Biocontrol Files

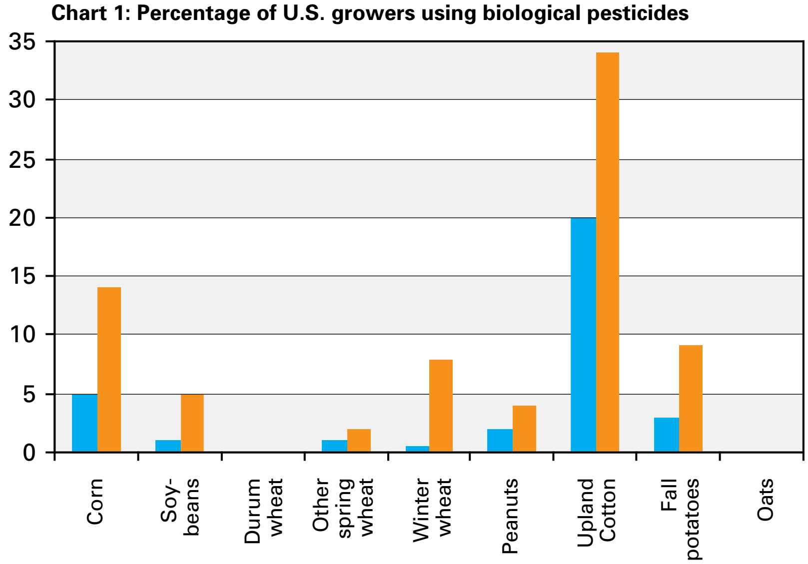
Issue #10, June 2007
www.biocontrol.ca
Disponible en français

Canada's Bulletin on Ecological Pest Management

Measuring uptake of biocontrol in field crops

The National Agricultural Statistics Service of the U.S. Department of Agriculture surveys a sample group of farmers every year on a variety of topics, including their pest management practices. Included in the surveys are questions which estimate uptake of biological pest control. One survey question asks growers which pest control products they use. Other questions estimate the percentage of farmers and acreage using beneficial organisms, natural/biological based products or biological pesticides.

Chart 1: Percentage of U.S. growers using biological pesticides



Use biological pesticides - national average

Highest state percentage

The only product used by more than 1% of growers on any of the nine field crops surveyed in 2004 and 2005 - corn, soybeans, fall potatoes, oats, upland cotton, durum wheat, other spring wheat, winter wheat and peanuts – was Pix Plus, which contains the bioagent *Bacillus cereus*. This product was used on 9% of national upland cotton acreage, rising to a high of 20% in Georgia.

Growers of the nine field crops were asked the following question: "Were any biological pesticides such as Bt (*Bacillus thuringiensis*), insect growth regulators (Courier, Intrepid, etc.) neem or other natural/biological based products sprayed or applied to manage pests in this field?" Chart 1 shows the percentage of farms for each commodity who responded positively to this question, and the highest percentage of positive responses from any state.

In three crops – upland cotton, fall potato and peanuts, growers were asked additional questions. One question asked: "Were floral lures, attractants, repellents, pheromone traps or other biological pest controls used on this field?" A second question asked growers if they had released beneficial organisms (insects, nematodes, fungi). Chart 2 (page 2) shows positive responses to these two questions.

There are several sources of information on uptake of biological pest management practices in Canada. Stats Canada conducted a survey of carrot, apple and grape growers in the winter of 2006, financed by Agriculture and Agri-Food Canada's Pest Management Centre. The survey included questions on pest management practices, including one on the release of beneficial insects. As of the date of publication, the results were being analyzed. An AAFC-funded survey conducted in 2001 (the Farm Environmental Management Survey) asked a national sample of growers if they employed a number of "alternative pest control" practices. Chart 3 (page 2) shows the percentages of farmers across Canada who reported using various kinds of biological options. The latest FEMS survey was conducted in the winter of 2007, and results should be available for analysis by AAFC staff by the fall of 2007.

