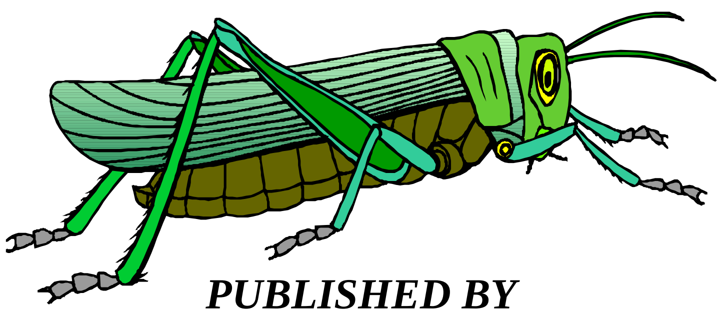
ADVANCES IN APPLIED ACRIDOLOGY - 2000



PUBLISHED BY

The Association for Applied Acridology International

Solutions without Limits by Scientists without Borders

PREFACE

As pest management techniques, perspectives, and products have become increasingly sophisticated in the last 20 years, our capacity to adapt and transfer the methods and knowledge has declined. Formerly effective programs have dramatically diminished their roles in assisting afflicted regions. While the ability for any single nation to sustain a critical mass of expertise in acridid (grasshopper and locust) pest management has diminished, the quality of geographically dispersed experience and knowledge is extremely high. The *Association for Applied Acridology International* has brought together the world's leading practitioners in this field to develop and provide unbiased analyses along with culturally, technologically, economically, and environmentally appropriate methods for managing locust and grasshopper outbreaks. The *Association* is the first and only humanitarian-based, NGO of entomologists in the world, providing expert advice, training, and applied research to people and nations in need. The demonstrable capacity of grasshopper and locust outbreaks to reduce the standard of living, displace human populations, induce famine, and erode environmental quality demands the highest level of practical expertise and experience in order to rapidly build the capacity of agricultural communities to implement safe and effective prevention and control programs. The *Association* consists of 26 Associates from 19 nations, representing more than 300 years of collective experience and 14 Institutional Partners comprising the world's best organizations dedicated to the study and management of acridids.

It is my distinct pleasure to have facilitated the production of the first issue of *Advances in Applied Acridology*, and it is my fervent hope that this report on the state of the art will become an annual publication. The purpose of this report is to clearly and concisely summarize the major developments in applied acridology within the last year for the scientific and management communities. As such, the report is organized into sections that are intended to provide a clear context for the reader to access the information. I would hasten to note that each author was limited to a single page of text in an effort to keep the report as "tight" and information-rich as possible. As such, the reader may find that an article of particular interest has rather less detail than desired. And this is precisely why we have provided the email address of each author; I invite you to directly contact the authors for further information on matters of compelling interest.

The editing of this issue consisted of generating a consistent presentation of the information, spelling, grammatical corrections, formatting, and organization. However, in no case was the editing intended to alter the meaning of the text, nor was there any attempt to "standardize" the information or generate consensus. As such, the reader may find instances in which reports make claims that are not in agreement – and such is the nature of the *Association for Applied Acridology International*. We do not constrain our Associates to a particular "party line". They are the finest scientists and managers in the world of grasshopper and locust bionomics, and we allow them complete intellectual freedom and professional autonomy to assess situations in the most rigorous and objective manner possible. As such, complex events and technologies may be perceived differently by our various Associates, and the opinions and judgements of this publication are those of the authors.

Finally, if you have any suggestions for how we might make the next issue of *Advances in Applied Acridology* more useful, informative, or relevant, please do not hesitate to contact me by phone (1-307-766-4260), fax (1-307-766-5025), or email (lockwood@uwyo.edu).

Jeffrey A. Lockwood
Director, *Association for Applied Acridology International*
1 March 2000

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SURVEY, FORECAST, AND DECISION SUPPORT

New Aerial Survey Strategy Finds Locust Swarms in the Punishing Terrain of Madagascar

R. Brown, South Africa, Plant Protection Research Institute, rietdb@plant2.agric.za

In support of control operations, a spotter aircraft (high wing Cessna 210) provided by South Africa, was flown to Madagascar to assist with aerial survey and reconnaissance (detection of locust targets remains a major constraint) specifically to demonstrate the concept of using a mixed fleet of fixed wing and rotary wing aircraft for scouting. Previously, only helicopters were used to locate swarm targets in Madagascar. Altogether, 30 h were flown over 8,000 km of punishing terrain on locust survey and intelligence gathering flights by an AAAI Associate in the Cessna.

From this beginning, a more sophisticated 'eye in the sky' type of operation has evolved. Madagascar subsequently chartered a fleet of fixed wing 'Joker' J 300, microlight aircraft and equipped these with advanced GPS map-guidance and satellite tracking systems. Digital zoom cameras were also used to record each spray target. In a follow up assignment, the purpose of which was to evaluate and report on the performance of the Joker operation, it was clear that a previously unimaginable advance had been made in the detection of flying swarms.

Not only was a more systematic aerial search for targets now possible, on to which spray aircraft could be vectored in by radio, but a full record of swarm details, such as type (stratiform or cumuliform), size, flying height, position, direction, *etc*. had become possible. On return to base, this information could be downloaded onto a computer and transferred as an email attachment. Visual proof of spray targets and precise tracks flown during air sorties were thus made immediately available to office controllers and could be permanently stored. Such unequivocal evidence of actual operations also served as a useful tool for mobilizing resources by management.

Brown Locust Survey System in Southern Africa Remains Vigilant During Recession

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The Plant Protection Research Institute issued five, brown locust (*Locustana pardalina*) early warning system (BLEWS) bulletins during 1999. The bulletins provide details of the number of brown locust control actions undertaken in each quarter degree square in South Africa and Namibia. Geographic Information Systems maps of the rainfall and ambient temperature are also provided. Bulletins were distributed to Departments of Agriculture and locust control officers within the southern African region as well as to the Food and Agriculture Organization of the United Nations and to some international research institutes. Brown locust situation bulletins will probably be posted on the Internet in the future to make them more widely available.

LOCDAT – A New Locust Database in Mauritania

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A new locust database was established in Mauritania in cooperation with the CLAA (Centre de la Lutte Antiacridienne) and GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit). Rather than fitting data into a particular format, the database was designed to fit existing data (locust survey and control radio protocols from 1989-99). LOCDAT comprises more than 160 different variables, including data on soil, relief, vegetation, locust breeding and locust control, in more than 15,000 data sets. LOCDAT provides a practical tool to monitor and improve locust surveys and control operations and to analyze ecological aspects of desert locust management on a landscape level.

Acknowledgement This study was funded by the governments of Canada, United Kingdom, Germany, Netherlands and Switzerland. These countries are acknowledged for their support. Cooperators in this project included: S. Attignon (IITA, Benin), S. A. Demba (CLAA, Mauritania), S. ould Ely (CLAA, Mauritania and ICIPE, Sudan), I. Rieger (NLU), I. Stolz (NLU). For details about our research visit our homepage (1 April 2000) at http://www.nlu.unibas.ch ihttp://www.nlu.unibas.chà

Potential for Integrating Locust and Sunn Pest Surveys in Turkey

C. Lomer, Turkey, Bilkent University, and J. Langewald (LUBILOSA), lomer@fen.bilkent.edu.tr)

Locusts are only occasionally pests in Turkey, the Moroccan locust sometimes entering from Crete or other Mediterranean breeding sites. A survey and forecast network exists for reporting on the sunn pest, *Eurygaster spp*. (Heteroptera: Scutelleridae), and this functions effectively. Some effort would be needed to include locust reporting in this framework. There might be a possibility of expanding a regional information network to cover both sunn pests and locusts, although this would take considerable investment of resources.

Technological Refinements of Locust Survey Improve Forecasting in Australia

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The Australian Plague Locust Commission integrates the latest locust and weather information into a Decision Support System (DSS) that forecasts the extent and timing of locust outbreaks so preparations can be made for their control. The basis of the DSS is information on habitat preferences, locust distribution and rainfall as analyzed in a Geographic Information System (GIS). Improvements in the past year have included direct transfer of locust survey data from the field by high frequency radio link to the GIS and application of National Oceanic and Atmospheric Administration (NOAA) data to more accurately detect areas of green vegetation. Locust migrations are modeled using a wind trajectory model, and the accuracy of the model outputs is being tested using a network of light traps and two vertically pointing radars positioned at inland sites to detect locust movements.

