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Source: Journal of Orthoptera Research, 14(2) : 207-212

Published By: Orthopterists' Society

URL: https://doi.org/10.1665/1082-6467(2005)14[207:WBWWSV]2.0.CO;2

We believe what we see—and vice versa: evidence versus perception in locust control

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Abstract

Sustainable development was defined in 1987 by the World Commission on Environment and Development, as a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainability has since become a guiding principle and basis for action in all fields of agriculture, including pest management. The principle is stipulated in the Declaration on Environment and Development of 1992 which calls for "research and development into pesticides that are target-specific and readily degrade into harmless constituent parts after use", as well as in the 'Plan of Implementation of the World Summit on Sustainable Development' of 2002 which calls for "promoting programs for the environmentally sound, effective and efficient use of … pest control". How do these obligations translate into the reality of locust control? The present paper addresses this question from different perspectives, representing the 3 pillars of decision-making for sustainable development: *capacity*, *understanding* and *willingness*. It concludes that substantial progress has been made over the last decade in improving the technological *capacity* for more target-specific control (application technology, biological control, barrier treatment). However, despite all evidence, these innovations are often perceived with suspicion by locust control practitioners and the public. The paper identifies a lack of confidence in the efficacy of some of the new technologies as a major constraint to their adoption. Improving the *understanding* of these technologies is key to overcoming this constraint. This may require believing what one does not see immediately. Only then may decision makers be *willing* to include new and more environmentally sound technologies into their control portfolios—and so progress towards sustainable locust control.

Key words

locust control, barrier treatment, biological control, *Metarhizium anisopliae* var. *acridum*, technology adoption

Introduction

Locust control involves the application of insecticides over vast areas. For example, from 1987 to 1989, about 250,000 km^2 of land in Africa and the Middle East were treated against the desert locust, *Schistocerca gregaria* (Forskål) (Showler 2002). Control operations during the 2003–2005 upsurge extended over 130,000 km^2 (Lecoq, this volume). Figures for other locust species are lower but still impressive. In Madagascar from 1997 to 2000, more than 42,000 km^2 of land were sprayed against the Malagasy migratory locust, *Locusta migratoria capito* Saussure and the red locust *Nomadacris septemfasciata* (Serville) (Peveling *et al.* 2003), and in Kazakhstan in 2000, more than 80,000 km^2 were sprayed against the Italian locust, *Calliptamus italicus* (L.) (W. Kambulin, Ministry of Agriculture, pers. com.).

In preventive control, spraying operations focus on hopper bands in locust breeding areas. These are often located in desert or semi-desert, steppe, savanna and grassland biomes, *i.e.*, far away from agricultural areas. Timely control of nymphal populations is crucial to preventing swarm formation and subsequent damage to crops. However, control operations in remote areas are costly and logistically demanding. Moreover, the use of insecticides in natural landscapes and rangeland may pose a risk to wildlife and—with respect to insecticide residues in meat and milk—to livestock production, and has therefore become increasingly unpopular among environmentalists as well as livestock producers. Thus, there have been, and still are, both environmental and economic incentives for the development of sustainable locust control techniques leading to reduced environmental risks while assuring an effective and efficient level of control (Peveling 2001).

Research into new technologies and tactics in locust control gained momentum in the early nineties (Krall *et al.* 1997). Apart from innovations in ultra-low-volume (ULV) spraying techniques (*e.g.*, improved atomizers and track guidance systems), the research followed 2 main tracks. The first concerns reestablishment of the barrier treatment technique against hopper bands. In the past, this widely practiced technique relied on the use of persistent insecticides such as dieldrin (Wilps 2004). . It was abandoned following the ban on organochlorines in the late eighties. The second concerns development of locust-specific biological control agents based on entomopathogenic fungi (Lomer *et al.* 1997, Milner 1997). Both research tracks lead to the development and commercialization of locust insecticides suitable respectively for barrier treatment or biological control. However, adoption of barrier treatment and biocontrol differs greatly among locust-affected countries. The present paper examines factors and mindsets explaining these differences in innovation adoption.