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Chart 2: Percentage of U.S. growers using biological pest control options

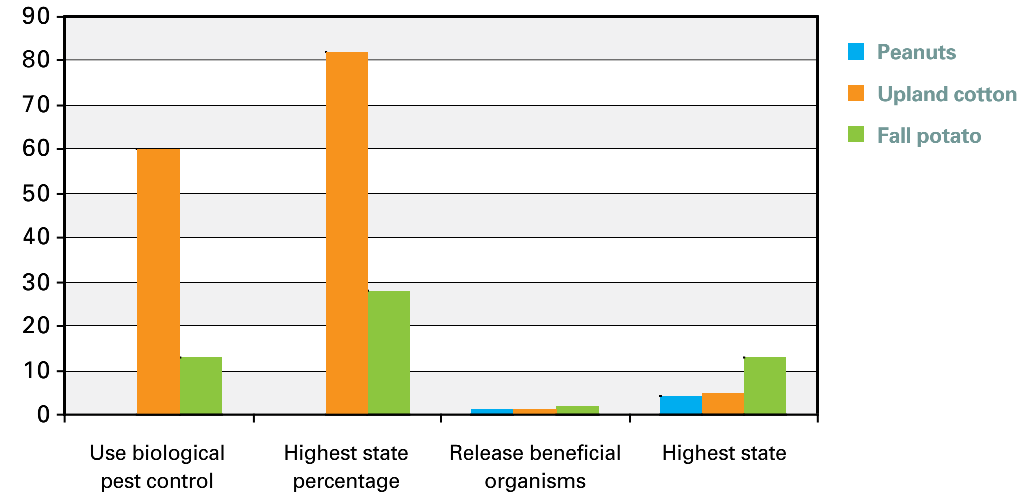
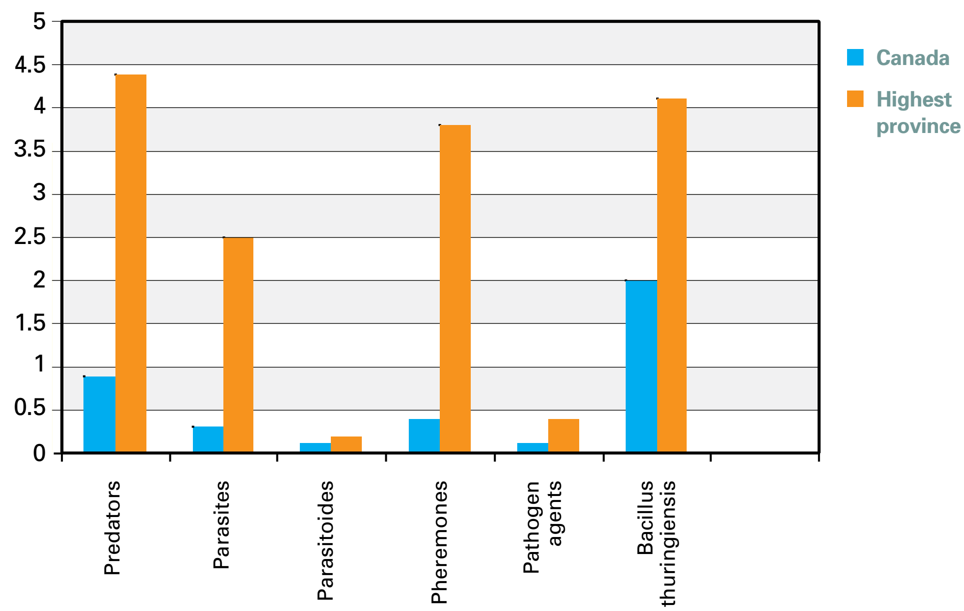


Chart 3: Percentage of Canadian growers using biological pest control options



Analysis of the results remains difficult, especially in the U.S., because some survey questions do not isolate biocontrol options, but lump them in with other "alternatives" to chemical pesticide use. However, the results of the most recent FEMS survey in Canada should provide some insight into whether biological pest management is gaining popularity in Canadian crop production. And, because the U.S. and Canadian surveys cover roughly the same biological pest management options, they should provide a basis for better cross-border comparisons. ■

Biocontrol Files: Canada's Bulletin on Ecological Pest Management is a quarterly publication which reports on tools and developments in ecological pest management. The co-publishers World Wildlife Fund Canada, the Biocontrol Network and Agriculture and Agri-Food Canada welcome additional partners and sponsors committed to advancing knowledge and adoption of ecological pest management.