GIS and Satellite Imagery Enhance Grasshopper Surveys in Argentina

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In the southwestern Buenos Aires province (Benito Juárez county) of Argentina, an area historically prone to grasshopper outbreaks, seasonal surveys of grasshopper densities and species diversity have been conducted since 1996 by a joint research team from La Plata National University (UNLP) and the Direction of Satellite Images (DAIS). Geographic Information Systems (GIS) and remote sensing techniques are being used to study environmental factors governing population dynamics of grasshoppers.

For each year, remote sensing (Landsat TM) data are used to generate and update landuse coverages that are integrated into the GIS. Maps of landscape, annual rainfall, soil texture, and soil type are superimposed on the grasshopper historical density map for analysis. More details can be found in Cigliano & Torrusio (1999).

New Approaches Allow Fast, Accurate, and Cost-Effective Grasshopper Surveys in the US

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Due to federal budget cuts, the United States Department of Agriculture abandoned the rangeland grasshopper survey in 1996. Sound pest management requires information on the spatial distribution and population densities of pests. Based on development of a Geographic Information System for rangeland grasshoppers in Wyoming and collaborative research to develop a sequential, binomial sampling system for grasshoppers, we developed a "complete survey package" that has been implemented throughout Wyoming 1998-1999. This survey provided the information necessary for six counties to qualify for federal disaster relief and allowed pest managers to prepare for the impending outbreak.

Computerized Decision-Support System Provides Reliable Assistance to Pest Managers

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With the federal and state governments withdrawing from rangeland grasshopper survey and control programs in the 1990s, local pest managers and agricultural producers need reliable information regarding control strategies. A cooperative project with the University of Wyoming's Artificial Intelligence Laboratory developed a decision-support software system (CAse-based Rangeland Management Advisor, CARMA) that allows inexperienced users to generate forage loss estimates and action recommendations that are indistinguishable from those that would be provided by a panel of human experts. Pest management districts have been trained in the use of CARMA.

CONTROL: CHEMICAL

Viability of Swarm and Band/Barrier Control of Locusts in Madagascar

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Intervention tactics against migrating swarms dictate the use of fast acting insecticides. A demonstration trial with a newly developed chloronicotinyl compound -- imidacloprid UL (Trade name Confidor®) -- was therefore conducted in northern Madagascar. Like the synthetic pyrethroids, toxicity was almost immediate with subsequent high kills recorded, confirming its use for adult swarm control. The use of lower dosage rates of deltamethrin UL (Decis®) against adult swarms was also monitored during routine aerial operations and found to give effective control.

One mission involved monitoring a residual swarming population found in the barrier treatment areas, at the conclusion of the campaign in April 1999. Given that the swarms were determined to be of local origin and that 70,000 ha of young adult swarms had to be treated afterwards in this area, there were serious doubts about the efficiency of barrier spraying for hopper control with fipronil UL.

Imidacloprid Shows Promise Against the Migratory Locust in Madagascar

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Product development with imidacloprid 10UL (trade name Confidor®) was undertaken for Bayer (Pty) Ltd against adult swarms of the Malagasy migratory locust in northwestern Madagascar. A consultancy report on the efficacy of the aerial application was submitted to Bayer.

Fipronil and Fenitrothion for Locust Control in Australia: Less is More

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Fipronil (Adonis® 8.5 UL) was tested operationally against Australian plague locust, *Chortoicetes terminifera*, nymphs (bands) and adult swarms, and the chemical was found to be effective at 1.25 and 0.6 g a.i./ha. At the latter dose, mortality was 70% in 2 days increasing to >95% in 4 days at temperatures of 27 to 32 ºC (moderate field temperatures by Australian standards). At higher temperatures of 35 to 42 ºC, mortality at the higher dose was usually >95% within 2 days of treatment. It was further noted that fipronil appears to work more quickly when locusts are heat stressed.

During 1996, an outbreak of migratory locust, *Locusta migratoria*, began and the Queensland Department of Natural Resources with technical assistance from the Australian Plague Locust Commission (APLC) undertook a program of preventive control. During 1996 to 1998, treatment of 5,000 to 15,000 ha was able to keep populations in check but an extra generation in early spring 1998 produced a larger population. Treatment of 70,000 ha in each of the next two generations led to population collapse with little control required in the third generation. During these control operations decreasing doses of fenitrothion (Sumithion® ULV) were evaluated.

Following initial control of 4,000 ha at 510 g ai/ha, a further 135,000 ha was treated at 320 to 380 g ai/ha with equivalent efficacy. This reduction in insecticide use represented significant cost, logistical and environmental savings.

Discontinuous Applications of Fipronil Against Acridids in Russia: Do barriers work?

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In 1997-1999, a series of trials of a water-based formulation of fipronil, Adonis® 40EC, was conducted in several locations in Russia by the specialists of the All-Russian Research Institute for Plant Protection (VIZR) in St. Petersburg. Results of two of the trials are discussed below.

In Volgograd region (South of Russia's European part), the targets were represented by hopper bands (mostly 1-2 instars) of the Italian locust (*Calliptamus italicus*), with pretreatment densities ranging from 1,045 to 1,177 individuals/m^2. The standard treatment consisted of a blanket application of the pyrethroid deltamethrin (Decis®) at a dose rate of 12.5 g of a.i./ha. Fipronil was applied to 50% of the area, by alternating swaths of 24 m wide. The dose rate in the "barriers" was 4 g of a.i./ha (*i.e.*, 2 g of a.i. per protected ha). Both treatments were applied to 30 ha using a boom nozzle tractor-drawn sprayer. In both cases, emulsifiable concentrate formulations were used. The results are summarized in the following table.

Treatment / Day	**D 0**	**D 1**	**D 2**	**D 3**	**D 5**	**D 8**	**D 15**	**D 22**	**D 28**
Decis, Density / m^2	1045	345	71.3	55.3	160	241	490	501	520
Decis, Mortality, %	0	67	93.1	**94.7**	84.7	77	53.1	52	50.2
Adonis, Density / m^2	1177	573	518	417	82.8	7.7	6.9	6.3	6.3
Adonis, Mortality, %	0	51	56	64.6	93	99.3	99.4	**99.5**	**99.5**

In East Siberia, the targets were represented by a community of non-swarming grasshoppers with *Aeropus sibiricus*, *Bryodema tuberculatum*, *Pararcyptera microptera*, and *Stauroderus scalaris* predominating in the assemblage. Fipronil was intended to be applied using two, parallel treated swaths of 20 m alternated with a 40 m wide untreated swath (50% coverage). However, because of the still weather and total absence of drift, the actual treated swaths were only 13 instead of 20 m wide, so that only 7.8 out of 24 ha were treated (32.5% coverage). The dose rate applied to the treated swaths was 3.08 g of a.i./ha (*i.e.*, 1.00 g of a.i. per protected ha). The posttreatment counts were done separately in the treated and untreated swaths (see the table below).

Day	D 0	D 1	D 2	D 3	D 4	D 7	D 15	D 21
TS Mortality, %	0	75.2	86.4	88.1	92	**92.9**	89.8	82.4
UTS Mortality, %	0	0	36.3	46.9	58	64.7	**72.7**	50.4
Ave. Mortality, %	0	37.2	61.4	67.5	75	78.8	**81.2**	66.4

TS - treated swaths; UTS - untreated swaths; Ave. - Average between treated and untreated swaths.

The amazing fact was that, starting from the second day post-treatment, grasshoppers began to die even in the untreated swaths! The probable reasons are: migration of insects between treated and untreated swaths, and activity of the natural enemies within untreated swaths. These findings support the possibility of use of the discontinuous applications of persistent acridicides to control both locusts and grasshoppers. More details are available in:

Naumovich, ON (1997) Report to Rhône-Poulenc on the trials of Adonis® 40EC against *Calliptamus italicus* in Volgograd region (in Russian);

Latchininsky, AV and J-F Duranton (1997) Efficacy of the EC formulation of Fipronil on Siberian grasshoppers. Part II - Large-scale trials. Document 565 CIRAD-GERDAT-PRIFAS - VIZR, Montpellier/St. Petersburg, 50 pp., 20 tab., 6 fig. (In French with English and Russian summaries).