Guiding principles.—Sustainable development was defined (1987) by the World Commission on Environment and Development as a development "meeting the needs of the present without compromising the ability of future generations to meet their own needs". Sustainability has since become a guiding principle and basis for action in all fields of agriculture, including pest management. The principle is stipulated in the 'Rio Declaration on Environment and Development' (1992), which calls for "research and development into pesticides that are target-specific and readily degrade into harmless constituent parts after use", as well as in the 'Plan of Implementation of the World Summit on Sustainable Development' (2002) which calls for "promoting programs for the environmentally sound, effective and efficient use of … pest control". These guiding principles constitute the policy framework for innovation development and the adoption of environmentally sustainable techniques in locust control. Notwithstanding that sustainability encompasses more than the adoption of such techniques, it is treated in this paper in a more narrow sense, as a strategy that minimizes environmental effects while guaranteeing an effective control.

Incentives and prerequisites for innovation adoption

Innovations are usually adopted because of either their direct commercial value, or because they are designed to maintain long-term productivity of the resource in question (Guerin 1999). This paradigm for innovation adoption in environmental management, however, does not translate easily into locust control because incentives are different for promoters, adopters and beneficiaries of innovations.

First, adoption of sustainable control techniques is often motivated by political considerations (*e.g.*, necessity to comply with guiding principles) of decision makers (promoters) rather than by the demand of professional locust control operators (adopters). Pressure groups such as livestock producers, bee keepers and conservationists also come into play at this point, and may demand development and implementation of sustainable practices to prevent negative effects on their commercial and/or environmental interests. In contrast, operators have little personal incentive to adopt innovations, because they do not directly benefit from them (in terms of protecting their own crops). From this perspective, technology adoption follows a top-down rather than bottom-up trajectory. Likewise, farmers (beneficiaries) may be ignorant about and largely unaffected by the means and environmental consequences of controlling locusts far away from their fields, unless—of course—in case of failure to contain locust infestations, or if locusts breed near to or even within cropland areas. In this case, however, farmers are likely to be more concerned about effective than environmentally sustainable practices.

Willingness, *understanding* and *capacity*, the 3 pillars of decision making for sustainable development (Gallopín 2002), are fundamental prerequisites for technology adoption (Fig. 1). Only where these domains overlap (the *willing*, *wise* and *able* sphere) are decisions and actions appropriate in terms of moving towards sustainable practices. In the present paper, Gallopín's model will be used to outline and discuss the status of, and constraints to, technology adoption in locust control.

Barrier treatment

Technology development. — Reduced cost, higher work rates and lower environmental risks are the main drivers for the resumption of the barrier treatment technique. Though already practiced in the early days of modern locust control, the technique can be considered as innovative, because it relies on new control agents, spraying devices and modes of application (Wilps 2004). Barrier treatments require moderately persistent insecticides such as benzoylureas (insect growth regulators, IGRs) and phenylpyrazoles. Specific ULV formulations for locust control became available in the early nineties, and verified dose rates for barrier treatments with diflubenzuron (benzoylurea) and fipronil (phenylpyrazole) against desert locust hopper bands were already established in 1996 (FAO 1996). Dose rates for the IGR triflumuron were amended 1 y later (FAO 1997; see also Matthews, this volume). Operational field trials were conducted within both the private and public research domain. Support from the international donor community was motivated mainly by the presumed economic and environmental advantage of barrier treatments over full-cover treatments.

The evidence. — Several field trials demonstrated the efficacy of barrier treatments against hopper bands of the desert locust (Dorow 1996, Wilps & Diop 1997, Rachadi & Foucart 1999) and the Malagasy migratory locust (Scherer & Rakotonandrasana 1993, Cooper *et al.* 1995, Dorow 1996). These trials showed that maximum control is usually achieved about 10 d after treatment, and that overall efficacy is comparable to blanket treatments. The speed of control varies depending on active ingredient, dosage, barrier spacing and hopper- band mobility. IGRs have to be ingested to be effective, whereas fipronil combines contact and stomach activity. Thus, the speed of control is usually faster with fipronil than with IGRs.