Submissions and letters to the editor are welcomed. Guidelines for submission are available on request from biocontrol-network@umontreal.ca.

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French translation by: Alain Cavenne

Website production: Biocontrol Network

Appreciation is owed to NSERC for its support to the Biocontrol Network, including for public awareness regarding bio-pesticides.

Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada

Biological control of root maggots in canola

Neil Holliday, University of Manitoba

Root maggots, notably the cabbage maggot *Delia radicum*, are pests of canola on the Canadian prairies, and cause an estimated $60 to $100 million in damages annually. Their incidence and the severity of damage they cause are increasing. In canola, there is usually one generation of cabbage maggots each year. Female root maggot flies lay eggs at the base of canola plants at the bolting stage. The eggs hatch into larvae, which tunnel in the canola roots. The larva moults to a pupa, contained in a barrel-shaped puparium, which passes the winter in the soil. Adults emerge the following spring.

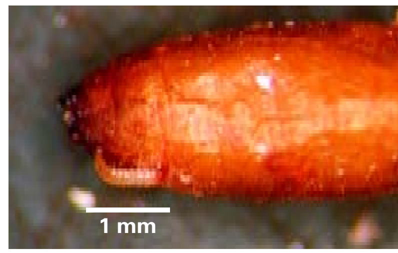
There are no safe, practical insecticidal methods to control the larvae, which feed on canola roots in July. Cultural controls are helpful, but may conflict with production objectives. Cabbage maggot originated in Europe, so classical biological control, in which specialized natural enemies from the area of origin are introduced, is a promising alternative. We have been exploring this option since 1999.

There are a number of steps which researchers must take before a potential biological control candidate is ready for release. The first step in our search for a suitable candidate was to compare the species of parasitoids (parasites that kill their hosts) of cabbage maggots in prairie canola with those in brassica crops in Europe. Most parasitoid species in the two regions were the same, but one, *Aleochara bipustulata*, was found only in Europe. *Aleochara bipustulata* is a small rove beetle, the eggs of which are laid near root maggot puparia. The newly-hatched beetle larvae seek puparia, which they enter and parasitize. Adult *A. bipustulata* eat the eggs and larvae of root maggots.

Before selecting *A. bipustulata* as a candidate biological control agent, we needed to establish that it does not occur in North America. The literature reports that *A. bipustulata* occurs in North America, but our examinations of voucher specimens and museum material showed that North American records of *A. bipustulata* were misidentifications of a related species, *A. verna*.

We were also concerned that *A. bipustulata* might interfere with an existing Canadian parasitoid of root maggots, *A. bilineata*. At CABI in Switzerland, where both species occur naturally, we compared parasitism of cabbage maggots in field cages with either *A. bipustulata* or *A. bilineata* or a combination of the two. Parasitism was highest in the mixed species treatment, so it appears that parasitism of the two species is complementary. We also found that *A. bipustulata* larvae seldom enter previously parasitized puparia, so there is little risk of *A. bipustulata* attacking the established Canadian parasitoid inside a puparium.

We have studied the risk of *A. bipustulata* parasitizing insects other than the target cabbage maggot. We tested 18 non-target species, chosen to represent taxonomic groups or beneficial species of concern. A no-choice test was used, so that the alternative for a beetle larva that did not attack the non-target species was death. We found that six non-target species were suitable hosts for parasitoid development. Some are close relatives of cabbage maggot, many of which are also pests. Others were species with small puparia, and we will investigate whether the small *A. bipustulata* that emerge from them are able to reproduce. One beneficial species was parasitized. This was *Lonchaea corticis*, a predator of the white pine weevil, a pest in Canadian forests. However, we found *A. bipustulata* only on the soil surface in crops and not in forests, even though we sampled forests intensively. *Lonchaea corticis* occurs under the bark of terminal branches on coniferous trees, where it is unlikely to be encountered by *A. bipustulata*. Still to be done are tests of the range of prey species eaten by the adult beetles.



