THE YEAR OF THE LOCUST

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Introduction

The desert locust (*Schistocerca gregaria*), which is perhaps the most dramatic and potentially devastating species renowned for its dramatic population build ups and migrations across whole continents, has, in recent years, been in a fairly stable period of recession. However, far from meaning that locust and grasshopper problems are in abeyance, the last couple of years has seen a wealth of reports indicating significant locust activity throughout many parts of the world. Here we summarise some of these accounts and touch on the various pest control interventions (usually chemical) used in response to these locust outbreaks. We then go on to provide an up date of progress in a number of research programmes which are aiming to develop sustainable biologically-based control solutions to locust and grasshopper problems.

The global locust problem

Latin America

Northern Peru was affected this year by one of the largest locust plagues it has ever seen. At least 15 million Peruvian Locusts (*Schistocerca piceifrons peruviana*) covering an estimated area of 50 square miles were recorded. The Peruvian Government took preventative measures to minimise crop losses by aerial and ground spraying of insecticides. Brazil has been subjected to several large locust outbreaks in the past decade and has recorded increasing populations during the last 10-15 years (Barrientos, 1992, 1994), resulting in extensive economic damage to both basic and commercial crops as well as pastures. During the last outbreak in 1993, approximately 2 million ha were infested in Mato Grosso.

Central Asia

In 1999 the central Asian republics of Turkmenistan and Kazakhstan were hit by a plague of locusts which spread into Uzbekistan and Russia. Experts estimated as many as 2,500 Moroccan Locust eggs per square meter in southern Turkmenistan, which originated from Iran. Kazakhstan was unable to pay for the necessary aerial insecticide spraying needed to control the insects resulting in the devastation of up to 7 million ha of land. In neighbouring regions locusts were recorded to be destroying large crop areas (up to 300,000 ha in Uzbekistan) and advancing at a rate of 30 miles a day in Russia. At the end of last year it was estimated that 2 million ha of land in Pavlodar was infected with locust eggs and due to insufficient resources to combat the problem, resulted in a severe outbreak this year in both Kazakhstan and North Western China.

Huge swarms of locusts have been destroying crops in northern China – a region, which is already suffering from its worst drought in more than a decade. Two areas have been concurrently struck by locust plagues. These include north-central (provinces of Shandong, Henan, Hebei, Anhui, Shanxi and Shaanxi and Tianjin Municipality) and north-western (Xinjiang Uygur Autonomous Region) China. In North-central China at least 930,000 ha of crops have been affected, most of which has occurred on farmland found in poor mountainous areas. In North-western China, more than 2 million ha of farmland was damaged by locusts. Agricultural experts predicted an additional 1.3 million ha of farmland would be damaged. Pest control officials of north-west China resorted to desperate measures to control the worst plague for a decade by introducing 10,000 chickens to 'gobble up millions of locusts.'

Australia

Australia expects a major locust outbreak of the Australian plague locust, *Chortoicetes terminifera*, this year. Swarms broke up during May and June with the onset of cool weather but adults continued to persist in high numbers and lay eggs. Significant crop damage occurred on some properties in South Australia, New South Wales and northern Victoria.

South Africa

In 1999/2000 locust control teams were operating against upsurge populations of brown locusts (*Locustana pardalina*) until the end of May. 50000 hopper bands and 10000 adult swarms were treated. In spite of this, projections suggest that should environmental conditions be suitable early in the coming season (October 2000) locusts may reach outbreak levels in 2001. Locusts are not a major threat in this district when confined and controlled in their recession zone of the Karoo.

Madagascar

Since 1997, more than US$35 million has been spent on pesticides for control of migratory locust (*Locusta migratoria*) swarms in Madagascar. Although a wide range of insecticides have been used throughout various regions of the world to combat locust emergencies {e.g. diflubenzuron and triflumuron (insect growth regulators), deltamethrin and phenothrin (pyrethroids), chlorpyrifos (organophosphate), and propoxur (carbamate)}, the early and mid-

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phases of the Madagascar locust control campaign placed heavy emphasis on the use of fipronil, which had never before been used anywhere in a full-scale emergency campaign. Colin Tingle of the Natural Resources Institute (NRI) recently carried out an ecological assessment on the use of fipronil and criticised its use suggesting it is a danger to health and the unique ecosystem of the island. In 1998, a USAID team also confirmed these findings.