The RAAT Strategy Fast-Becoming the "Standard" for Grasshopper Pest Management

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The Reduced Agent-Area Treatment (RAAT) strategy has been developed and refined in Wyoming over the last 5 years. This approach to rangeland grasshopper management applies less insecticide (50% of traditional rates) to fewer hectares (as little as 33% of the infested land) in an optimized system of application (treated swaths are interspersed with untreated refuges based on our knowledge of insect movement and chemical degradation). This strategy maintains high levels of efficacy (80 to 95%), uses 60 to 75% less insecticide than standard methods, and increases the benefit:cost ratio by 2- to 3-fold. The effectiveness of RAAT is a function of movement of grasshoppers into the treated swaths and conservation of biological control agents in the untreated refuges. A 16,000 ha RAATs program in Wyoming in 1999 reduced the amount of insecticide by 6,000 kg and saved $100,000.

CONTROL: BIOLOGICAL

Mycopesticide Attains Registration and Commercial Production in Africa

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The LUBILOSA (Lutte Biologique contre les Locustes et les Sauteriaux) *Metarhizium*-based mycopesticide (Green Muscle®) is now available commercially from two companies: NPP/Calliope in France and BCP (Biological Crop Protection) in South Africa. Links to the companies are available through the LUBILOSA web site (http://www.cgiar.org/iita/research/Lubilosa/index.htm). The product has been registered in South Africa, and registration is pending for the CILSS countries.

Green Muscle® is listed by the FAO Pesticide Referee Group as the only pesticide locust control classified as causing "low environmental risk"in all categories and "unlikely to present acute hazard in normal use" following WHO human toxicity classification. Several donors have placed orders for Green Muscle® for use in Niger and Mali in the 2000 field season. Within the framework of the LUBILOSA research program, the GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit) component will focus on the sustainable use of this agent in the control of non-migratory locust species in the Sahel zone. The goal will be to integrate this mycopesticide into locust control methods in this region of Africa.

Operationalizing Mycopesticides for Grasshopper and Locust Control in Africa

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Effective biological pesticides based on oil formulations of deuteromycete fungal spores have been developed for use against locusts and grasshoppers. The isolate IMI 330189 of *Metarhizium anisopliae (flavoviride)* var. *acridum* has been registered, extensively field tested, and its operating characteristics explored. Advantages of *M. anisopliae* were found to be efficacy and persistence, low vertebrate toxicity, little environmental impact, conservation of natural enemies, and potential for recycling. Additional socio-economic advantages include the possibility of local production, ease of disposal and versatility in use. Strategies are being developed to integrate biological control agents into locust and grasshopper management schemes. For *Metarhizium* the accent is placed on treating the pest before it invades crops and situations with a high premium on environmental issues.

Source: Lomer, CJ, RP Bateman, D Dent, H De Groote, OK Douro-Kpindou, C Kooyman, J Langewald, Z Ouambama, R Peveling and M Thomas (1999) Development of strategies for the incorporation of biological pesticides into the integrated management of locusts and grasshoppers. *Agricultural and Forest Entomology* **1**: 71-88.

Aerial conidia of *Metarhizium anisopliae (flavoviride)* var. *acridum* are produced in a purpose-built facility at the International Institute for Tropical Agriculture in Benin using a standard, two-stage mass-production system. The yields average 31.1g of dry conidia powder per 1kg of rice substrate, the production capacity is 300 to 350 kg of conidia/year, and the production costs are estimated at US$21 per 100 g (the recommended dose for 1 ha). The incubation period and temperature are identified as key factors, although they account for <40% of the yield variation. The handling time, a principal limiting factor, could be reduced by increasing the substrate quantity per unit of production.

Source: Cherry, AJ, NE Jenkins, G Heviefo, R Bateman and CJ Lomer (1999) Operational and economic analysis of a West African pilot-scale production plant for aerial conidia of *Metarhizium* spp. for use as a mycoinsecticide against locusts and grasshoppers. *Biocontrol Science and Technology* **9**: 36-51.

Public-Private Partnership Provides a Powerful Approach to Biocontrol in Africa

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Within the scope of public-private cooperation, eastern Africa is to be supported in the production and marketing of a biological locust-control agent based on the entomopathogenic fungus *Metarhizium*. The approach consists of efforts to: 1) further develop the production technology (fermentation process) researched by the GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit)/BBA to manufacture the fungal agent on an industrial scale, 2) produce the fungus-based agent in a joint venture with Ethiopian partner companies, and 3) market the control agent in east Africa. The GTZ's task is to assist in establishing the requisite contacts in the partner country and to support product registration and the search for new marketing opportunities. Partners involved include: FZB Biotechnik GmbH Berlin (Federal Biological Research Centre for Agriculture and Forestry), Darmstadt (BBA), Ethiopian partner companies, University of Addis Ababa, and GTZ.

Mycopesticides Appear Promising for Locust Control in Australia

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Bands of the Australian plague locust, *Chortoicetes terminifera*, treated with 1 to 4 x 10^{12} conidia/ha of *Metarhizium anisopliae* declined by >90% at 8 to 14 days after treatment. Mortality was also high with *Locusta migratoria* treated at 3 to 4 x 10^{12} conidia/ha, although at lower doses, mortality was decreased. At the low dose of 1 x 10^{12} conidia/ha, *Metarhizium* is price competitive with insecticides, and the aim will be to test *Metarhizium* at an operational level during the year 2000.

New Grasshopper Pathogen Isolated in Argentina: The Next Breakthrough in Biocontrol?

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As a result of field surveys recently conducted in southwestern Patagonia (Santa Cruz province, Argentina), a new microsporidium (Protozoa: Microspora) was discovered and isolated from the endemic grasshopper *Tristira magellanica* (Orthoptera: Tristiridae). Whether this microsporidium possesses significant potential as a microbial control agent of grasshoppers, as do *Nosema locustae* or *Johenrea locustae* (for details see Johnson, 1997; Lomer *et al.*, 1999), is not yet known. Laboratory bioassays will be conducted soon, as a first attempt to explore such a possibility.

Development of a Mycopesticide to Control Grasshoppers in Brazil Progressing Rapidly

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Native species of grasshoppers have caused severe losses in crop systems in Brazil through seasonal outbreaks determined by environmental conditions. The most serious outbreak occurred from 1984 to1988 in Mato Grosso State, Central West Brazil, where *Rhammatocerus schistocercoides* invaded approximately 2 million ha. Outbreaks of different species were recorded in other regions. In the South, Rio Grande do Sul State, *R.. conspersus* invaded *ca.* 50,000 ha in 1991 and 1992. In the northeast, outbreaks of *Schistocerca pallens* were recorded many times (1888, 1985-1996). In the past year, there have been infestations in at least nine states (Mato Grosso, Rondônia, Minas Gerais, Goiás, Bahia, Alagoas, Paraiba, Rio Grande do Norte and Pernambuco), and the estimated dispersion areas are very large: 2.1 million ha for *R. schistocercoides*, 50,000 ha for *R. conspersus*, 230,000 ha for *S. pallens*.

The control of grasshoppers in Brazil has been based exclusively on chemical insecticides (fenitrothion and malathion). An integrated research project was initiated in Brazil in 1993 at Embrapa (Brazilian Agricultural Research Corporation) Genetic Resources and Biotechnology with the specific objective of developing bioinsecticides based on entomopathogenic microorganisms, especially fungi, to control grasshoppers. Activities were centered in surveys, characterization, production, formulation, and field evaluation. Emphasis has been given to development of the fungus *Metarhizium anisopliae* var. *acridum*, the most promising candidate as biocontrol agent against grasshoppers.

Because fungi are the only group of pathogens found (isolated) infecting grasshoppers so far, they are being studied with respect to correct identification, molecular characterization, production, formulation, interaction, physiology, and infection process. The isolates considered most promising are being tested in the laboratory and field. The efficacy of a mycoinsecticide based on the isolate CG 423 of *Metarhizium anisopliae* var. *acridum* formulated in vegetable oil has been tested against *R. schistocercoides* several times since 1995.

