E-1225

Biological Control of Insect and Weed Pests in North Dakota Agriculture

Laurence D. Charlet, USDA, ARS, Research Entomologist
Denise Olson, Assistant Professor
Phillip A. Glogoza, Extension Entomologist

IPM is an ecologically-based pest management strategy that forms a part of the overall crop production system. Ideally, it incorporates all appropriate methods from many scientific disciplines into a systematic approach to minimize pest damage. IPM control tactics include a variety of approaches including cultural control, resistant plant varieties, chemical control, and biological control.

The use of biological control is a fundamental tactic for pest suppression within an effective Integrated Pest Management (IPM) program. Biological control refers to the use of natural enemies against a pest population to reduce the pest's density and damage to a level lower than would occur in their absence.

Biological control as a management tool dates back over 1,000 years when ancient Chinese citrus growers used ants to control caterpillar larvae infesting their trees. It is one of the safest methods of control since it is not toxic, pathogenic or injurious to humans.

Biological control has the advantage of being self-perpetuating once established and usually does not harm nontarget organisms found in the environment. In addition, it is not polluting or as disruptive to the environment as chemical pesticides, nor does it leave residues on food, a concern to many people today. However, the use of biological control does require detailed knowledge of the pest's biology and population dynamics, as well as the natural enemies associated with the pest and their impact. Control is usually not complete with this IPM method since a residual population of the pest is often necessary for the natural enemies to remain in the environment, so some noneconomic population levels of pests must be acceptable or tolerated.

Biological control also fits well in combination with other IPM strategies. There are many factors (crop, pest complex, environment) that can influence the success of beneficial organisms in reducing pest densities to manageable levels. In many situations the biological control method will need to be utilized in concert with other tactics. Selecting the least disruptive management tactic is recommended by IPM and should help conserve natural enemies.

The use of biological control to manage pests is divided into three types of approaches. **Importation** refers to the search for better natural enemies to introduce and permanently establish. The need for importation biological control occurs when a pest is accidentally introduced into an area and its natural enemies are left behind. An attempt is made to locate these enemies and introduce them to reestablish the control that often existed in the native range of the pest. This may be from another country or another region of the same country.

The three approaches to biological control are termed **importation**, **augmentation** and **conservation**.

NDSU EXTENSION SERVICE
North Dakota State University
Fargo, North Dakota 58105
JANUARY 2002

Augmentation is an attempt to reduce a pest's population to noneconomic levels by temporarily increasing natural enemy numbers in an area through periodic releases. The natural enemies then seek out and attack the pest. In some cropping systems, technology has been developed to rear natural enemies artificially so these releases can be made economically. A number of commercial companies have been created to produce a wide variety of natural enemies, both predators and parasites.

The third approach, **conservation**, is concerned with protecting the natural enemies that are already present in an area. In conservation, an attempt is made to manipulate the environment or the farming practices to protect the natural enemies or provide needed resources (e.g. alternate prey or food for adults) for them to survive and build up populations to levels where they can manage the pest and prevent it from causing economic damage to crops. Naturally occurring or indigenous natural enemies prevent many plant-feeding insects from achieving pest status. Conservation of these natural enemies allows them to operate near their full potential. Conserving natural enemies requires the use of farming practices that are less disruptive to natural enemy populations. Insecticide use destroys the target pest as well as many natural enemies that are present. Reduced or carefully timed insecticide treatments lower the negative impact on beneficial organisms. Effective conservation of natural enemies depends on: understanding the agroecosystem; use of selective pesticides; use of the least disruptive formulation of the chemical; application of the insecticide only when necessary and based on reasonable economic injury levels of the pest; and pesticide application at the time or place that is the least injurious to natural enemies.

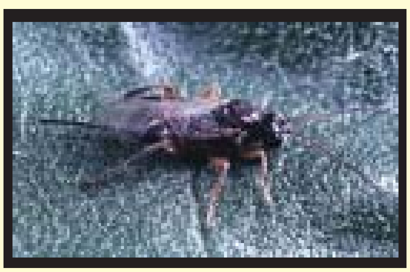


Figure 1. Parasitic wasp.

Figure 2. Parasitic fly.

Natural enemies of insect pests fall basically into three types. **Parasite** (also called parasitoid) adults are free-living; the immature stage lives on or inside a host and kills the host before the host completes its development. Parasites lay one or more eggs on the outside of the host body or they insert the eggs inside their host. The immature parasite feeds on the host and requires only a single individual prey to complete its development. Free-living adults may feed on nectar from flowering plants or obtain nutrients by piercing the body of host insects and withdrawing fluids (host-feeding). Parasites attack a particular stage of the host, but all host stages are attacked by various parasites. Parasites are often small, easily overlooked and can be difficult to distinguish from other small nonparasitic flies and wasps. Parasites are not harmful to humans and tend to attack and parasitize one, or at most a few, closely related species of pest insects.