Fipronil is highly toxic to some birds, fish reptiles and insects. There is evidence of a decline in the large eared tenrec (*Geogale aurita*), Madagascar bee-eater (*Merops superciliosus*) and the chameleon (*Chameleo oustaleti*) (Tingle, 1996). But the biggest impact has been on Madagascar's termites which are a very valuable food source for a whole range of other animals; 10 months after spraying, 90% of colonies were destroyed. Emergency funds for spraying campaigns were provided by the European Commission (EC) and Coopération Française, with technical assistance from the FAO, the international body charged with responsibility for coordination of locust control. Initially, the World Bank also provided funding but withdrew its support in 1998 because of concerns over the inappropriate use of pesticides.

Progress towards sustainable control

The increased prevalence of locust outbreaks globally in the last few years and the methods employed to control them, highlight the difficulty in dealing with pests that can rapidly increase population size and travel large distances to attack crop growing regions away from the source areas. Clearly, development and implementation of effective preventive control strategies remains a major challenge. Part of this challenge involves the integration of alternative 'safer' forms of control that reduce the reliance on broad spectrum chemicals.

A previous article in this journal (Thomas and Blanford, 1998) described the work of a multidisciplinary research programme (LUBILOSA) which has developed a biopesticide, based the entomopathogenic fungus *Metarhizium anisopliae* var *acridum*, for control of locusts and grasshoppers in Africa. The biopesticide (commercial name "Green Muscle") has been approved by the FAO for use in conservation and environmentally sensitive areas and in 1998, was registered in South Africa for use against brown locust. It is now undergoing registration in the CILSS states in west Africa for grasshopper control. Although still in the process of being implemented within operational locust and grasshopper control programmes in Africa, it is interesting to report that just as we see locusts and grasshopper problems occurring in different parts of the world, this novel technology is now being picked up and applied in a number of programmes:

- In southern Europe an EU-funded programme, entitled ESLOCO, is currently testing the biopesticide against the Moroccan locust (*Dociostaurus maroccanus*) and Italian grasshopper (*Calliptamus italicus*) in Spain and Italy.
- In Africa, one of the main locust species is the red locust (*Nomadacris septemfasciata*). Its recession zone is mainly within the central and southern region of Africa and includes parts of Uganda, Tanzania, eastern Zambia and Mozambique. A new DFID funded programme has brought together a number of collaborators to evaluate the biopesticide against red locust and develop an appropriate biologically-based control strategy.
- Although in Latin America, locust and grasshopper biocontrol is still at an early stage, the use of biopesticides is being investigated. Workers at EMBRAPA have started development of a biopesticide using a local strain of *Metarhizium anisopliae* var. *acridum*, with first field trials commencing in 1998. More recently, field trials have been conducted against the South American Plague Locust, Rhammatocerus schistoceroides, in Mato Grosso state, Brazil.
- In Mexico, two strains of *Metarhizium* have been isolated from acrdids and, together with collaborating researchers from CSIRO in Australia, high virulence has been demonstrated in laboratory tests indicating their potential for locust control (Barrientos-Lozano and Milner, 2000).
- Finally, in Australia the APLC, using an indigenous strain of *M. anisopliae* var *acridum* have carried out a number of recent trials against Migratory locust and the Australian plague locust (*Chortoicetes terminifera*) with exceptionally good results. Bands of migratory locusts treated with *Metarhizium* declined in size by >90% 7–15 days after treatment. During late October 1999 Australian plague locusts covering more than 700 ha were treated with *Metarhizium*. At moderate-high doses, there was a rapid decline in numbers in the second week after treatment. And all doses used resulted in a >90% decline in numbers. Trials against the wingless grasshopper (*Phaulacridium vittatum*) gave about 85% control of grasshoppers and provided excellent recovery of a severely damaged lucerne crop. The success of these trials and their associated laboratory tests have led the APLC to initiate registration procedures for this *Metarhizium*-based biopesticide under the name "Green Guard". In the coming season it will be tested at a truly operational scale in trials up to 30,000 ha (Milner, 2000).