The implementation of entomopathogenic fungi as bioinsecticides against grasshoppers in Brazil is greatly limited by the lack of a consistent production system, short shelf-life, and their slow action in killing the host. Emphasis is being given to optimize the production system for *M. anisopliae* var. *acridum* and to increase its storage life at room temperature. The slow action in killing the host is mitigated by the apparent reduction in mobility and food consumption of the infected insects, and by the fact that young nymphs of *R. schistocercoides* usually occur in natural vegetation instead of cultivated areas. Moreover, the isolate CG 423 of *M. anisopliae* var. *acridum* is highly virulent against the grasshoppers *R. schistocercoides* and *Styphra robusta*, which makes it a good candidate as mycoinsecticide in Brazil. Nevertheless, searching for new isolates of *M. anisopliae* var. *acridum*, other species of pathogenic fungi and natural enemies associated with grasshoppers in Brazil must continue.

Field Trial with Entomopathogenic Fungus in Brazil Yields Promising Results

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In 1998, a set of experiments was conducted in the Chapada dos Parecis region, a permanent zone of grasshopper outbreaks in Mato Grosso state. Experiments were performed in zones of natural vegetation, against bands in third nymphal instar. Three nymphal bands were treated with the mycoinsecticide formulation based on conidia of the entomopathogenic fungus *M. anisopliae* var. *acridum*, strain CG 423. Three non-treated bands were used as controls. The application was made with the aid of a hand-held ULV sprayer adjusted to deliver 2 l of formulated material per ha, with each liter containing 1×10^{13} conidia. Treatments were limited to the surface and immediate borders of grasshopper bands (5 to 10 m). The efficacy was evaluated through band survival after treatment (grasshopper numbers, surface, density, behavior and daily movement of the band), allowing the insects to move freely in their natural environment. Insects were regularly surveyed and maintained in the laboratory to estimate the infection rate as well. Results from field and laboratory assays showed a clear effect of the product 10 days after treatment. At 14 days post-spraying, mortality caused by the mycoinsecticide in the field was *ca*. 88%.

Understanding the Role of Thermal Ecology in Developing and Refining Biopesticides

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The role of pathogens in insect population dynamics remains poorly understood and their performance in biological control is erratic. Temperature and host thermal behaviour, both the active interaction with environmental temperature and solar radiation via thermoregulation and the passive interception of these factors by thermal generalists, are central to understanding host-pathogen interactions. Pathogenicity, the latent period of infection and host recovery rate can all vary dramatically across and between seasons due to thermal biology of the host and changes in environmental temperature. Such effects have not been thoroughly explored in any previous investigations but may have major implications for disease dynamics in insects and possibly in ectotherms in general, and for development of effective biopesticides.

Source: Blanford, S and MB Thomas (1999) Host thermal biology: the key to understanding host-pathogen interactions and microbial pest control? *Agricultural and Forest Entomology* **1**: 195-202.

Formulation and Delivery Methods Critical to Development of Mycoinsecticides

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The use of oils has been shown to enhance the efficacy of mycoinsecticides, herbicides and hyperparasitic fungicides. Oils can also enable fungal pathogens to remain active under conditions of low humidity, and thus create opportunities for expanding the (presently limited) range of mycopesticide applications. Formulations of mycoinsecticides in oil present special opportunities when used in ultra-low volume (ULV) applications – and have been proven for acridid control (using aerial conidia of *Metarhizium anisopliae* var. *acridum*). However, for most of the world's agriculture, other nozzles such as hydraulic and air-shear atomizers are the mainstay of pesticide application.

This study focuses on motorized sprayers, capable of achieving good coverage at acceptable (low-medium volume) rates of application. The paper presents some data on the atomisation of oil-based formulations, comparing standard rotary sprayers with various motorized mistblowers. The principles of delivering microbial agents to their target sites are illustrated by estimating the numbers of spores "packed" into each droplet size class.

> Source: Bateman, RP and RT Alves (2000) Delivery systems for mycoinsecticides using oil-based formulations. *Aspects of Applied Biology* **57**: (in press).

CONTROL: OTHER (IPM, CULTURAL, MECHANICAL)

Cultural Control of Grasshoppers via Egg Pod Destruction Not Feasible in West Africa

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In West Africa, digging up egg pods has often been suggested as a cultural control option. However, careful analysis by the LUBILOSA project of this technology has suggested that for various physical, social and cultural reasons it is not feasible. Further research on the utilization of egg parasitoids as classical biological control agents is recommended in:

> Lomer, CJ, RP Bateman, H De Groote, D Dent, C Kooyman, J Langewald, R Peveling and MB Thomas (1999) Development of strategies for the incorporation of microbial pesticides into the integrated management of locusts and grasshoppers. *Agricultural and Forest Entomology* **1**: 71-88.

Research Steadily Moves Locust Management in Africa Towards IPM

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Migratory locusts (*e.g*, the desert locust *Schistocerca gregaria*) constitute a permanent threat to agricultural crops in Africa owing to their capacity for virtually unpredictable mass propagation, swarming and transboundary migration. In only a handful of cases can the periodic but irregular plagues of locusts be controlled by the affected farmers themselves. Consequently, locust control measures are implemented by state plant-protection services and supra-regional organizations. These costly control campaigns often have to rely on financial backing from external sources. To date, wide-area control has been conducted almost exclusively with chemical insecticides, which may disrupt the ecosystem and endanger the users' health in the process. Thus, the key to efficient control lies, *inter alia*, in improved early detection techniques. However, since mass outbreaks usually cannot be avoided, ecologically sound locust control methods need to be researched and applied. From 1989 to 1998, research on locust management in Africa has been focused on: 1) inventorying crop losses, 2) developing new prevention and control strategies, 3) preparing biotope maps of selected breeding sites using satellite data, and 4) developing or testing insect growth regulators, (*e.g.*, neem and melia) and entomopathogenic organisms (*e.g.*, *Metharizium*) as alternative control agents.

A Cooperative Approach to Implementing IPM Practices for Locust Management in Africa

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Countries affected by locust plagues are supported by GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit) in their monitoring and control efforts and advised on the further development of appropriate strategies. Bilateral emergency aid is provided in the form of: 1) supplies of materials and equipment, and 2) deployment of short-term expert consultants (strategic and economic consultancy services). These consultancies include: 1) training and upgrading measures, 2) preparation of extension, 3) improved early-warning and preventive control techniques, and 4) strategic discussions.

An integrated locust control strategy is developing in cooperation with the United Nations' Food and Agriculture Organization (FAO) within the scope of the Emergency Prevention System for Transboundary Pests (EMPRES), a programme being implemented in the Central Region (*i.e.*, countries in the Red Sea region). EMPRES is focusing on sustainably improving data collection and processing and enhancing communication structures within the countries concerned and with the FAO in Rome. It has also prioritized active support for investigating and developing new control measures.

APPLICATION TECHNOLOGY

Differential GPS Enhances Precision and Logistics of Locust Control Programs

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A SATLOC DGPS (Differential Geographic Positioning System) track guidance and data logging system has been purchased by the Australian Plague Locust Commission (APLC) and fitted to a contract spray aircraft (Cessna 185) for evaluation. This aircraft has been used extensively for trials and operational control recently and the increased precision during application has proved the value of such systems especially in featureless terrain where conventional marking of spray runs is very difficult. A procedure for incorporating target data collected by the system into the APLC GIS is currently underway. A requirement for all APLC contract spray aircraft to be equipped with DGPS systems will become mandatory with the next tender.

Helicopters with Hydraulic Atomizers allow "Surgical Strikes" Against Locust Bands

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Treatment of Australian plague locust bands using fipronil (Adonis® 8.5 UL) applied from a helicopter fitted with hydraulic AU7000 Micronair atomizers was evaluated. The maneuverability of this survey & spraying platform and the specialized application equipment allowed direct coverage of bands with a "spot" dose of 2.5 g ai/ha thereby minimizing the area treated within an infested block *e.g.*, 3 to 10 ha within a 100 ha area that otherwise would have received a blanket treatment of 1 g ai/ha if sprayed with a fixed wing aircraft.