The agents of biological control include **parasites, predators**, and **diseases**.

Parasites are usually members of the order Hymenoptera (wasps, Figure 1) and a few are members of the order Diptera (flies, Figure 2). Parasites are often considered more effective natural enemies than predators because many have a narrower host range, require only one host to complete development, have an excellent ability to locate and kill their host and can respond rapidly to increases in host populations. There are thousands of different species of parasites in North America. Most insects, including pest insects, are attacked by one or more species of parasites.

Predators include birds, fish, amphibians, reptiles, small mammals, and arthropods. Arthropods (insects, mites and spiders) are the most important predators in pest management and include lady beetles, ground beetles, syrphid flies, green lacewings, assassin bugs, predaceous bugs, minute pirate bugs, predatory mites, and spiders. Predators are usually larger than the prey which they capture and kill. They may use camouflage to "sit and wait" for prey or may be active hunters. Predators usually deposit their eggs near their prey so the immatures can immediately find their host and begin feeding. Immature stages are mobile, usually consume more than one prey during their development, are often generalist feeders (more than one species of host is attacked), and usually both the adults and immatures feed on the prey insect.

Many of the true bugs are predatory insects. They are predaceous as nymphs and adults, are very active hunters, and have a varied diet. Their prey range from insect eggs, young caterpillars, aphids and spider mites to other plant bugs. Common members of this group are the minute pirate bug (Figure 3) and flower bug, *Orius tristicolor* and *O. insidiosus*, which are abundant throughout North America. These small (1/8 inch) black and white insects overwinter as adults. The nymphs are a yellow-orange color. Both stages feed on aphids, insect eggs, thrips, and young caterpillars. Several species of damsel bugs (*Nabis* spp., Figure 4) are common predators throughout the region. These predators are ½ inch or less in size, and range in color from mottled brown to black. They feed on insect eggs, numerous caterpillars, aphids, and plant bugs. The twospotted stink bug, *Perillus bioculatus* (Figure 5), is one of the species of stink bugs found in the region. Adult stink bugs are ¾ inches long. They attack slow moving prey, including some major insect pests, such as larvae of the Colorado potato beetle and sunflower beetle. They also consume numerous species of caterpillars.

Assassin (Figure 6) and ambush bugs (Figure 7) are medium sized insects, ranging in size from ¼ to 1½ inches. They are green, brown to black, with some species having red or orange markings along the body margins. Their first pair of legs is enlarged for capturing prey. They have powerful beaks used to impale their prey and suck out the body fluids.

The adult and larval stages of many beetles are insect predators, and they can be found in varied habitats. They may be found living in the soil, on the soil surface, or on plants. They may feed on all types of insects, other arthropods, and slugs and snails. Their prey may be varied or specific. The carabid, or ground beetles, range in size from 1/8 to 1½ inches long. They have flattened bodies and range in color from black to iridescent blue or green. They are recognized by their prominent jaws. Their worm-like larvae live in the soil. Adults seek prey on or beneath the soil; some species climb plants in search of prey. Lady beetles include numerous species, are common predators of aphids and other small insects and insect eggs, and many of the adults are readily recognized (Figure 8). Often brightly colored red and orange and bearing spots, the adults can also be brown or black with spots. The larvae (Figure 9) are elongate and taper from the head to the tail.

Figure 3.
Minute pirate bug,
Orius trsticolor.

Figure 4.
Damsel bug,
Nabis spp.

Figure 5.
Twospotted
stink bug,
Perillus bioculatus.

Figure 6.
Assassin bug.

Figure 7.
Ambush bug.

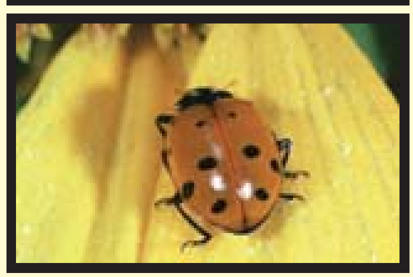


Figure 8.
Lady beetle adult.

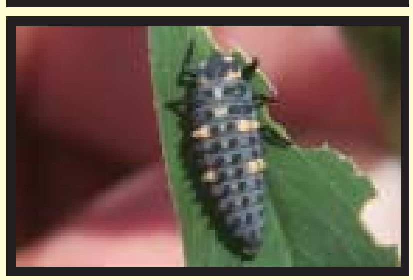


Figure 9.
Lady beetle larva.