Surprisingly, barrier treatments with IGRs or fipronil were never used operationally against the desert locust, even though the 2004-2005 upsurge provided ample opportunities. In contrast, fipronil barriers were applied on a very large scale to control the 1999-2000 Malagasy migratory locust plague (Peveling *et al.* 2003) and have become an established technique in the preventive control of the Australian plague locust, *Chortoicetes terminifera* (Walker)(APLC 2004, 2005). Diflubenzuron is widely used in barrier (and full-cover) treatments against Italian locust and grasshoppers in Central Asia, but is of marginal importance elsewhere in locust-affected countries. Remarkably, adoption of the barrier technique is lowest in the developing world.

The perception. — It is the very nature of barrier treatments that they are effective only on large spatial and temporal scales. Thus, control operators need to have confidence in the technique and accept that the success of their work—in terms of controlling locust infestations effectively—may not become evident immediately. Yet, there are numerous indications that the contrary is the case, in particular —but not only—in the developing world. Without the sight of killed locusts, operators tend to believe that barrier treatments are not or insufficiently effective. One of the principal fears is that hoppers molt into the adult stage and fly away before passing through a barrier. Another fear related exclusively to IGRs, is that later instars are not susceptible to this class of insecticide. These fears are nourished by suspicions held by the local population about the efficacy of barrier treatments. How can treatments be effective that do not produce massive and immediately visible locust kills?

Indications of the lack of confidence in the barrier treatment technique are manifold. They are best reflected in practices to modify the technique so as to yield more striking effects. One practice is to respray an area before the first treatment unfolds its full effect. Another one consists of gradually reducing barrier spacing. Such modifications are intended to accelerate the speed of control of hopper bands. A third, and fairly unusual practice, is the mixing of IGRs with fipronil. This practice reflects the disbelief that IGRs *alone* are effective in controlling nymphal populations. It may also explain why IGR stocks sometimes linger in pesticide stores for many years instead of being used in barrier treatments.

Neither of the aforementioned practices represent official policies. They are rather informal adaptations on the operational level—and were confided as such to the author on several occasions in several countries. However, they clearly illustrate problems encountered in the adoption of the barrier-treatment technique. According to Gallopín's model, these problems are related mainly to a lack of