The Powerful Potential of the AgDRIFT® Model to Improve Locust Control

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A computer model called AgDRIFT® has been developed over a number of years by various organisations in the United States including the Environmental Protection Agency (EPA), the United States Department of Agriculture (USDA) and the Spray Drift Task Force (SDTF). It was developed initially to estimate deposition of materials released from aircraft and more recently to assist with predictions of possible drift events. It is currently used in risk assessments to gauge whether particular pesticide formulations and application regimes are likely to cause problems with off-target contamination. Since ultra low volume (ULV) locust spraying is in effect a drift spraying technique, the model has potential uses in the understanding and refinement of ULV spraying parameters for safer and more effective control. More information and background can be found at the following World Wide Web location: http://www.agdrift.com/agdrift_web/Agdrift_intro.htm. The software is currently in version 1 and is freely available (together with support) from Milton Teske (milt@cdiprinceton.com), but a charge will be made for user support in Version 2 (under development, expected June 2000) and subsequent versions.

Although the core of the program is a series of complex calculations, the interface with it is very simple. The parameters such as droplet spectrum, windspeed and emission height are entered and the model will display a graph of downwind deposition (see Figure 1). It can cope with tractor mounted boom-and-nozzle applications, orchard airblast equipment, and aerial spray equipment. The level of interaction is split into three tiers. Tier 1 is a basic level where very few variables are required (or allowed) to be entered; Tier 2 is for more experienced users where many parameters can be changed within certain limits; and Tier 3 where there are no limits to the parameters, but where warning messages appear if parameters are changed outside the normal working range for high volume spraying.

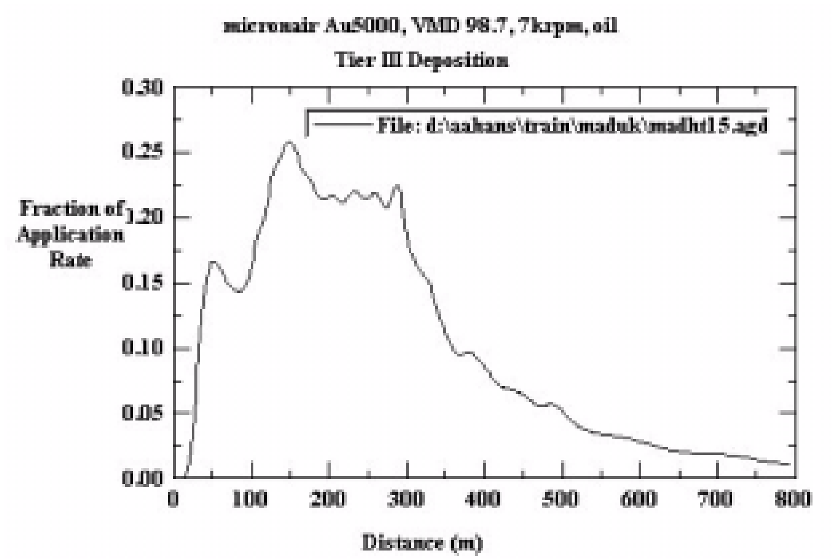

Figure 1. *Downwind deposition predicted by AgDRIFT® for Micronair AU5000 with typical locust droplet spectrum, 15 m emission height and 5 m/s wind (other parameters typical).*

Understanding of the influence of parameters on spatial distribution of ULV spraying is limited in most users by the inability to see where the spray is going. Sampling the spray has disadvantages: 1) the array often has insufficient samplers to give more than a few points of data - usually at ground level and 2) the most frequently used form of ULV sampler, static oil-sensitive paper, has low collection efficiency for the very important sub-50 µm diameter fraction of the spray. There are devices which can help visualise distribution of spray over time after emission such as the Laser Imaging Detection and Ranging (LIDAR) - a laser-based piece of equipment which provides an image of the spray cloud at intervals as it moves through the plane of an oscillating laser beam. However, this equipment is currently expensive and unwieldy. AgDRIFT® has possible uses in the following:

- a rough appraisal of whether particular ULV locust spray parameters are likely to give the distribution, deposition and therefore efficacy expected
- a rough assessment of the likely risk that ULV spraying operations in a particular place with particular parameters will contaminate ecologically sensitive areas or human habitations

Further development is planned by the US Forest Service under USDA. A separate model called FSCBG will be rolled into AgDRIFT® to provide active ingredient accountancy, GIS linkages and plan views with isopleths of likely deposition for particular spraying operations, in addition to the single plane deposition profiles currently produced. Mosquito control groups in the United States are considering extending the model to suit their interest in very fine sprays and greater release heights.

In conclusion, AgDRIFT® has potential as a decision support tool in locust spraying operations in that combinations of spray parameters can be given a 'virtual' field test for likely efficacy and then refined accordingly before being tested in the field. It also has potential uses in establishing approximate dimensions of buffer zones around exclusions areas, which can then be validated by field tests. The further development of AgDRIFT® with the integration of FSCBG functions will improve users' ability to quantify and visualise the likely outcomes of particular ULV locust spraying techniques.

Inaugural Tests of Foggers Adapted from Aircraft Engines Appear Promising in Russia

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Aerosol foggers with optimum dispersion were used for control of the Italian locust (*Calliptamus italicus*) outbreaks in the Kulunda steppes of Novosibirsk Region during July of 1999. This technology has been developed by the Institute of Chemical Kinetics (Siberian Branch, Russian Academy of Sciences). Each fogger consists of an aircraft engine mounted on the vehicle. The fogger can be used for spraying both chemical and biological formulations. Optimal size of aerosolic droplets can be selected in the range of 1-50 mkm. The working rate is from 1,000 to 15,000 ha/hr.

In 1999, pyrethroid insecticides (mainly Sumialpha® and Karate®; 2.5% EC) were used for Italian locust management at spray volumes of 0.2-0.4 l/ha. There were three foggers (one of the Novosibirsk Department of Forestry and two of the Institute of Chemical Kinetics) used in this program. Effectiveness of treatments was high, but long-term studies are needed. This appears to be the first attempt to use this type of the fogger in managing a locust outbreak.

The Pied Piper Carrier: Vegetable Oil Attracts Grasshoppers into Treated Barriers

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Reduced Agent-Area Treatments (RAATs) for rangeland grasshopper management and barrier treatments for locust control apply insecticide to fewer hectares in an optimized system of application, while sustaining high levels of efficacy. There remains an opportunity for further economic and environmental cost reductions through the manipulation of grasshopper behavior with plant oils. The use of recently discovered attractants and feeding stimulants of grasshoppers may allow even greater reductions in the amounts of insecticides and protection of non-target organisms in RAATs programs. Fatty acids that attract grasshoppers are abundant in various vegetable oils that can be used as inexpensive carriers of insecticides. These oil-based formulations draw grasshoppers into treated swaths and stimulate feeding on toxic vegetation. This tactic may allow another 33% reduction in pesticide use and treatment costs.

ENVIRONMENTAL IMPACT

Leading Laboratory in Ecotoxicology of Acridid Control Entering a New Era

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CERES/LOCUSTOX is a Regional Centre created in 1989 by the Senegalese and Dutch governments and the United Nations' Food and Agriculture Organization (FAO). It is specialized in research on ecotoxicology, toxicology and environmental chemistry of pesticides, specifically those used in locust and grasshopper control. The Centre is the main provider of environmental data to FAO's Locust Pesticide Referee Group which evaluates pesticides on efficacy and selectivity for locust control. Its major activities are to: 1) study the effects of pesticide applications in Africa on man, livestock and the environment, 2) collect information useful to decision makers and users for registration and for selective and low risk procurement and use of pesticides, 3) diffuse methods and tools considered to contribute to Good Practice of pest and disease control under sahelian conditions, 4) work in an environment that meets the requirements of Good Laboratory and Field Practices (GLP/GFP/ISO Standards), and 5) provide experienced and internationally acknowledged expertise. By the end of 1999 the Centre will be an autonomous foundation. It has a staff of 25, specialized in terrestrial and aquatic ecotoxicology, mammalian toxicology, environmental chemistry and training.

