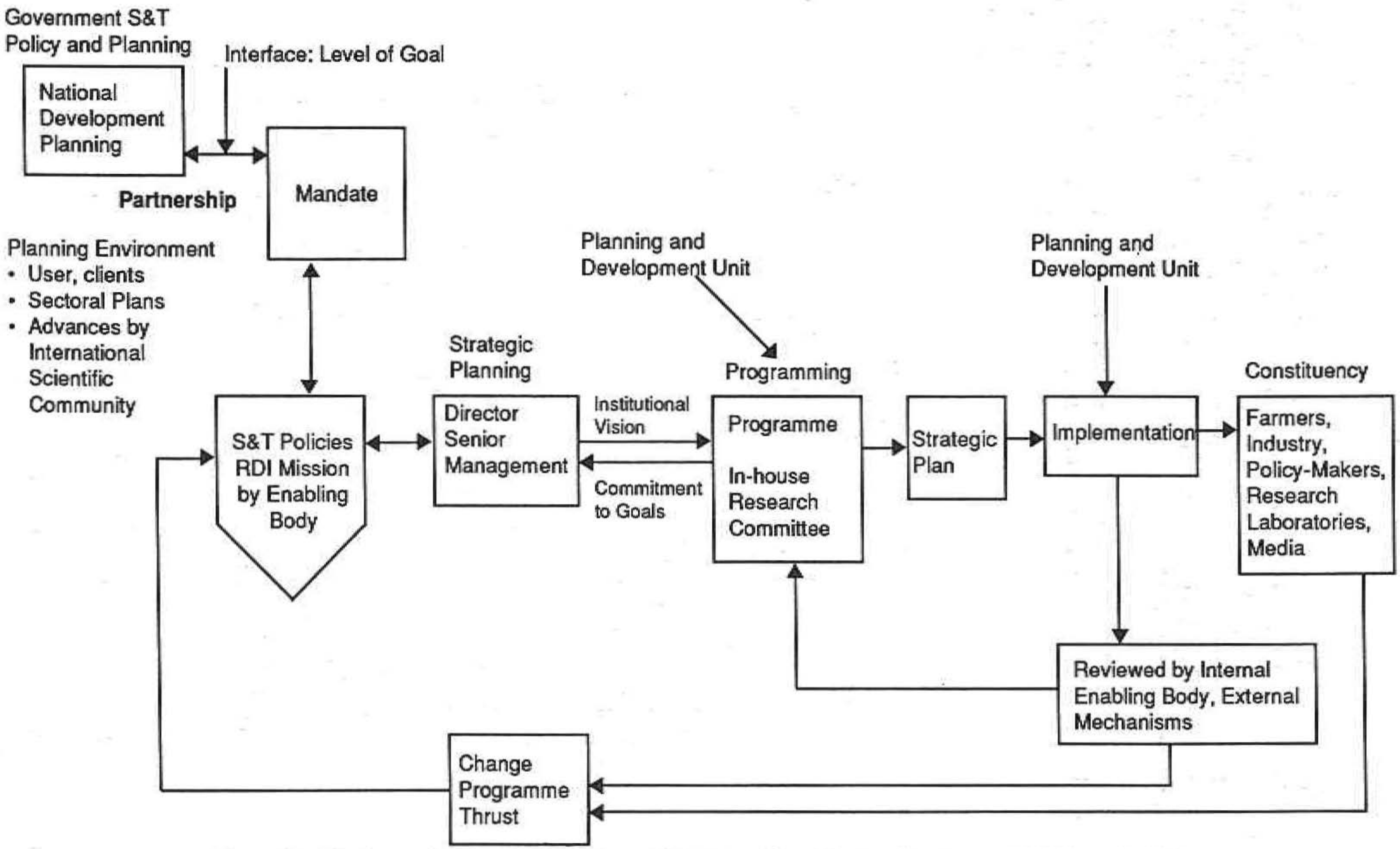

Fig. 1. Model of strategic planning: Levels at which International Centres interface with National Institutions

of the needs of ICIPE's constituency and the prevailing environment, which is embodied in its vision of the future. An interaction of scientists and planners produces broad areas of scientific activity and resource allocation and the output is the strategic plan. In this interaction, the scientists know the best possibilities for advancing scientific knowledge and technology while the planners know which of these possibilities can produce added value to society.