Their color varies and they may be black, brown, or dark blue, with bright spots or stripes on their back. The eggs are yellow and laid in clusters on the undersides of leaves.

Lacewing adults (Figure 10) are fragile-looking insects with four lace-patterned wings. They are green or brown and about 1 inch long. Their eggs are laid singly on top of a slender stalk attached to a plant. The elongate, flat, mottled brown larvae (Figure 11) move quickly over the plant in search of prey. They have large, sickle-shaped mandibles that they use to capture and hold prey as they suck out the body fluids. The larvae feed on many soft bodied insects, chiefly aphids, as well as small caterpillars, insect eggs, and mites. They are most abundant later in the season.

Figure 10.
Green lacewing adult.

Figure 11.
Green lacewing larva.

Figure 12.
Hover or syrphid fly.

Figure 13.
Syrphid fly larva.

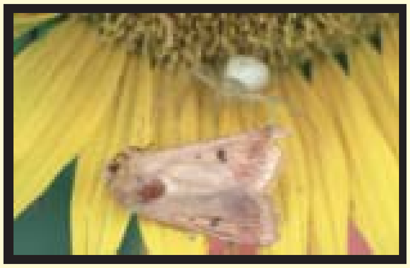


Figure 14.
Crab spider feeding on moth.

Hover flies (Figure 12) are bee-like, with yellow and black bands that ring the abdomen. They can be seen hovering around flowers where they feed on nectar and pollen. The predatory larvae (Figure 13) are legless, slug-like maggots, often pale green in color. They are voracious predators of aphids.

All spiders are predaceous and are generalist feeders. The size and color of spiders vary considerably depending on the group they belong to. Wolf spiders are colored to blend in with the soil since that is where they search for prey, whereas the crab spiders (Figure 14) are often the color of their background, such as leaves or flowers. Their methods for capturing prey are varied, ranging from web spinning to active hunting. All stages of insects are consumed by spiders.

Diseases also occur among insects. Insect diseases are caused by fungi, viruses, bacteria, protozoans, and other microorganisms. Insect-parasitic nematodes are also included in this group of natural enemies. Insect-parasitic nematodes are small worms that attack and kill insects that live in moist habitats. A few species are currently being sold commercially for insect control. Insect pathogens, including nematodes, are an important component in suppressing pest species. Some insect pathogens and nematodes are commercially available and can be manipulated to achieve biological control of specific pests. Both diseases and nematodes, like parasites, tend to be specific to certain species or groups of pests; they do not harm nontarget organisms, such as beneficial insects, animals, humans, or plants. They can quickly spread through an insect population causing rapid mortality in a short period of time, and can be important in the natural control of pest populations. This phenomenon, called an **epizootic**, occurs when the insect pest population level is high or environmental conditions are especially suitable for the pathogen or disease-causing organism, enabling the disease organism to spread from insect to insect very quickly. In high-value crops, the pest population usually cannot be allowed to reach a level where an epizootic can occur. However, epizootics can be an important natural control of pests of forests, rangeland, and certain types of field crops.

Insect viral pathogens vary in how they attack and kill their host. Most insect viruses need to be ingested to successfully infect their host, though some can be transferred from the parent insect to the offspring through the egg. Symptoms usually occur within a few days after the virus is ingested. The infected insect (Figure 15) will appear sluggish, feeding will stop, and the cuticle will have a pale discoloration and will often hang from its legs. The infected insect will die one to two days after the symptoms appear. The decomposing cadaver will burst, liberating the viral particles into the environment. Important groups of viruses that attack insects are the nuclear polyhedrosis viruses (NPV), cytoplasmic polyhedrosis viruses (CPV) and granulosis viruses (GV). Viruses usually attack the caterpillar stage, such as the *Helicoverpa* NPV that invades the corn earworm larva or the codling moth GV that infects the codling moth larva.

The bacteria most important in insect pest management are in the genus *Bacillus*. Species in this genus form spores that are toxic to the insect when ingested. Symptoms of infected insects include a loss of appetite, sluggishness, discharge from the mouth and anus, discoloration and liquefaction and putrefaction of the body tissues (Figure 16). *Bacillus thuringiensis* (commonly called Bt) is the most widely-used bacterium for insect pest control. Different strains of Bt are specific against caterpillars, mosquito larvae and some beetles and their larvae. *Bacillus popillae* and *B. lentimorbus* cause “milky disease” of white grubs. “Milky disease” refers to the white discoloration of the insect blood. The spores of *B. popillae* and *B. lentimorbus* survive in the soil and are ingested by the grubs as they feed on roots of grasses. *Bacillus thuringiensis, B. popillae,* and *B. lentimorbus* have been formulated into microbial insecticides by several companies for application to crops in an augmentative manner. Most recently, genes that produce Bt toxins have been genetically engineered into crop plants (corn, cotton, tobacco and potato) for season-long protection against larval pests and some adult insects. Larval and adult pests ingest the toxin after they have fed on the foliage and subsequently die. A beneficial soil bacterium, *Saccharopolyspora spinosa*, produces a natural metabolite, Spinosad, when cultured under aerobic fermentation conditions. Spinosad has been formulated as a microbial insecticide. Insects become poisoned with Spinosad when they ingest treated foliage or come into contact with the microbial sprays of the metabolite. Sickened insects stop feeding, become limp and are unable to move, and may appear to have weak tremors. Spinosad is effective against a wide spectrum of insect pests, including armyworms, European corn borer, diamondback moth, leafminers, and Colorado potato beetle.