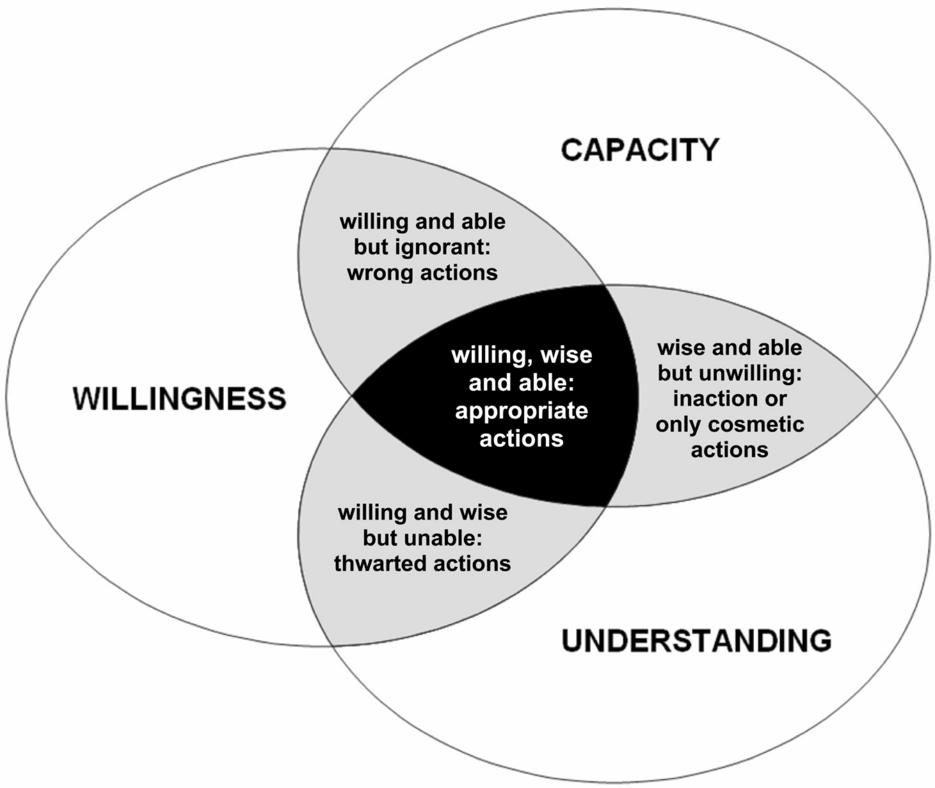

Fig. 1. The 3 pillars of decision making for sustainable development (after Gallopín 2002). Intersections of the 3 domains determine the type and quality of actions taken. Australia is the first country that successfully adopted barrier treatment and biocontrol technologies in preventive locust control (*willing*, *wise* and *able*). Adoption in other locust-affected countries is compromised by a lack of understanding and/or insufficient capacity, but sometimes also by insufficient evidence of the feasibility of these technologies.

understanding of the barrier-treatment concept (hence lack of confidence) and—to a lesser extent, to insufficient *capacity* to apply barrier treatments.

Biocontrol

Technology development. —The first attempts to control locusts with entomopathogenic fungi date back to the mid 1930s (Schaefer 1936). However, this approach was no longer pursued in view of the development and increasing predominance of synthetic insecticides in the following decades. Moreover, fungal agents were long considered maladapted to arid and semi-arid climates. Nevertheless, research into biological locust control was resumed in the 1990s (Lomer *et al.* 2001). In the developing world, the research was driven by growing concerns of funding agencies and the donor community over adverse environmental and human health effects of synthetic chemical insecticides. Consequently, technical and financial assistance was provided on the condition that recipient nations support and eventually adopt more environmentally friendly control techniques. In contrast in the developed world, biocontrol research was driven both by policy and market demands. For example, Australian livestock producers, in particular organic growers, are extremely sensitive about meat contamination due to chemical pesticides (Guerin 1999) and therefore have strong interest in using biological control techniques on their grazing properties.

Research in Australia and Africa led to the discovery of a new variety of the green muscardine disease, *Metarhizium anisopliae* var. *acridum* Driver & Milner (Deuteromycotina, Hyphomycetes), that is highly pathogenic and specific to acridids. The research was conducted nearly exclusively within the public domain. Strong public support was motivated by the expected environmental benefit of this biocontrol technique. Two strains from Australia and Africa were developed independently into ULV mycoinsecticides for locust control (oil-formulated conidia). Verified dose rates for desert locust control were already established in 1997 (FAO 1997). Production technologies were eventually transferred to the private sector within private-public partnership programs. Today, commercial mycoinsecticides are registered in several African countries and in Australia.

The evidence. — Operational field trials were conducted against different locust and grasshopper species (Langewald *et al.* 1997, 1999; Price *et al.* 1997; Hunter *et al.* 1999, 2001; Milner & Hunter 2001). These trials provided clear evidence of the efficacy of mycopesticides based on *M. anisopliae* var. *acridum*. Depending on climatic conditions, maximum control is usually achieved between 10 and 20 d post-treatment. In favorable conditions, effects can be longer lasting with fungal than with chemical short-residual insecticides, thanks to the residual activity of the inoculum (Langewald *et al.* 1999, Hunter *et al.* 2001). However, the ability of acridids to thermoregulate above tolerated temperatures for fungal growth (Blanford *et al.* 1998), which may increase host survival time, has been identified as a constraint on the operational use of mycopesticides (Lomer & Langewald 2001).

Nevertheless, *M. anisopliae* var. *acridum* has become one of the 3 most common locust control agents in Australia, together with fipronil (for barrier treatments) and fenitrothion (for rapid action). Its use is recommended against nymphal populations in environmentally sensitive areas (*e.g.*, adjacent to waterways) and organic farming areas. In contrast, adoption of the technology in Africa has not advanced very far. During the 2004-2005 upsurge of the desert locust, the fungus was not used at all, even though operational field trials, under the auspices of FAO in Algeria and Niger in 2005, apparently gave promising results. In contrast, large-scale field trials with a Malagasy strain against the Malagasy migratory locust have been pending for several years. In other parts of the world, biocontrol agents based on *M. anisopliae* var. *acridum* are currently under development and/or review for registration and are likely to be introduced in the near future, in particular in Asia and South America.