***Aleochara larva* chewing a hole in the puparium of a cabbage maggot before entering to parasitize it**

Photo by K. Riley

We are preparing to identify Eurasian populations of *A. bipustulata* which are compatible with the prairie climate and the seasonal patterns of cabbage maggots in canola. We have modelled maggots' time of emergence on the prairies and investigated the over-wintering biology of *A. bipustulata* in Europe. We also have a method of attracting or retaining *A. bipustulata* in an area. Because insects may disperse after release and be unable to find mates, our retention method should prove valuable following an operational release for biological control.

Recently, concern about the risks of classical biological control to non-target organisms has resulted in the development of protocols to assess the risks and benefits of a proposed introduction. Our programme follows these protocols closely. Thus, when our studies are complete, regulators will be able to judge whether the possible risks are outweighed by the potential for *A. bipustulata* to halt or reverse the trend of increasing root maggot infestations in prairie canola. ■

Bioherbicides for field crop weed control in the Prairies

An interview with Sue Boyetchko, Agriculture and Agri-Food Canada

Biocontrol Files: How did your work on bioherbicides begin?

Sue Boyetchko: I was doing a postdoc with Agriculture Canada, working with soil bacteria to control an invasive weed called downy brome. I soon realized that, in order to get funding support and interest from industry, we had to select a more economically important target. Green foxtail and wild oat are the two most economically important grass weeds in the Canadian Prairies, so I diverted my focus to those two weeds, and the program expanded from there.

BF: Can you tell me a little about the impact of green foxtail – what kind of crops it attacks, what are the costs to producers?

SB: Producers probably spend $300-$400 million in the Prairies to control grass weeds, including green foxtail. Those are very old figures – I don't know what the costs are today. Green foxtail and wild oat occur in a whole variety of crops – cereals, oilseed crops, and pulse crops. Also, many grass weeds, including green foxtail and wild oat, are resistant to one or more herbicide modes of action. From what we're seeing, there's not a lot of new chemistry being developed for chemical herbicides. What we're trying to do is develop the next generation of herbicides, which I think is bioherbicides.

BF: Which biological agents have been tested on green foxtail and what kind of results have you had?

SB: We've focused on a lot of *Pseudomonas* bacteria, and one *Pseudomonas fluorescens* strain in particular has proved to be consistently effective throughout the last ten years of testing. In our lab screening work, we look for a minimum of 80% weed control, and in the field, we're looking for control that is comparable to the industry standard. We've been able to achieve up to 80-90% weed control in the field.

BF: What kind of work have you done on the *Pseudomonas* so far?

SB: We've characterized some of the secondary natural products, we have done a lot of fermentation research, and we've custom designed some fermentation media. One of my colleagues, Dr. Russell Hynes, is very involved with the formulation research. We've developed a Pesta formulation, based on grain flours, through collaboration with some USDA scientists. We also have information on stability and shelf life.

We've done a lot of background work to reach this stage, and we've always done field testing to validate it, and made improvements in formulation and fermentation in order to get the bioherbicidal activity up to 80%. But now the scale-up aspects are important, not just with fermentation but also with formulation and the kinds of impacts the bio-processing has on the bacteria. We have a postdoc looking at dispersion of the agents, and we're working with some weed scientists on some of the agronomy.

BF: What is the commercial status of the work at this point?

SB: We were issued a U.S. patent in 2005, and a Canadian patent last year, but we're still in what I would call the pre-commercialization phase. There's a small company who is interested and is working with us, but we need to work out the formulation and the agronomy before we're ready for a pre-submission consultation. For example, we need to determine what rates of application will be economical for farmers. We will have to improve the formulation, look at how we can increase the titre of the active ingredient, increase dispersion once it's applied to the soil, and determine the optimum placement of the granules in relation to the crop.

BF: So the *Pseudomonas* product is applied to the soil?

SB: Yes. It affects green foxtail and wild oat only at germination and early root stages. The bacteria produce secondary metabolites. Two of the metabolites that we have identified are pseudophomin A and pseudophomin B. They're very complex chemicals, too complex to synthesize. But the bacteria produce enough of these compounds that they have an inhibitory effect on the weeds. I should add that our bacteria do control the herbicide-resistant weeds I mentioned; they appear to have modes of action that are different than the chemical herbicides on the market.

BF: What's next for this work?