The basic technology developed in the LUBILOSA programme may well provide the basis for an alternative to chemical insecticides for a range of locust and grasshopper species globally. However, what is also emerging from these programmes is that the ability to demonstrate the scientific feasibility and potential of this technology, does not automatically lead to its broad uptake by control practitioners. To discuss this important issue further, we draw briefly on some of the experiences of the programmes in Australia and South Africa to examine how different constraints and incentives within a particular system act to influence the rate and scale of implementation of the biopesticide technology.

Constraints and incentives for adopting biopesticide technologies

Biological constraints

Unlike chemical insecticides the biopesticide is based on a living biological agent. Consequently, much more than a chemical, its effectiveness (i.e. the process of germination and penetration, proliferation inside the host and ultimate death of the host) is a product of a dynamic interaction between the fungus, the locust and the environment. In particular, recent work in the LUBILOSA programme has revealed that temperature, and critically the effect of environmental conditions on host body temperature, has a profound effect on the efficacy of the pathogen (see Blanford *et al.*, 1998; Blanford & Thomas, 2000). Under ideal conditions (i.e. constant temperatures of 25–30°C which are optimal for the pathogen) time to death following treatment with the biopesticide may be a matter of just 4–7 days. However, field conditions are not constant and temperature may fluctuate widely over a 24 hour period and over the duration of a control campaign. Furthermore, the majority of pest acridids appear to be active behavioural thermoregulators. That is, they employ a suite of behaviours to maintain a preferred, or set point, body temperature relatively independent of ambient temperatures during the day. Consequently, internal growth of *Metarhizium* may fluctuate widely over time and thermal conditions. For example, in the Sahelian zone of West Africa, or in the central recession zone of the Australian Plague Locust, relatively short days and mild nights high-level, repeatable, control has been achieved with *Metarhizium*, even at reduced doses. On the other hand, in the Karoo in South Africa, with relatively long day lengths and cool nights, effective control of the brown locust has proved difficult, even at high dose level. The key to understanding and managing this variability is an understanding of the ecology of the host-pathogen interaction.

Logistic and infrastructure constraints

Following from above it is clear that understanding and predicting performance of the biopesticide is complex and there is a need to develop appropriate use strategies – a simple ‘spray and pray’ approach is not sufficient. These strategies should optimise biopesticide use in terms of its operating characteristics within an IPM framework. This means that if conditions indicate that the pathogen will work too slowly, either because fast knock down is required for economic reasons or because speed of kill is too slow to be managed in practical terms, then alternative control methods should be used. If, on the other hand, conditions indicate that the pathogen will perform satisfactorily (i.e. where it acts relatively rapidly or where speed of kill is not an issue, and also considering its benefits in terms of environmental impact), then it should be used. Where the challenge lies is determining where and when these different conditions apply. The underlying practical dimension to this is having the necessary infrastructure and logistic support to implement and even develop a strategy in the first place.

Regulatory and political constraints

Biopesticides, like chemical pesticides, generally need to go through registration procedures. Product registration is time consuming, costly, and tends to follow the chemical pesticide model requiring studies on efficacy, toxicity and impact against target, non-target and beneficial species. It can certainly be argued that some of these chemical derived tests are inappropriate for biological organisms such as fungal entomopathogens, and thus place an unnecessary constraint in implementing the technology. However, even where appropriate, a further problem exists in that requirements are not standardised and considerable variation exists between and even within regions. For example, ‘Green Muscle’, though fulfilling the registration requirements for South Africa, requires a number of additional tests for registration with CILSS. Furthermore, regulations in Madagascar, for example, only permit the use of local *Metarhizium* strains for locust and grasshopper control. Thus, although essentially homologous to those being tested in Madagascar, the strain of *Metarhizium* used in Green Muscle which was originally isolated in Niger, cannot be used. This necessitates compilation of a separate registration dossier for the new isolate. For Madagascar, that is remote from the African continent, such regulations might be apt. However, for mainland countries where pathogens may be widely dispersed by highly mobile locust hosts, such restrictions appear inappropriate (though exist nonetheless).