The perception.—The skepticism towards biocontrol bears resemblance to the one towards barrier treatments and is centered around the fact that effects express themselves rather subtly. First, the chances of finding dead locusts in the field are even slimmer than with barrier treatments, because weakened locusts are preyed upon and those succumbing to the fungal disease are scavenged. The disappearance of cadavers is more pronounced with fungal than with chemical insecticides, because the latter often have a repellent effect and/or are toxic to predators and scavengers as well. Thus, diminishing population densities are the principal and sometimes the only sign of effect. Second, it may take several weeks until full control is achieved, *i.e.*, the speed of kill under field conditions is relatively slow. The presence of seemingly healthy locusts, contrasted by the absence of cadavers in spray areas, may understandably call the efficacy of mycopesticides into question. In the early days of field testing fungal pathogens against locusts, even scientists were astounded by the lack of visual evidence of field mortality.

Unfortunately, the notion that mycopesticides do not work may at times be right. For example, extreme day/night temperature fluctuations may impede fungal pathogenesis and increase the chances of survival in infected locusts. In such situations, the use of mycopesticides may not be indicated at all. Worse, mycoinsecticides lose their viability if exposed to high temperatures for longer periods of time during storage and transport (Moore *et al.* 1996, Lomer & Langewald 2001). Inadequate use of good quality products or unintentional use of degraded products are ill-suited to create confidence in biocontrol technologies. Using obsolete chemical insecticides would, of course, have the same effect, yet the risk of product deterioration through inadequate storage or handling is, by far, higher with biocontrol agents.

It has been shown that the efficacy of *M. anisopliae* var. *acridum* against grasshoppers can be accelerated by mixing the mycopesticide with pyrethroid insecticides such as lambda-cyhalothrin (Douro-Kpindou *et al.* 2001). This approach may indeed broaden the scope for the use of mycopesticides in acridid pest control. However, it also reflects, implicitly, a lack of confidence in fungal control, just as mixing of IGRs with fipronil reflected a lack of confidence in IGRs (see p.208).

From Gallopín's model it is obvious that the problems encountered in biocontrol are related to both a lack of understanding of —and lack of trust in—the functioning of biocontrol, and an insufficient capacity to adopt good biocontrol practices. It is also obvious that the biocontrol technique is even more complex, hence more difficult to adopt, than the barrier treatment technique.

Constraints to innovation adoption

Assuming that the guiding principles for sustainable development are accepted all along the hierarchies of locust control organizations and funding agencies, *i.e.*, from operator to manager, from store keeper to pesticide procurer and from recipient to donor; in other words, assuming that sustainable practices are common sense within the locust stake-holder community, the problem of innovation adoption lies in the insufficient overlap of the *understanding* and *capacity* spheres (Fig. 1). The crucial question is why Australia has successfully adopted both barrier and biocontrol technologies, whereas countries in the developing world failed to do so, even though the technologies have, by and large, been developed in parallel? The negative perception of these technologies among end-users as outlined in the previous paragraphs, is an important, but not the only, explanation for this failure.

One fundamental constraint lies in the ephemeral character of institutions and services responsible for locust control in many developing countries. Only those countries affording permanent locust control centers or similar perennial structures have a chance to build and sustain capacities required for innovation adoption. This is particularly true for complex technologies such as barrier treatment and biological control. According to Guerin (1999), innovations will generally not be adopted if they are perceived to be difficult to integrate into existing practices or too complex for users to understand.

The absence, weakness or unawareness of pressure groups in developing countries is another major constraint to innovation adoption. For example, pastoralists in the Sahel produce mainly for their subsistence and domestic markets. Maximum residue limits (MRLs) for meat or milk do not exist or are not endorsed. Hence, residues resulting from livestock grazing in spray blocks within withholding periods are unlikely to be detected and to cause marketing problems. Thus, there is no reason for pastoralists to demand that control practices be modified. In contrast, export-oriented livestock economies such as Australia's would face serious problems if MRLs were exceeded. In these countries, there is strong pressure from the livestock industry (and other stakeholders such as beekeepers' associations) to adopt environmentally sound locust control techniques and policies.