SB: We have a graduate student who is researching the environmental fate. We're trying to understand what happens to the bacteria once they're placed in the soil, how they are dispersed. We're also looking at what happens to the product in different temperature, moisture and soil conditions.

BF: Assuming that things go successfully, do you have any prediction how soon a product might be available on the market?

SB: Oh, I wish I could tell you. I'd like to say *yesterday*. We've been working on this for a long time, but hopefully we'll reach a stage in the next few years where we will know exactly where we're going. We'll have the agronomy worked out so that we can arrive at the registration stage and start looking at the data requirements to get this thing registered. ■

International efforts at biological control of grasshoppers and locusts

Introduction

Grasshoppers and locusts are serious pests of grassland areas in Sahelian Africa, North and South America, Australia and Asia. African locust outbreaks are particularly severe: 250,000 hectares were treated with insecticides in the 1987-89 desert locust outbreak and 130,000 hectares in 2003-2004.

Locust plagues - and the amount of damage they may cause - are exceedingly difficult to predict. Swarms may cross desert areas en route to the sea, attack farmers' subsistence crops, or infest high-value crops. While the dollar value of crop damage in Africa may be modest by Canadian standards, communities in which the great majority of farmers grow subsistence crops can suffer severe disruption.

Chemical insecticides are typically used to control grasshoppers and locusts. While this is unlikely to change in emergency situations, a growing awareness of the environmental downsides of chemical control is driving greater demand for biocontrol options, and in particular, for integrated and preventive strategies which aim at early intervention. These kinds of strategies avoid the financial and environmental costs associated with large-scale curative treatments.

In many countries, locust and grasshopper populations are monitored closely, and controlled as soon as outbreaks threaten. When pests cross national borders, internationally coordinated operations are required. A variety of coordinating bodies have been established in Africa, including the International Red Locust Control Organization for Central and Southern Africa, and several Food and Agricultural Organization (FAO) bodies.

Plagues arise when such efforts fail, when access to breeding areas is impossible, and when interventions begin too late. Once they develop, plagues necessitate widespread insecticide applications, with far greater financial and environmental costs than preventive control.

Grasshopper biology and biological control

Grasshoppers and locusts generally have very high reproductive rates and display rapid population increases in response to favourable conditions. Species such as the desert locust have relatively short developmental times and breed continuously. In unfavourable conditions, the eggs of some species may remain in diapause in the soil for two or three years.

Mortality from natural enemies does not generally keep populations in check, as grasshopper and locust population growth and movement outpaces their natural enemies. Also, pathogen impact on populations is minimal.

Metarhizium

The LUBILOSA (Lutte Biologique contre les Locustes et Sauteriaux) project, which operated in Africa from 1989-2002, was founded on research which showed that mixing oil rather than water with fungal spores (aerial conidia) would retain potency longer in dry environments, and therefore be much more infective. The project developed the first effective mycopesticide for locust control, based on the fungal species *Metarhizium anisopliae var. acridum*. Efforts in three independent programs – in Australia, Madagascar, and Brazil – also selected isolates of *M. anisopliae var. acridum* for development.

The LUBILOSA team selected *M. anisopliae var. acridum* because of its common presence in Sahelian Africa, where it coevolved with grasshoppers and locusts, making strains host-specific and minimizing the risk of infecting non-target insects. The most effective strain against a range of Sahelian grasshoppers and other locusts was found to be *M. anisopliae var. acridum* IMI 330189. The product is now registered in South Africa, several West African countries, and Sudan, under the name "Green Muscle".

A variety of reasons have been cited for the relatively slow uptake of the product, including cost, a general lack of familiarity and confidence in non-chemical solutions, the ephemeral nature of the institutions responsible for locust control in developing countries, and the absence of pressure groups to advocate for sustainable solutions. However, isolated projects have achieved good community uptake, for example in a LUBILOSA-sponsored farmer participation project in Benin.

Metarhizium uses enzymes to penetrate the insect cuticle. Inside the insect, the fungal mycelium continues to grow, producing yeast-like cells called blastospores, which proliferate, and in some cases produce toxins. Under conditions favourable to the fungus, *Metarhizium* overcomes insect defences and kills the insect.