Ecotoxicological Studies Vital to Sound Pest Management Practices in Acridology

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Recent research developments at CERES/LOCUSTOX addressed a number of important issues relevant to the environmental effects of grasshopper and locust control. First, an epidemiology database has been created of the spatial distribution of grasshopper control operations in Senegal from 1988 to 1999. The data will be used to identify risk areas and groups within the population to be monitored. Next, base-level cholinesterase activity has been determined in most livestock species, including camels. The data will be used to investigate (alleged) cases of poisoning after spraying with organophosphate-esters and carbamates. Third, field data have shown that at least one very abundant termite species in the Northern Sahel (*Psammotermes hybostoma*) is extremely vulnerable to long-term effects by pesticides to which it is sensitive. After local depletion, recovery to measurable density level may take 3 years. Finally, field observations on farmers exposed to carbaryl dust, while using various dusting methods showed that the health risk of dusting is limited. Of 135 users, 3% showed a cholinesterase inhibition exceeding World Health Organization standards, and no cases of acute intoxication were recorded. The complete list of publications of the Centre can be found on the Food & Agriculture Organization web-site: www.fao.org/News/global/ Locusts/Locustox/Ltoxhome.htm

Biogeographic Analysis Reveals Risks of Locust Control to Biodiversity in Northern Africa

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A biogeographical approach to identifying environmentally sensitive areas (*i.e.*, regions of high biodiversity as measured by species richness and areas with high levels of endemism and/or restricted distribution of small mammals, reptiles, amphibians and fish) in the desert locust zone in Africa north of the equator were mapped on a 1˚ grid square. These areas were matched with historical data on the distribution of desert locust in the recession and invasion zone to calculate a Geographical Exposure Index (GEI). This index depicts areas hosting diverse and/or endemic vertebrate faunas (hot spots) which are likely to be subjected to desert locust control operations. The objective is to provide a biogeographical database and decision-making tool for environmentally sound locust management.

Acknowledgement This study and the following studies reported by R. Peveling were funded by the governments of Canada, United Kingdom, Germany, Netherlands and Switzerland. These countries are acknowledged for their support. Cooperators in this project included: S. Attignon (IITA, Benin), S. A. Demba (CLAA, Mauritania), S. ould Ely (CLAA, Mauritania, and ICIPE, Sudan), I. Rieger (NLU), I. Stolz (NLU). For details about our research visit our homepage (1 April 2000) at http://www.nlu.unibas.ch ihttp://www.nlu.unibas.chà

Toxicity of Fungal and Chemical Locust Control Agents to Lizards

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A laboratory study was conducted in Mauritania to assess the toxicity of prey insects infected with *Metarhizium anisopliae* to *Acanthodactylus dumerili* (Reptilia: Lacertidae). Lizards were fed 3rd instar desert locusts which had been infected 5 days earlier. The locusts were dosed such that they would have died on the feeding day. These locusts were considered to carry a maximum load of fungal toxins. The dose (number of diseased locusts per unit body weight) was higher than that tested in dietary studies with birds during registration. Fipronil (Adonis® 4 UL) was used as a toxic standard to validate the test system and to confirm earlier results. Fipronil was administered orally at 30 µg a.i./g body weight. No lizards fed on diseased locusts died during the 3 to 4 week post-exposure period. The measurement endpoints of locomotor activity, food consumption and body weight were similar among treated and control lizards. The LD_{50} of fipronil was estimated at 30 µg a.i./g body weight. Despite this high toxicity, field mortality is unlikely to occur at current dose rates. However, surviving lizards did not fully recover until 4 weeks post-exposure. Locomotor activity, prey consumption and body weight remained significantly lower than in the control group, and mortality gradually increased for weeks after treatment. Further subacute dietary toxicity tests are necessary to fully assess the risk to reptiles.

Environmental Impact of Fungal and Chemical Control Agents on Non-Target Arthropods

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In 1997 and 1998, medium and large-scale field trials with the mycopesticide *Metarhizium anisopliae* (Green Muscle®) against Sahelian grasshoppers were carried out in Niger. Spores were sprayed at 5 x 10^{12} conidia/ha. Fenitrothion (220 g a.i./ha, 1997) and fipronil (2 g a.i./ha, 1998) were used as toxic standards. Hymenopteran parasitoids such as Scelionidae, Braconidae and Trichogrammatidae were monitored in millet fields from the tillering stage to maturation. In 1998, epigeal and arboreal savannah arthropods were also monitored. Parasitoids and other non-targets were not adversely affected by the fungus. Even the two chemicals caused only a slight and transitory decline in parasitoid abundance. In contrast, ants (Formicidae) and two herbivorous beetles, *Euryope rubra* (Chrysomelidae) and *Dereodus marginellus* (Cucurlionidae), were significantly reduced by fipronil (80-100%). In the latter two species, no recovery was observed until the end of the trial (7 weeks post-treatment).

Fipronil Versus Chlorpyrifos: Which is Softer on Non-Target Organisms in Siberia?

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Two insecticides, fipronil and chlorpyrifos, were selected to evaluate the side-effects of grasshopper control treatments on non-target insects in Russia. Field trials were performed near Ust-Ordynsky, 70 km northeast of Irkutsk in the Baikal region, Siberia. The experimental site was located on terraced slopes of the Kuda River in fields of perennials (cropped with *Bromopsis inermis*) and in natural pastures. The experiments were conducted from 28 June until 25 July on plots that had received blanket treatments of chlorpyrifos (205 g a.i./ha) and fipronil (4 g a.i./ha) and a control plot (without treatment).

Treatments were applied by a tractor fan sprayer with a spray coverage of about 20 m. Applications were carried out on 1 July (chlorpyrifos) and 3 July (fipronil) to control high densities of non-swarming grasshopper adults (9.6 to 11.0 individuals/m^2). The grasshopper complex consisted of *Aeropus sibiricus*, *Stauroderus scalaris*, *Chorthippus albomarginatus*, *Pararcyptera microptera*, and *Arcyptera fusca*. Arthropods were collected with sweep nets and/or pitfall traps on the following sampling dates: 1 d before treatment and 1, 3, 5, 7, 14, and 21 d after treatment.

The data obtained in this region of Russia support the following conclusions. Sensitivity of taxa to fipronil is mainly determined by the combination of four factors. First, vertical distribution of the organisms' ecological niche must be considered in context of the dispersion of the treatment by the sprayer. In this context grass-dwelling species appear to be more sensitive to fipronil than the ground dwelling taxa (*e.g.*, Thomisidae *vs.* Lycosidae). Second, the width of the niche under consideration (in this case the term "niche" refers to the vertical dispersion of the surfaces in the ecosystem space, where the taxon dwells) is critical. As such, there is a higher sensitivity of the taxa occupying both ground and grass microhabitats, compared with the taxa residing only on the ground (*e.g.*, Lygaeidae *vs*. Cydnidae). The third factor is the mode of the taxon's feeding behaviour (*e.g.*, chewing or sucking mouthparts). For example, this factor may account for slower recovery of chrysomelids, relative to other herbivores and predators with similar initial declines (*e.g.*, Miridae and Chalcidoidea). Fourth, one must consider the peculiarities and extent of locomotor activity (*e.g.*, sedentary or flying) in the ecosystem space. This factor leads to the equal sensitivity of the grass- and ground-dwelling cicadellids to fipronil. The former taxon's habitat may be more heavily treated but its locomotion can be characterized as grass-flying (minimizing contact with surrounding surfaces), and although the latter's habitat may be less toxic, its movements create permanent contact with surfaces. The role of other factors, such as a species' sensitivity to insecticide and the structure of its cuticle, have not been systematically investigated.

In terms of the comparative effect of fipronil and chlorpyrifos treatments on non-target arthropods, the most abundant non-target taxa can be divided into four categories according to the relative effect of these insecticides on relative abundance: 1) groups in which the effect of fipronil is greater than that of chlorpyrifos, 2) groups affected by both insecticides nearly equally, 3) groups in which the effect of fipronil is less than that of chlorpyrifos; and 4) groups in which the effect of both insecticides is nominal. The analyzed arthropod families were distributed among the mentioned above categories. Category 1 includes Acrididae, Lygaeidae, Carabidae, and Cicadellidae (from pitfall traps) and Acrididae, Chrysomelidae, Lygaeidae, Miridae, Ichneumonidae, Muscidae, Pyralidae (from sweep netting). Category 2 includes Aranei and Cydnidae (from pitfall traps), and Chalcidoidea and Aranei (from sweep netting). Category 3 includes Dermestidae, Formicidae, and Silphidae (from pitfall traps), and Aphidae, Psillidae, Formicidae, and Agromyzidae (from sweep netting). On the basis of the number of taxa found in category 1, we may conclude that in the ecosystem studied fipronil had more severe effects on the arthropod community than did chlorpyrifos. The cases where the effect of fipronil was less than chlorpyrifos (category 3) warrants further discussion. The representatives of the families belonging to this category are less likely to come into direct contact with the insecticides due to the peculiarities of their mode of life. We suggest that this situation could be explained by the effect of chlorpyrifos vapors, since it is known that it belongs to the group of organophosphate insecticides with highly volatile active ingredients (the evaporative potential of chlorpyrifos is >10-times that of fipronil).