ICIPE's budgetary process is closely linked to the management and programming of scientific activities through this strategic planning process. This is necessary because

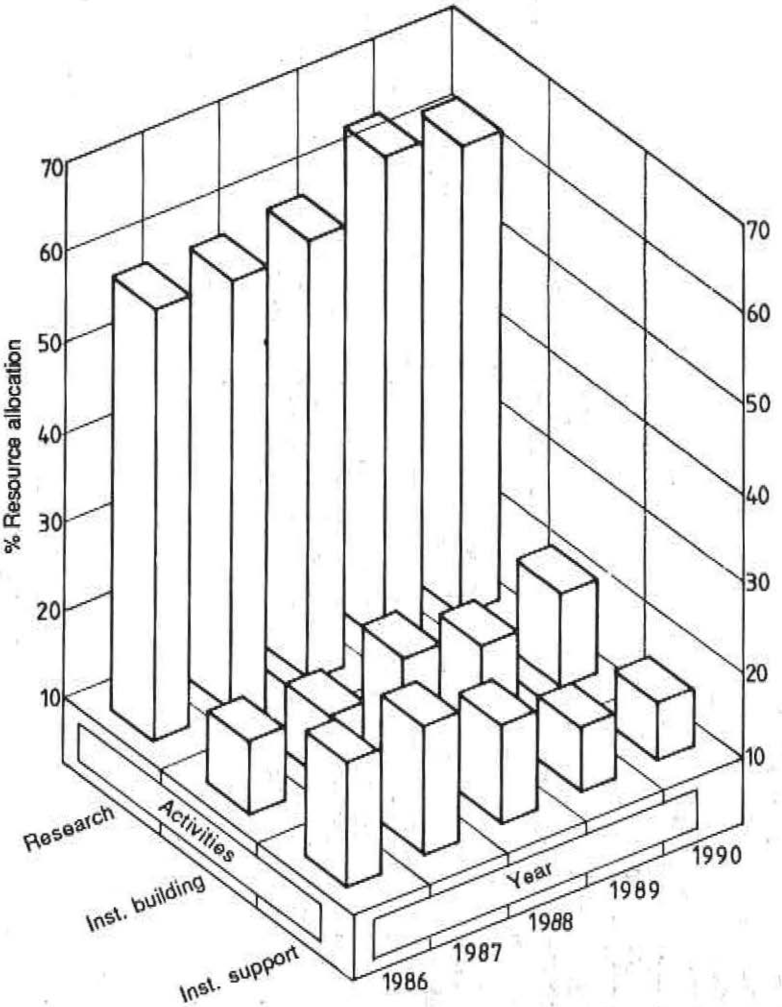

Fig. 2. ICIPE resource allocation 1986–1990

the ICIPE has no long-term guaranteed base level budget and income to finance it. For every budget cycle, the total budget is reviewed in terms of the programme thrust; and the funds mobilised and allocated according to the approved priority in the strategic plan. In this budget process, the PDU analyses with individual Programme, their programme activity and relate allocation of budgetary provision to those areas with high pay-off.

ICIPE's annual budget has grown from US $23,000 in 1970 to $11 million in 1991. Because the Centre exists to generate knowledge and technology, and to offer education and training for capacity building, the resources are devoted to programme activities. Direct research costs therefore account for 57% of the operating costs; 25% is allocated to training, information and networking; while institutional costs (overheads) account for only 18% (Fig. 2).

Monitoring and evaluation are key elements in project management. The ICIPE has instituted several mechanisms which include project reports, reviews at Annual Research Conferences and an external review appointed by the donors every three to four years. These reviews measure outputs against costs in terms of economic and social benefits to its constituency.