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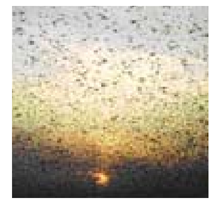
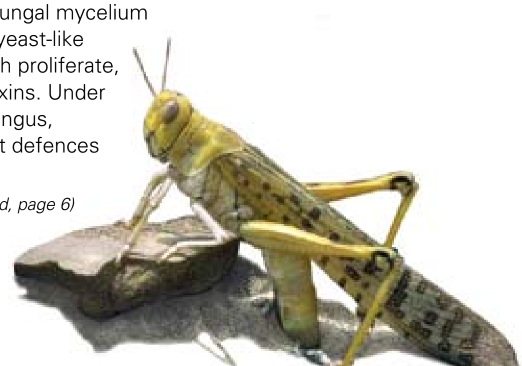
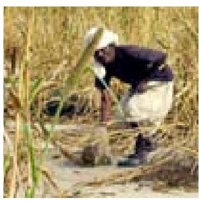


Desert locust swarm approaching Nouakchott (Mauritania, 1993). The swarm covered an area of 14 km^2 when settled and contained 12-14 billion insects



International efforts at biological control of grasshoppers and locusts (continued)



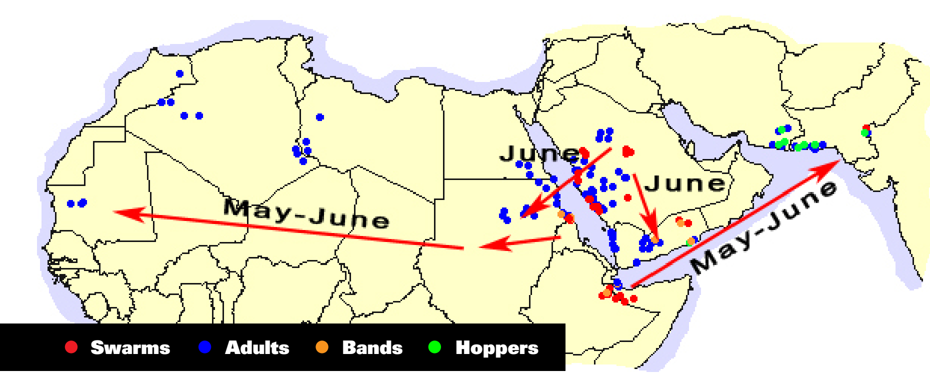
A farmer desperately tries to protect his precious pearl millet crops in Wadi Falkat, Eritrea by scaring the hopper bands with a hand full of sand

Grasshoppers' and locusts' best immune defence against fungal infection is thermoregulation. Many species maintain daytime body temperatures which are significantly different from ambient temperatures. Such temperatures can be maintained for a number of hours, given the right environmental conditions. There is evidence of a behavioural fever response, in which locusts thermoregulate to a higher temperature in response to fungal infection. Under the hot and sunny conditions which enable thermoregulation, pathogens cannot develop inside infected insects, increasing incubation time. Conversely, cloudy conditions and ambient temperatures between 26-32º C discourage effective thermoregulation, allowing rapid fungal growth and reducing incubation time.

The *Metarhizium* biopesticide is an oil-flowable concentrate, similar to chemical pesticides, and can be applied similarly to chemical pesticides, although it requires protection from excessive heat and direct sunlight. Most locust and grasshopper control operations employ ULV applications of oil formulations. Formulation improvements have extended spore storage time up to four years. The full effect of 70-90% mortality can be expected after 14–20 days, with shorter times under overcast conditions, and longer times under hot, sunny conditions.

In field trials, *M. anisopliae var. acridum* IMI 330189 outperformed the chemical insecticide fenotrothion in every respect except speed of kill. A single application provided season-long control (2-3 months). Successful trials have also been conducted in Australia, Madagascar, and Brazil.

Graphic analysis of locust situation in Red Sea and Horn of Africa from FAO Locust Control website



In the LUBILOSA project, research by a variety of public agencies was followed by transfer of the technology to the private sector. In essence, the donors and other contributors agreed to transfer their intellectual property rights to LUBILOSA. CAB International, acting on behalf of the project and its partners, licensed two companies to manufacture the product under the trade name "Green Muscle R." License fees and royalty payments are accumulated in the LUBILOSA trust fund, and disbursements are made to developing countries pursuing the development of biological pesticides.