SOCIOPOLITICAL AND POLICY ISSUES

Institutional Reorganization to Facilitate Preventive Management of the Desert Locust

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In the Western part of the distribution area of the desert locust, *Schistocerca gregaria*, the coordination of monitoring and control operations currently depends on two organizations: OCLALAV and CLCPANO. The countries directly concerned (Algeria, Libya, Mali, Morocco, Mauritania, Niger, Senegal, Chad, Tunisia) have frequently taken the opportunity to affirm their commitment to the concept of preventive control. However, they recently recognized that the current institutional situation was unsuited to an effective application of preventive control in western Africa. As such, there are now plans to establish a new, single structure of regional cooperation. Such a structure appears necessary to allow effective and sustainable implementation of the preventive control strategy, as proposed within the framework of the EMPRES Program of FAO (Emergency Prevention System for Transboundary Pests Program of the Food and Agriculture Organization of the United Nations) for the western region and to support genuine, regional cooperation. The new institution may be named, "Commission FAO de lutte contre le Criquet pèlerin en région occidentale" ("FAO Commission for Desert Locust Control in the Western Area").

National Grasshopper Management Board of the US Identifies Critical Issues

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The National Grasshopper Management Board of the United States met in January of 2000 to develop and refine policy and management recommendations that are intended to facilitate grasshopper and Mormon cricket control. The Board addressed the needs to: 1) communicate the survey results showing that the outbreak that began in 1998 expanded in 1999, and threatens to be extremely serious in the coming year, 2) increase the efficacy of the US Department of Agriculture's "crop protection" program, 3) complete the environmental documentation necessary to allow the application of diflubenzuron to public lands, and 4) restructure the federal subsidy program for grasshopper control, should congressional funding be restored.

OPERATIONS AND LOGISTICS

The Locust Situation in Southern Africa: Good News and Bad News

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Although the brown locust, *Locustana pardalina*, remained in recession in South Africa and Namibia, AAAI Associates Roger Price and Dick Brown continued to interface with the migratory locust (*Locusta migratoria capito*) problem in neighbouring Madagascar. During 1998, a major build-up of migratory locusts led to widespread invasion of the island by emigrant swarms. Despite strenuous intervention efforts, renewed outbreaks developed in the 1998-1999 rainy season, necessitating further emergency control measures.

Altogether, five missions were undertaken to Madagascar. These involved field assessments, aerial surveys, managerial support services for the national locust organisation and product evaluation for international chemical companies (AgrEvo and Bayer). Numerous helicopter missions (one of which almost ended in a near fatal crash!) to evaluate the current locust situation and to provide strategic managerial backup for the locust organisation were completed in Madagascar. One such mission, for example, involved assessing a residual swarming population found in the barrier treatment areas, at the conclusion of the campaign in April 1999. Samples drawn from these swarms were dissected and their degree of cuticle hardness, coloration, fat body content and ovary development determined. From the results obtained with predominantly teneral and immature specimens, it was concluded that the swarms were all of local origin and certainly not immigrants from distant outside sources, as was being asserted by those responsible for this campaign.

Current and Future Perspectives of the Migratory Locust Plague in Madagascar

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Since the early 1990s there has been a gradual population increase of the Madagascar migratory locust, *Locusta migratoria capito*, due to suitable climatic conditions, in particular rain. An outbreak situation was reached in early 1997 and control activities were initiated by the Government with assistance from the donor community and under the overall coordination of the Food and Agriculture Organization of the United Nations. The control strategy was mainly based on the use of barrier treatments with fipronil 7.5 g ai/l against hopper bands and blanket treatments of swarms with deltamethrin 17.5 g ai/l. Farmers were also provided with insecticide powder (propoxur and fenitrothion) to protect their crops. There is a general consensus that the control activities, consisting of 2,954,000 ha protected by barrier treatment and 780,267 ha treated by cover sprays between May 1998 and May 1999, have reduced the locust populations considerably. However, currently the locust situation retains many characteristics of an outbreak, and survey and control activities must be continued over the months and years to come. Medium and long term objectives are to reestablish a preventive control organization, as the scientific basis for such a preventive strategy currently exists in Madagascar.

Environmental Changes Precipitate a Serious Locust Outbreak in Indonesia

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Serious outbreaks of oriental migratory locusts, *Locusta migratoria manilensis*, have been reported on different islands of the Indonesian archipelago since early 1998, especially in southern Sumatra, but also in Java, Kalimantan (Borneo), Sumba, Timor, Sulawesi (Celebes), and Flores. In the long term, the intensive deforestation that has been under way over the last 20 years is certainly partially responsible for these outbreaks. The drought that prevailed in the region in 1997 also seems to be a major recent factor that prompted these outbreaks. In 1999, the situation continued to be serious in several islands, especially in Sumba. By the beginning of January 2000, swarms of millions of locusts were described arriving on Waingapu city in the Eastern part of Sumba.

The Success Story of Desert Locust Survey and Control in Pakistan

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Pakistan is invaded by the desert locust, *Schistocerca gregaria*, twice a year. The area is arid and in some years above average rainfall is received which encourages vegetation and makes large areas available for oviposition and development of locusts. There are two breeding seasons/zones: Baluchistan province is the winter/spring zone while Sindh and Punjab are the summer breeding zones. There is a small overlapping area of Lasbela. The total area under invasion is 300,000 sq. km, of which 70% is in Baluchistan. At stake are the major field crops, orchards, and plantations worth *ca*. $9 billion to the nation's economy. The potential damage liable to occur in this region has been estimated at 50% of the global loss through this pest (Bullen, 1969). Hence, the desert locust survey and control work had been a priority job of the workers of the Department of Plant Protection.

The department has a network of outposts adequately staffed and equipped. Sufficient quantity of effective and safe pesticides is kept, and 21 aircraft and >100 vehicles are maintained for survey and control. The survey period is February to May in Baluchistan and June to October in Sindh and Punjab, while year around watch is kept over Lasbela. The assessment of locusts and habitats in recessions and search for swarms and hoppers during outbreaks is undertaken as per "The Desert Locust Guidelines II", Survey (FAO, 1994). Aerial survey is sometimes undertaken to locate swarms and vegetation cover. Locust reports including forecasts are sent fortnightly to national headquarters and FAO Rome through electronic media. During an outbreak, the information flow is nearly instantaneous. Pakistan had upsurges during 1949 to 1962, 1964 to 1965, 1972 to 1976, 1978, 1983, 1989 to 1990, 1993, and 1996 to 1997; the recession period being intermingled. To give an idea of the magnitude of locust activity, the following figures on the population densities and areas of infestation in Pakistan are presented:

Year	**Swarms (No.)**	**Groups/hopper bands (No.)**	**Area infested (km^2)**
1978	350	150000	39000
1983	96	21945	8000
1989	39	2193	5316
1993	497	66254	19000
1997	441	25349	1800

Keeping in view the high vulnerability of the crops, the above mentioned locust activity over such a large infested area would have shattered the economy. Thanks to survey and forecasting that initiated early control campaigns, the swarms and hoppers were successfully controlled by ground and aerial pesticide application mainly through ULV technique. As a result, the entire cultivated area remained safe. These activities have helped to protect the national crop wealth efficiently, economically and safely and have earned the appreciation of growers, traders and administrators. For instance, a gold medal was conferred upon the department by the Karachi Cotton Association for high quality work in 1993. Sustained efforts will continue and for further improvement, the assistance of donors in procuring vehicles, replacing old aircraft, and training workers in satellite imagery analysis and ecological studies is required.