NETWORKING

The previous speakers have elaborated on the purposes of networks. There are centralised networks operating from one central point and radiating information outwards to the members. There are decentralised networks whose purpose is not only access to information but also brings people together to generate and apply technology. In Fig. 3, an attempt is made to illustrate the second model with the PESTNET **network.**

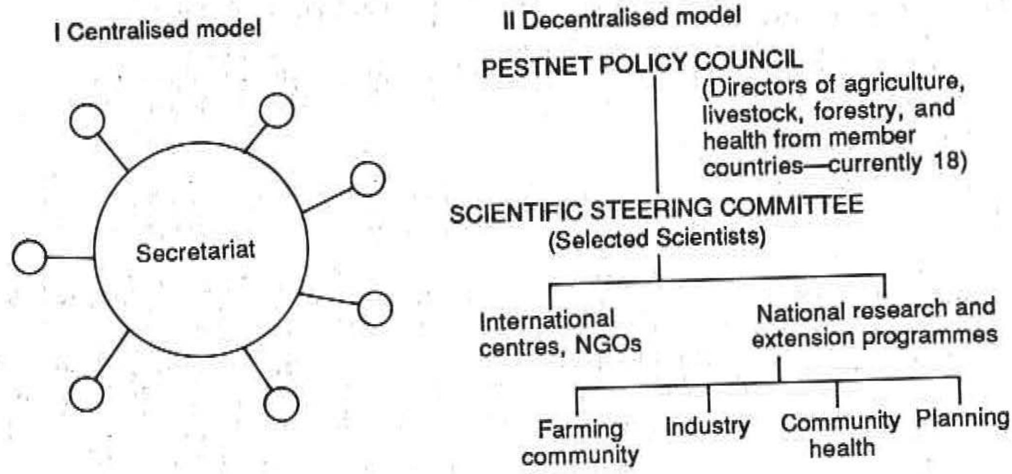

Fig. 3. Model 2 of PESTNET

Networks mobilise people around key issues of importance and they survive only to the extent that they have well defined aims and priorities, contributions of the members and the benefits of the network to each member. Networks are effective in tackling regional problems.

The principle of integrated pest management (IPM) which seeks to apply the pest management strategy in the stage of the pest's minimum mobility makes ICIPE's long-term approach to locust control very cost-effective and offers opportunity for maximising the benefits through networking. In this case, through networking, each country can apply the technology in the recession areas (within it). They would also provide advocacy for a regional effort in managing this migratory pest. However, networking is not a substitute for the main task of improving national programmes. In this respect, the network can play a role in institution building through training workshops and travel of scientists to more advanced research laboratories to learn new techniques and advances in science. In this way, the National Programmes will become self-reliant while at the same time making for a stronger network of collaborating partners. It is important to harmonise the work of networks so that the same people are not overstretched by several networks operating in the same country.

Plucknett has identified several prerequisites for the success of networks. I have reviewed some of these as they relate to the funding and sustainability of networks , and as they apply to the ICIPE:

- Defined problem and agenda for action
- Harmonisation of work of networks within a country
- Regional consortium approach leads to cost reduction and maximum benefits
- Availability of personnel and role of network in institution building
- Strong leadership (Steering Committee and Coordinator)
- Donor funds required for meetings, publications and research
- Membership willing to commit resources for long-term sustainability

Defined problem and agenda for action assures strong self-interest and the desired research thrust should make it possible to include it in the national programme for funding.

Harmonisation of work of networks within a country safeguards against over-stretching the people and against spreading funds too thinly among several networks.

Regional consortium approach leads to cost reductions and to maximum benefits. This is one reason which makes networks attractive to external donors. Networking reduces cost by reducing duplication of efforts while benefitting from the strength of each of the participants. They use existing facilities and staff, and share existing information for generation of new knowledge and technology.

Availability of personnel makes for strong networks because the partners can participate fully; while at the same time networks have a role in institution building in strengthening the weaker partners.

Strong leadership is imperative for successful networking. Networks must be organised under strong leadership. Effective coordination is a major factor in obtaining the commitment from the members. A coordinator acts as a focal point for the distribution of information and for convening meetings.

Donor funds are usually required to support the initial stages of the network to facilitate initial research, meetings, publications and travel. However, long-term funding must come from the national governments and industry and therefore the success of the network will depend on the commitment of the members.