Other biological agents

While *Metarhizium* is the first-choice inundative biocontrol agent, complementary agents with intergenerational persistence are needed. Microbial agents such as the bacteria *Nosema locustae* have been tested extensively in Argentina and China, with good results. Hymenopteran egg parasitoids such as *Scelio spp.* may also be valuable within an integrated strategy that employs rational use of chemical pesticides with biological agents such as *Metarhizium*.

Conclusions

Because of the specificity of the fungus, *Metarhizium* has limited effects on non-target organisms, including locusts and grasshoppers that are not considered pest species. Thus its use should enhance the impact of natural enemies and lead to the development of truly integrated pest management. The mycopesticide is a living biological agent, so training in storage, application, and monitoring will be necessary. Further climate-based research will be necessary to ensure that the mycopesticide is used to its best effect and not under conditions that are unfavourable to its efficacy.

The goal of sustainable biocontrol of locusts and grasshoppers depends on a commitment by donors and decision makers to fund preventive work on biological control, monitoring, surveillance, and prediction rather than reactively treating plagues that have escaped early vigilance. Other required components may be sustainable small but flexible national locust control units for prevention and the creation of emergency action plans, ready to quickly mobilize and organize resources in the event of an upsurge. Emergency funds are thus essential and should be created. In the words of Michel Lecoq of CIRAD (Centre de cooperation internationale en recherche agronomique pour le développement), "Locust control seems now to depend more on political and institutional choices than on scientific and technological innovations." ■

Biocontrol News Digest

PURDUE UNIVERSITY, NOVEMBER 10, 2006: What's eating aphids? Two bugs that farmers should know, by Steve Leer – Farmers could save $10-$12 per acre on insecticide treatments for soybean aphids by turning to a control method that money can't buy, says a Purdue University entomologist. That control option, according to Bob O'Neil, is the aphid's insect enemies.

Research by O'Neil, fellow Purdue entomologists and colleagues at four other Midwest land-grant universities found that in most cases, predators are able to consume enough of the population to keep aphid numbers below crop-damaging levels.

"There's quite a few predators in soybeans, but when you take a look at who is out there, in what numbers, and who is having a major impact, it comes down to a few species doing the heavy lifting," O'Neil said. "Early in the season there's a predatory bug called the insidious flower bug, also known as the minute pirate bug. That particular insect is important when there are relatively few numbers of soybean aphids in the field."

"Later in the season — in August and into September — when soybean aphid populations are higher, there's another set of predators that come in. These tend to be the predatory beetles. One of them is the Asian lady beetle and it does a great job. So between the minute pirate bug and the lady beetle, you've got a kind of one-two punch."

"Pirate bugs eat up to eight aphids per day," O'Neil said. "The lady beetles consume 30 to 40 a day. Between the two predators, aphid populations often stay below significant yield loss — or "economic threshold" — levels. The economic threshold is 263 aphids per plant."

"Not only could farmers be spending money needlessly on insecticides but also reducing the predator population," O'Neil said. "They need to be able to identify their friends as well as their enemies in the soybean field."

A Web site created from the aphid research can help farmers do just that. The Soybean Aphid Biological Control site (http://www.entomology.wisc.edu/sabc/resources.htm) is a collaborative effort of Purdue, Iowa State and Michigan State universities; the universities of Illinois, Minnesota and Wisconsin; the Illinois Natural History Survey; and the U.S. Department of Agriculture. It is supported by a grant from the North Central Soybean Research Program.

NAPA VALLEY REGISTER, MARCH 10, 2007: Farmer vs. Ant, by Julissa McKinnon – This growing season, grape farmers have a new and organic weapon in their ongoing efforts against exotic and troublesome Argentine ants.

As the weather warms, ants come out of winter hiding and begin tending and defending the vine mealybug - a tough-to-spot, slime-secreting vineyard scourge.

To date the tiny yet formidable vine mealybug has infested approximately 500 of Napa Valley's 45,000 vineyard acres. The insect poses a big threat to Napa Valley's sustainable and organic grape-growing trend, in part because Argentine ants have been busily fighting off the mealybug's natural predators. The ants not only defend the mealybugs but sometimes move them to more protected locations so the ants can feed off the mealybug's honeydew secretions.