Environmental externalities have been identified as an important impediment to innovation adoption (Hazell & Wood 2000). They arise whenever there is a mismatch between those who degrade resources and those who bear the consequences. Hazell & Wood (2000) argue that those who cause externalities (*e.g.*, control operators responsible for the pollution of a stream) have little or no incentive to modify their behavior because they do not bear the costs of their actions. In Gallopín's diction, operators would be *willing* and *able* but *ignorant*—hence taking wrong actions (Fig. 1). On the other hand, those who bear the consequences (*e.g.*, downstream fishermen) have every incentive, but little or no effective means to modify the behavior of those causing the externalities. (If they had, they would become a pressure group).

Listing all possible factors that might impede technology adoption in locust control lies beyond the scope of the present paper. However, in addition to those discussed in more detail above, at least 3 other factors are worth mentioning: 1) insufficient guidance during the technology transfer process, 2) the hastiness of responses in emergency situations, which generally favors the use of established, rather than innovative, control techniques and 3) the unavailability on the market of new technologies when needed, *e.g.*, shortages in the supply of mycopesticides produced by small or medium-sized enterprises with limited production capacities.

Facilitating innovation adoption

Contrary to on-farm crop protection, which is the responsibility of individual farmers, locust control is strongly institutionalized and centralized. This can be an advantage because it allows *implementing* technologies directly instead of *transferring* them via intricate extension pathways, provided there is the political will to do so. Creating the understanding and building the capacity necessary to adopt innovations is therefore mainly a matter of adequate and sustained training of control managers and operators. In the developing world, this requires a long-term commitment of the donor community to assist in providing this training.

This paper identifies a lack of confidence in barrier treatment and biocontrol techniques as a major constraint to their adoption. Operators were shown to be quite creative in their attempts at "enhancing control efficacy" by modifying prescribed use patterns, thereby unknowingly putting inherent economic and environmental benefits at stake. Creating confidence in the new technologies is key to getting away from such practices; the Australian example can be a blueprint to convince managers and operators of the feasibility of the new. However, paving the field for technology adoption also requires a fundamental change of attitude towards what an effective control should be. Operators must understand that in a preventive control setting, reducing locust populations over large spatial and temporal scales is more important than achieving spectacular local effects.

Information management and communication are critical to innovation adoption (Guerin 1999). In developed countries, information can be disseminated via the print media, radio, television and the internet. In developing countries, resources are still much more limited, with the exception of local radio stations that have proliferated over the last years. In locust-affected countries in Africa, community radio stations have become prominent as centers for disseminating information about environmental and human health risks of locust control. They could also be used to inform the public about the advent and characteristics of new locust control technologies. This would also reduce pressure on locust control operators from public expectations that spray operations must yield mass mortality to gain credibility.

Barrier treatment and biocontrol are relatively complex control techniques. Therefore, technical stewardship is needed through the entire adoption process. First, the efficacy of the control techniques must be demonstrated in different field situations. Second, concurrent use patterns must be clearly defined, refined and modified if necessary. Third, this knowledge must eventually be integrated into an overall control strategy. Without stewardship, the techniques might be used incorrectly or in settings where they are inappropriate, and eventually be abandoned, a phenomenon known as technology disadoption (Guerin 1999). To facilitate technology adoption, it has also been proposed to assign treatments to specialized teams, *i.e.*, teams particularly trained and equipped for barrier treatment and biocontrol (Peveling & El Hadj 2005). This would be more efficient, sustainable and cost-saving than qualifying all spray teams belonging to a locust control institution.

Last but not least, donor support, including support by FAO, should be conditional—where technically and strategically feasible—on the integration of barrier treatment and/or biocontrol techniques into the control portfolios of recipient countries, this of course within the limits of national legislation and sovereignty.

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