Members willingness to commit resources can assure sustainability of the network. Grants from outside cannot be guaranteed to continue indefinitely. The association of donors could preclude some countries, and in these days of human rights index and democracy, some countries within the network may be regarded by some donors as undesirable. At least governments can and do provide personnel and facilities, while industry could support those activities which have potential returns for it.

ICIPE'S EXPERIENCE IN PARTNERSHIP NETWORKS

In participating in networks, the ICIPE has applied the principle of partnership of independent, self-sustaining members with a shared commitment to goals. These networks have therefore been preceded by Planning Workshops which have identified and defined the problems and agreed on a plan of action.

The African Regional Postgraduate Programme in Insect Science (ARPPIS) was established at the Planning Workshop held at the Rockefeller Foundation Bellagio Study and Conference Centre in 1981. On this occasion, African Universities and Research Centres agreed to pool limited resources to start a Ph.D. degree programme in insect science at the ICIPE. This network now embraces 20 African Universities and serves many research centres. Its programme is managed by the Academic Board composed of representatives of all the participating universities.

Following the same pattern, the Pest Management Research and Development Network (PESTNET) was established after two Planning Workshops held in Nairobi in 1985 and 1986. Its research priorities are set by the Steering Committee which will from 1992 be guided by a Policy Council comprising of Directors of Agriculture, Livestock, Forestry, and Health from the member countries.

As alluded to earlier, donor funds are usually needed in the initial stages of establishing a network. In the experience of ARPPIS and PESTNET, this is important. For both of these networks, some donors were willing to take the risk and provided seed funds which steered these networks through their infancy (Tables 1 and 2).

Table 1: ARPPIS Funding

	1983–1985	1986–1991
PLANNING (1981)	• Rockefeller Foundation	
SECRETARIAT — Administration — Academic Board — Publications	• Australia • Arab Fund for Econ. Dev. in Africa	• ICIPE Core Funds
TEACHING STAFF	• ICIPE • Participating Universities	• ICIPE • Participating Universities
STUDENT FELLOWSHIPS	• Ford Foundation • Germany • Netherlands • UNDP • IFAD • USAID	• Ford Foundation • Germany • Netherlands • UNDP • IFAD • USAID • Sweden • Norway • Denmark

Table 2: PESTNET Funding (1987–1991)

Activity	Donor
Planning meetings (1985,1986)	• UNDP (+cp) • USAID
PESTNET SECRETARIAT Coordination Publications	• UNDP Regional Bureau for Africa
STEERING COMMITTEE ANNUAL CONFERENCES	• UNDP Regional Bureau for Africa • Member countries (Staff time)
Pest Management Documentation and Information	• UNDP Regional Bureau for Africa
Interactive R&D	• Participating countries • UNDP Regional Bureau for Africa

Eventually the Secretariats of these networks will be moved from the ICIPE to one of the member countries. The members would then have to select one of the stronger partners to host the Secretariat.

SESSION IV:

CLOSING

RECOMMENDATIONS

INTRODUCTION

The Locust Research Programme of the International Centre of Insect Physiology and Ecology was initiated in 1989. The long-term objective of this Programme is to develop an alternative biorational and sustainable desert locust management strategy.

In order to achieve this goal, intensive and carefully planned fundamental research of the source and nature of signals mediating the processes of gregarisation and the synchronised locust behaviour leading to swarm formation has to be undertaken. It is believed that certain semiochemicals, in particular pheromones and plant kairomones are involved. Population management may also be attained by means of biological control agents.

During the initial stages greater emphasis has been laid on laboratory investigations to provide a sound basis for field research. Field research on locust is an extremely difficult undertaking because of the mobile nature of the insect and the low numbers of solitary populations in recession areas. The recession area covers several countries in Africa, the Middle East and Asia. Hence it is important to exchange information on locust research and management between scientists within and outside the region and to facilitate collaborative efforts.

A Workshop on Effective Networking of Research and Development (R&D) on Environmentally Sustainable Locust Control Methods, Among Locust-Affected Countries was held at the ICIPE, Nairobi from the 16–18th September 1991 in order to look into the existing locust research activities and to identify future partners for collaborative research.