This spring, for the first time, prospects look more promising for growers committed to environmentally-sound ant control. Using a recently approved liquid ant bait, growers could expect to see a decline in ant numbers after a year or two. Ant bait researchers assure the time lag is for the better.

"We're trying to kill them slowly," said Monica Cooper, a researcher with UC Berkeley's ant control studies. "We want them to keep coming back and feeding it to the colony because these colonies are so big it takes a long time to infiltrate," Cooper said.

Argentine ants, which are strictly liquid feeders, are lured by the high-sugar content in the liquid bait, which is also laced with deadly traces of boron - a certified organic pesticide.

Researchers intentionally gave the ant bait a low toxicity so that worker ants live long enough to share the poisoned feed with the queen ant and ant larvae - which they feed.

Beating back the Argentine ant paves the way for growers to begin relying on the mealybug's natural predators to tame the white and waxy pest. A mealybug destroyer, known as the Australian ladybug, preys by piercing the mealybug and sucking the juice out of it. Then there are the parasitic wasps that lay their eggs inside the bodies of the adult mealybug. As the new wasps hatch, they feed on the mealybug.

But with ants guarding the mealybugs, natural predators seldom make it past a mass ant ambush to their mealybug meal. "Ants are very successful at driving off predators," said Katey Taylor, the viticulturist for Domaine Chandon who also leads the Vine Mealybug Workgroup.

Spring Mountain Vineyard has been working with UC Berkeley researchers to test the effectiveness of the mealybug's predators. So far the experiment suggests that the mealybug's enemies show some promise as a reliable form of biological control. "After getting ants under control," Taylor said, "introducing the mealybug natural predators may become a much more viable way of beating back the soft-bodied pest." ■

Resources:

Books

TIn 2005, the U.S. Sustainable Agricultural Network (SAN) published *Manage Insects on Your Farm: A Guide to Ecological Strategies* as a vehicle to improve natural defenses against pest insects of crops while simultaneously encouraging preservation of beneficial organisms for biocontrol purposes. Authors M.A. Altieri et al have included examples of pest (insect) management in various locales globally while revisiting long-espoused principles of ecologically based pest management. The 135-page work, SAN Handbook Series Book 7, can be ordered as a softbound document or freely downloaded from http://www.sare.org/publications/insect.htm. SAN, 10300 Baltimore Ave., Bldg. 046, BARC-WEST, Beltsville, MD 20705-2350, USA. E-mail: sanpubs@sare.org. Fax: 1-301-504-5207.

New regulatory developments

Regulation of Biological Control Agents, or "REBECA," is a European Union policy support action that reviews possible risks of biocontrol agents, compares regulation in the EU and the USA, and proposes alternative, less bureaucratic and more efficient regulation procedures while maintaining the same level of safety for human health and the environment, but accelerating market access and lowering registration costs. See http://www.rebeca-net.de/

Events

August 12-16, 2007, Quebec City, Quebec. 40th Annual Meeting of the Society for Invertebrate Pathology and the 1st International Forum on Entomopathogenic Nematodes and Symbiotic Bacteria annual meeting. Contact: SIP 2007 Secretariat at: Hospitalité Québec, 580 Grande Allée Est, Bureau 140, Québec, Qc G1R 2K2, Canada. Tel: +1 (418) 522-8182. In North America (Toll free): (800) 618-8182. Fax (in North America): (418) 529-7548. E-mail: conference@hospitalite.com Website: http://www.sip2007quebec.com/

October 28 - November 1, 2007, Montreal, Quebec. Joint Meeting of the Association of Natural Bio-control Producers, the IOBC Global Working Group on Arthropod Mass Rearing and Quality Control, the ASTM subcommittee E35.30 on Natural Multi-Cellular Biological Control Organisms and the International Biocontrol Manufacturers Association Invertebrate Biocontrols Group. Hosted by the Biocontrol Network of Canada. On-line registration form at http://www.anbp.org/joint_meeting_form.htm

Suddenly it all made sense. Late at night, in a nest of shredded manila files in the middle drawer of the filing cabinet, the paperwork had been mating.