In South Africa, the Government is looking to cut back expenditure on locust control operations. To achieve this aim and simultaneously incorporate the biopesticide, requires a significant re-design of the whole control programme with investments in improved forecasting and monitoring, and a move to optimised, more systematic spray tactics to replace the somewhat ad hoc treatment of individual hopper bands conducted presently. At the same time, the short-term option of simply putting a more expensive biopesticide product into the existing chemical pesticide regime is not very attractive. This in spite of recognised pressure from environmentalists and ‘green’ farmers to reduce chemical inputs in the Karoo. In contrast, in Australia, not only is the biopesticide competitively priced, but more importantly the central outbreak area for plague locust is now dominated by organic beef production. Thus, the only option for controlling locusts and still maintaining organic status, with associated access to this premium market, is to use a biological product. This provides an overriding economic incentive to implement the biopesticide, above and beyond any environmental pressure.

Conclusions

Locusts and grasshoppers are truly cosmopolitan pests. They often inhabit remote areas, which can be inaccessible, maybe politically unstable and have underdeveloped infrastructure. Accordingly, locust control with even conventional insecticides is a considerable challenge. As we have suggested, for biopesticides, there are further constraints, not immediately apparent in their chemical counterparts. Though these constraints should not be underestimated, the reported impact of fipronil in Madagascar should be a salutary lesson in the continued problems associated with non judicious use of chemical pesticides. To this end, the ongoing activities of LUBILOSA and the growing body of programmes embracing the biopesticide technology, is encouraging. The recent success of the work in Australia shows that where the necessary ecological, logistic and

BULLETINS ON LOCUST OUTBREAKS

FAO Desert Locusts Bulletin http://vwww.vita.org/disaster/locust/

BBC News Online: Locusts warning in Turkmenistan (2000a) http://news6.thdo.bbc.co.uk/hi/english/world/asia%2Dpacific/newsid%5F744000/744895.stm

BBC News Online: China plagued by locusts (2000b) http://news.bbc.co.uk/low/english/world/asia-pacific/newsid_792000/792251.stm

BBC News Online: Locusts swarm across Central Asia (1999) http://news.bbc.co.uk/low/english/world/asia-pacific/newsid_401000/401128.stm

BBC News Online: Peru battles locust plague (2000d) http://news6.thdo.bbc.co.uk/hi/english/world/americas/newsid%5F800000/800771.stm

political constraints are satisfied, the move to operational use can be rapid. What is now required is that other Governments and donors take on board the need for this holistic approach. In this way, sustainable preventive locust control incorporating the use of biopesticides, may become reality.

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ACRONYMS AND FURTHER LOCUST CONTROL INFORMATION

LUBILOSA: LUtte BIologique contre les LOcustes et les SAuteriaux (Committe for biological control against locust and grasshoppers)
http://www.cgiar.org/iita/research/Lubilosa/INDEX.HTM for Green Muscle

ESLOCO: Environmentally Sustainable Locust and Grasshopper Control

DFID: Department for International Development
http://www.dfid.gov.uk/

APLC: Australian Plague Locust Commission
http://www.affa.gov.au/aplc

EMBRAPA: Empresa Brasileira de Pesquisa Agropecuaria (Brazilian Institute for Agricultural Research)
http://www.embrapa.br

CSIRO: Australian Commonwealth Scientific and Industrial Research Organization
http://www.csiro.au

CILSS: Comité permanent Inter-états pour la lutte contre la sécheresse dans le Sahel (includes the following countries: Burkina Faso, Mali, Mauritanie, Niger, Sénégal et Tchad, Gambie, Cap-Vert, Guinée-Bissau) (the Permanent Inter-state Committee for Drought Control in the Sahel)
http://www.cilss.org

FAO (EMPRES): Emergency Prevention System (EMPRES) for Transboundary Animal and Plant Pests and Diseases (The Desert Locust Component)
http://www.fao.org/WAICENT/FaoInfo/Agricult/AGP/AGPP/EMPRES/

NRI: Natural Resources Institute
http://www.nri.org

PPRI: Plant Protection Research Institute
http://www.arc.agric.za/lnr/institutes/ppri/ppricore.htm

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