The participants of the Workshop from locust-affected countries, regional and international organisations as well as those from the ICIPE deliberated on various aspects of locust research and management. From the countries and institutional reports presented it became apparent that:

1. The current fire-brigade control strategy which depends on the use of insecticides is inadequate.

2. Alternative methods of control which are environmentally friendly and sustainable are needed.

3. Such new approach is information intensive and that at present, there are wide knowledge gaps especially in locust behaviour and ecology.

4. The locust-affected countries lack sufficient trained manpower in laboratory personnel, national agricultural centres and extension services, and have inadequate logistics and financial resources.

Hence, it is important that resources are pooled and efforts co-ordinated so that effective biorational and sustainable locust management strategies can be effected and be extended to the resource limited farmers.

RECOMMENDATIONS

The participants to the Workshop on Effective Networking of Research and Development on Environmentally Sustainable Locust Control Methods agreed to:

Establishment of a long-term "Collaborative Research Network on Environmentally Sustainable Locust Management" among locust-affected countries and research institutions working on locust.

Participants recommend that the network would be initially concerned with the following areas:

A. Human Resource Development:

(i) Short-term training.

(ii) Long-term graduate training.

(iii) Visiting Scientist Schemes.

B. Areas of Collaborative Research:

(i) Semiochemicals research including those derived from the host plants.

(ii) Collection of diseased locust and grasshopper materials and identification of pathogenic agents.

(iii) Ecological field studies including the testing of laboratory-generated technologies, on semiochemicals and biological control agents.

(iv) Establishment of at least one field base as appropriate, to facilitate the ecological studies in the locust recession areas.

C. The establishment and strengthening of collaboration with relevant national, regional and international institutions. There should be a strong interface with national extension services and farmers to serve the development of appropriate strategies.

D. Information Exchange and Retrieval:

(i) The provision and exchange of relevant literature using the existing PMDISS network.

(ii) Production of a newsletter highlighting relevant locust research.

(iii) The convening of a workshop to exchange information on research findings every two years.

IMPLEMENTATION

The ICIPE, as the lead institution, will prepare a draft proposal for submission to donors. This proposal will set out in detail the modalities for operating the network the initiation and approval of research projects and an initial administrative budget for the first phase of the network. This draft proposal will be finalised at a further meeting with countries, and donor institutions interested in joining or supporting the network.

CLOSING REMARKS

P.B. CAPSTICK
Deputy Director of Research,
The International Centre of Insect Physiology and Ecology (ICIPE)

Prof. Schultz, Mr. Mathur, distinguished guests and colleagues, it seems that we have finished our work here today and it is my pleasure to make a few closing remarks about the Workshop.

During, the last three days several significant things have occurred. Firstly, we have learnt a good deal about each others needs and the constraints that we each have. I personally have a much better understanding of the immediate history of the locust plague in Egypt, Libya and the Sudan and the constraints that have influenced the control actions that have been taken in the recent past.

Secondly, I am sure that those of you who are visiting us have a clearer understanding of the research and development thrusts in which ICIPE is involved and of the very early stage of our research. At the least, I am sure that you take away with you an informed picture of the excellent facilities that we have managed to assemble with the help of the donor community, guided and mobilised by IFAD.

Thirdly, during your deliberations you have recognised the need for collaboration between the various institutes and countries involved in the research, development and utilisation of locust control measures. Certainly, if we are to eventually achieve the presently distant goal of new, sustainable and environmentally acceptable locust control strategies based upon the semiochemical approaches we have described this week, we have a great deal of work ahead of us.

In this regard, I would like to stress that we are still at the beginning of the research and development process. ICIPE has, from the outset, stressed that this approach gives no guarantee of success and will require several years of concentrated, well funded, effort. We must be careful that we do not enthusiastically assume that the positive research results we have achieved so far represent the basis of new control strategies.

They do not. They do however provide encouraging evidence that we may be on the right path.

I believe it is important that the locust programme does not become an ivory tower generating merely interesting scientific results. This is a mission-oriented programme and it is essential that it does not lose sight of where and why the project was commenced. Which is why I am pleased that at this early stage in our research we have made positive contact with some of the countries whom we hope will be the eventual benefactors of our efforts. Indeed, if our solutions are to be realistic they must be developed in the context of field experience.