Communications: Training, Workshops and Meetings

Training Assures Safe and Effective Use of Dust Applicators in Madagascar

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Training on the correct use and calibration of certain manually operated dusters in use in the south of Madagascar was given in concert with the control programs. Brief guidelines were drawn up and issued to NGO field operators working with such equipment.

Workshop on Management of Migratory Pests Identifies Priorities in Southern Africa

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A workshop entitled "Migrant pests of Agriculture in southern Africa: Research priorities" was held at the Plant Protection Research Institute (PPRI) in Pretoria, South Africa, from 24 to 26 March 1999. The workshop was sponsored by the British Government's Department for International Development (DFID) Crop Protection Programme and was organized by the PPRI and the Natural Resources Institute, University of Greenwich, UK. The workshop was attended by 65 delegates from 7 southern African countries as well as delegates from the United Kingdom, the Food and Agriculture Organization of the United Nations, and the international red locust control organization (IRLCOSCA).

The aim of the workshop was to identify strategies that could be developed to improve the forecasting and control of locusts, quelea birds and armyworms within the southern African region. The workshop effectively summarized the knowledge base on the relevant migrant pests and described the control strategies currently employed. The priorities for future migrant pest research within the region were identified and the possible uptake pathways assessed. Research linkages and partnerships were identified and a range of project proposals has since been submitted to DFID for possible donor funding.

The summary report of the workshop detailing the research priorities is available on the World Wide Web at http://www.arc.agric.za/lnr/institutes/ppri/migrant/main.htm

Locust and Grasshopper Control Conference Addresses Emerging Crisis in Kazakhstan

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A round table locust and grasshopper control conference between the Plant Protection Institute, Almaty and certain international chemical companies (AgrEvo and Rhône-Poulenc) was held in the Republic of Kazakhstan. In addition to extensive discussion of the emerging crisis of locust and grasshopper outbreaks in Central Asia, a keynote paper delivered on brown locust control in South Africa stimulated much discussion.

Italian Locust Workshop Planned for West Siberia

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A special regional workshop will be organized to discuss the Italian locust (*Calliptamus italicus*) problem in West Siberia. This workshop probably will be held in Barnaul or Slavgorod (Altai Region) in March, 2000.

Locust Monitoring and Control Training in Indonesia: Capacity Building in Action

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For 2 years, several islands of the Indonesian Archipelago were subject to serious outbreaks of migratory locust, *Locusta migratoria manilensis*. To face the situation, a training seminar was organized from 12 to 17 July, in Kotabumi, southern Sumatra (Lampung Province) by the Ministry of Agriculture with the contribution of three CIRAD-PRIFAS experts. Twenty-nine participants from Food Crop Department and Plantations of 10 Provinces affected by locust infestations, attended the seminar. The purpose of the seminar was to help Indonesian operators to comprehend migratory locust dynamics, survey and application techniques, in order to overcome outbreaks. Lectures, tutorials and practice sessions were undertaken on the main aspects of the biology and ecology of the migratory locust, as well as on spraying methods and techniques. Some relevant insecticides usually recommended in locust and grasshopper control were introduced. The ultra low volume (ULV) spraying technique was presented, along with its potential applications in context of local conditions.

Training Opportunities in Biocontrol Sharpen the "Cutting Edge" of Pest Management

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A United Nations' Food and Agriculture Organization (FAO) training workshop on the development of biological pesticides for use against migratory pests was held in Ankara, from 24 May to 3 June 1999 at the Plant Protection Central Research Institute.

For more information, see http://www.fen.bilkent.edu.tr/~lomer/Sunnpw/Sunnpw.html

A training course for African insect pathologists was held at Virginia Polytechnic Institute in December 1999, hosted by Dr. R. Humber (CILSS/FAO/VPI/IIT).

A workshop on biopesticide regulation and registration is being planned for April 2000, in Bamako, Mali. Details are pending.

International Workshop Addresses Risks of Grasshopper Outbreaks and Management

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A NATO Advanced Research Workshop (co-sponsored by AAAI, The Orthopterists Society, and Rhône-Poulenc) on "*Acridogenic and Anthropogenic Hazards to the Grassland Biome: Managing Grasshopper Outbreaks without Risking Environmental Disaster*" was held in September in Estes Park, Colorado. There were 21 participants from 11 nations in attendance, and the proceedings of the workshop will be published by Kluwer as Grasshoppers and Grassland Health.

COMMUNICATIONS: PUBLICATIONS

Grasshopper Guide for Argentina Provides Vital Tool for Pest Managers

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The National Institute for Agrarian Technology (INTA) from Argentina has just released a brief, concise guide-type publication for the recognition and management of the most common grasshopper species in areas of Córdoba and Santa Fé provinces (Salto & Beltrame, 1999), a much needed tool for ranchers in the region. The contribution includes diagnostic keys, color pictures, and management briefings for 24 species. A list of insecticides registered for grasshopper control at the national level by the responsible authority (SENASA) is included, much valuable information that sometimes is not easily at hand.

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Progress in Biocontrol of Grasshoppers and Locusts: Formulations, Fungi, and Forecasts

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Efficacy and Ecotoxicology of Acridid Control Programs: From Antifeedants to Zastchita

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COMMUNICATIONS: ELECTRONIC (WEBSITES, ETC.)

Updates and Information from Australia

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For further information on the programs, methods, and strategies used by the Australian Plague Locust Commission, visit: http://www.affa.gov.au/aplc

Newest Information from CABI

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For further information on the research and development programs at CABI visit: http://www.CABI.ORG/Bioscience/index.htm (ihttp://www.CABI.ORG/Bioscience/index.htmà)

The LUBILOSA (Lutte Biologique contre les Locustes et Sauteriaux: biological control of locusts and grasshoppers) program has produced many publications throughout 1999. For details and reprints please contact Ms. Emma Thompson at CABI Bioscience, Silwood Park, Ascot, Berks, SL5 7TA, UK or visit: http://www.cgiar.org/iita/research/lubilosa/index.htm

Economics, Chemical/Biological Control and Ecotoxicology

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Various documents of potential relevance to applied acridology (*e.g.*, software, sampling methods, etc.) can be found at http://www.cgiar.org/iita/research/Lubilosa/index.htm.

Grasshopper Ecology and Management Perspectives from the United States

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The website "Grasshoppers of Wyoming and the West" includes information on biogeography, taxonomy, ecology, and management of rangeland grasshoppers. This site is also the portal to the AAAI webpage. It can be accessed via: http://www.sdvc.uwyo.edu/grasshopper/

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Association for Applied Acridology International

Our Mission::

As pest management techniques, perspectives, and products have become increasingly sophisticated in the last 20 years, our capacity to adapt and transfer the methods and knowledge has declined. Formerly effective programs have dramatically diminished their roles in assisting afflicted regions. While the ability for any single nation to sustain a critical mass of expertise in acridid (grasshopper and locust) pest management has diminished, the quality of geographically dispersed experience and knowledge is extremely high.

The ***Association for Applied Acridology International*** has brought together the world's leading practitioners in this field to develop and provide unbiased analyses along with culturally, technologically, economically, and environmentally appropriate methods for managing locust and grasshopper outbreaks. The ***Association*** is the first and only humanitarian-based, NGO of entomologists in the world, providing expert advice, training, and applied research to people and nations in need. The demonstrable capacity of grasshopper and locust outbreaks to reduce the standard of living, displace human populations, induce famine, and erode environmental quality demands the highest level of practical expertise and experience in order to rapidly build the capacity of agricultural communities to implement safe and effective prevention and control programs. The ***Association*** consists of 26 Associates from 18 nations, representing more than 300 years of collective experience and 13 Institutional Partners/Participants comprising the world's best organizations dedicated to the study and management of acridids.

The purpose of the ***Association for Applied Acridology International*** is to form a coordinated, operational pool of world experts, thereby creating opportunities for collaboration and enhancing access to this expertise by governments, agencies, and companies. This goal is captured in our motto:

Solutions without Limits by Scientists without Borders

For more information, select ***Association for Applied Acridology International*** from the left-hand frame at http://www.sdvc.uwyo.edu/grasshopper/