So we have taken the important step of recommending the formation of a network that will bring the countries and research institutions involved much closer together. I am sure that the framework of research collaborations, capacity building and information exchange that you have recommended will have major beneficial effects on the members of the network.

I must stress again, however, that this is a research network and not intended to supplant the existing control organisations who must remain in place to contain plagues in the immediate future using the measures that are currently available. Let us hope that our endeavours eventually make their control operations easier.

It remains for me to thank you all for having given up so much of your valuable time to come and attend this Workshop. I believe it has been well worthwhile and I would especially like to thank Professor Dr. Schultz and Mr. Mathur for accepting the task of chairing the most difficult sessions. The Working Group had a difficult task to formulate the deliberations of the Workshop into an acceptable format, and I am most grateful to them and to Mr. Mathur for chairing the group into the late hours last night.

But your presentations and contributions to the discussions have been the real basis of the Workshop and I would like to thank you all for coming and hope that this will be the first of many occasions on which we shall meet.

I would also like to express my thanks to the Organising Committee especially Miss Washika and her team of helpers.

Lastly, I would like to thank those donors represented here by Mr. Mathur whose financial assistance have made these last three days possible.

Thank you all, have a safe journey home.

ACRONYMS AND ABBREVIATIONS

AGRHYMET	Agronomie Hydrologie Météorologie (CILSS)
ARPPIS	African Regional Postgraduate Programme in Insect Science
ARTEMIS	African Real Time Environmental Monitoring and Information System
AVHRR	Advanced Very High Resolution Radiometer (NOAA satellite)
BCP	Biological Control Programme (IITA)
CABI	CAB International (formerly Commonwealth Agricultural Bureau)
CDA	The Documentation and Information Centre of the Ministry of Agriculture (Mozambique)
CD-ROM	Compact Disc Read Only Memory
CGLR	Consultative Group on Locust Research
CIDA	Canadian International Development Agency
CILSS	Interstate Committee for Drought Control in the Sahel (Comite Inter-Etats pour la Lutte contre la Secheresse dans le Sahel)
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement
DFPV	Department pour la Formation en Protection des Vegetaux
DGIS	Netherlands Directorate General for International Cooperation

DLCO-EA	Desert Locust Control Organisation for Eastern Africa
EEC	European Economic Community
EHTU	Ecologically homogeneous territorial unit
FAO	Food and Agriculture Organisation
g.a.i.	grammes of active ingredients
ICIPE	International Centre of Insect Physiology and Ecology
IFAD	International Fund for Agricultural Development
IIBC	International Institute for Biological Control
IITA	International Institute of Tropical Agriculture
INIBAP	International Network for Improvement of Banana and Plantain
IRLCO-CSA	International Red Locust Control Organisation for Central and Southern Africa
ISAR	Information Centre of the Institut des Sciences du Rwanda
LANDSAT TM	Land Satellite-Thematic Mapper
METEOSAT	Meteorological Satellite (European)
NADIC	The National and Agricultural Documentation and Information Centre (Uganda)
NOAA	National Oceanic and Atmospheric Administration
NRI	National Resource Institute (ODA)
OAU	Organisation of African Unity
OCLALAV	Office Centrale pour la Lutte Anti-acridiene et anti-avaire
ODA	Overseas Development Administration (UK)
PADIS	Pan-African Development Information System
PDU	Planning and Development Unit (ICIPE)

PESTNET	Pest Management Research and Development Network
PMDISS	Pest Management Documentation and Information System and Service
PPD	Plant Protection Directorate (Sudan)
PRIFAS	Acridologie Operationnelle — Ecoforce Internationale (Programme del Recherche Interdisciplinaire Francais pour l'Acridologie Sahelian)
SACCAR	Southern Africa Centre for Cooperation in Agricultural Research
SPOT	Satellite Probatoire d'Observation de la Terre
ULV	Ultra Low Volume
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific, and Cultural Organisation
USAID	US Agency for International Development
VRU	Variable Restrictor Unit

PROGRAMME AND LIST OF PARTICIPANTS

Monday, 16th September 1991

	OPENING
1330–1400 Hours	Registration of Participants
	SESSION I:
	CHAIRMAN: Dr. P.B. Capstick Deputy Director, ICIPE
1400–1415	WELCOMING REMARKS Prof. Thomas R. Odhiambo Director of the ICIPE
1415–1445	OPENING ADDRESS Mr. S. Mathur Economist, Technical Advisory Division International Fund for Agricultural Development (IFAD) Rome
1445–1515	An Overview on Research and Policies Prof. S. El Bashir Leader, Locust Research Programme
1515–1545	GROUP PHOTOGRAPH
	TEA/COFFEE BREAK

1545–1605	Locust Semiochemicals Research Prof. A. Hassanali Head, Chemistry and Biochemistry Research Unit
1605–1625	Behaviour Research on Desert Locust Dr. R.K. Saini Ag. Head, Sensory Physiology Research Unit
1625–1645	Locust Biocontrol Research Dr. S.K. Raina Locust Research Programme
1645–1705	Locust Rearing Dr. J.P.R Ochieng'-Odero Head, Insect and Animal Breeding Unit
1705–1730	DISCUSSION
1830 Hours	RECEPTION

Tuesday, 17th September 1991

SESSION II:

CHAIRMAN: Mr. S. Mathur

COUNTRY AND INSTITUTIONAL REPORTS

A. Country Reports

0900–0920	EGYPT: Dr. A.M. El-Gammal and Mr. Abdulla Gah El-Rasoul
0920–0940	LIBYA: Dr. Abdulgader Azzi
0940–1000	SUDAN: Mr. Hassan Abbas El-Tom and Mr. Shaaban S. Barsi
1000–1030	TEA/COFFEE BREAK

B. Institutional Reports

1030–1050	Mr. C. Muinamia Research Officer, DLCO-EA
1050–1110	The Specific Biomodel of the Desert Locust (Principles and Application) Dr. My Hanh Launois Luong CIRAD/PRIFAS
1110–1130	Dr. Mathew Cock IITA BCP/DFPV/IIBC Locust and Grasshopper Control Programme
1130–1150	Description of the Locust Biotopes in its Western Zone Habitats Dr. Michel Lecoq CIRAD/PRIFAS
1150–1210	Mr.Wolfgang Meinzingen Project Manager, UNDP/FAO/RAF/88/033
1210–1230	Dr. A.D. Gadabu Deputy Director IRLCO-CSA
1230–1250	Validation of Information Generated by Satellite in Order to Identify the Potentially Favourable Zones to the Desert Locust Mrs. Marie Francoise Grimaux CIRAD/PRIFAS
1250–1315	DISCUSSION
1315–1415	LUNCH BREAK

SESSION III:

CHAIRMAN: Prof. F.A. Schulz
Chairman
UNDP/FAO
Scientific Advisory
Committee (SAC)

	ICIPE'S EXPERIENCE IN COLLABORATIVE RESEARCH AND NETWORKING
1415–1435	Research Collaboration (Lead paper by Prof. S. El Bashir, Programme Leader, Locust Research Programme)
1435–1505	Capacity Building and Networking: ICIPE's Experience (Lead paper by Prof. Z.T. Dabrowski, Training Coordinator, ICIPE)
1505–1525	Information and Documentation (Lead paper by Miss D. Barasa, Documentalist, ICIPE)
1525–1600	TEA/COFFEE BREAK
1600–1615	Mobilisation of Resources for R&D Networking (Lead paper by Mrs. R.A. Odingo, Chief Planning Officer, PDU)
1615–1730	DISCUSSION

Wednesday, 18th September 1991

	Visit to Laboratories in ICIPE R&D Complex and Insect and Animal Breeding Unit
0830–1030	Visit to Laboratories
1030–1100	TEA/COFFEE BREAK
	SESSION IV:
	CHAIRMAN: Dr. P.B. Capstick Deputy Director, ICIPE
1100–1245	RECOMMENDATIONS
1245–1300	CLOSING REMARKS Dr. P.B. Capstick Deputy Director, ICIPE
1300 Hours	LUNCH BREAK
1900 Hours	CLOSING DINNER

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