Insect pathogenic fungi produce spores that germinate when they come in contact with the insect cuticle and when temperature and moisture conditions are favorable. Germinating spores penetrate the insect cuticle and invade the body cavity. Hyphae rapidly grow, filling the body cavity with a fungal mass, killing the insect. The fungus also may produce a toxin. Hyphae penetrate outward through the softer parts of the insect and under favorable moisture conditions produce spores that ripen and are released into the environment to complete the life cycle (Figure 17). Insects that are attacked by fungi often retain their shape but usually become hardened or “mummy-like” and appear “fuzzy” from the fungal growth. There are many genera of fungi that attack insects. The most important ones are *Metarhizium, Beauveria, Entomophthora* and *Zoopthora*. *Metarhizium anisopliae* and *B. bassiana* attack a wide range of insects, such as grasshoppers, true bugs, aphids, caterpillars, and beetles. *Entomophthora muscae* attacks many types of adult flies including the seed corn maggot and the hover fly, a beneficial. *Zoophthora radicans* attacks the potato leafhopper and many aphids, and *Z. phytonomi* infects the alfalfa weevil.

Figure 15. Caterpillar killed by viral infection.

Figure 16. Caterpillar killed by a bacterial infection.

Figure 17. Hyphae of pathogenic fungi produced on killed potato beetle. (USDA)

Maintaining Natural Order

Natural enemies do not destroy or eradicate all insect pests. However, they often prevent pest populations from becoming too high. Most biological control agents at work in agricultural and urban environments are naturally occurring ones that provide excellent regulation of many pests with little or no assistance from humans. In some cases, they do this year after year because the natural enemy is an established part of the environment. The existence of naturally occurring biological control agents is one reason many plant-feeding insects do not ordinarily become economic pests. The importance of such agents often becomes quite apparent when insecticides applied to control a key pest cause an outbreak of secondary pests because of the chemical destruction of important natural enemies. The second species, released from the pressure imposed by its enemies, now may increase to damaging numbers and require further insecticidal treatment.

If insecticides eliminate natural enemies, populations of pests may increase and emigrate to surrounding habitats, at a considerable distance from the site where the application took place. Therefore, the impact of insecticides may extend over long periods of time and large areas until natural enemies are restored. Obviously if insecticides are used often, the normal balance of biological control agents may never be reattained. There is great potential for increasing the benefits derived from naturally occurring biological controls through eliminating or reducing the use of insecticides toxic to natural enemies. The successful combination of insecticide use and biological control in an IPM program depends on more knowledge of the system — the ecology and the behavior of pests and natural enemies — plus the incorporation of available tools and techniques.

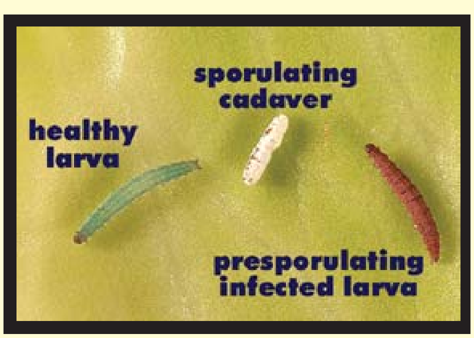


Figure 18. Fungal infection of diamondback moth. (USDA)

Canola Insect Pests

Crucifer flea beetle (*Phyllotreta cruciferae*), diamondback moth (*Plutella xylostella*) and bertha armyworm (*Mamestra configurata*) are the three major pests of concern for canola grown in the upper Midwest.

Crucifer flea beetle is the first pest to occur in canola fields in North Dakota and northwestern Minnesota. Overwintered adults move into canola fields in May and June and begin feeding on newly emerged seedlings, causing serious damage. Although natural enemies do not play a key role in reducing damage, cultural control methods can help reduce plant losses. A firm seed bed that is well tilled and adequately fertilized will help plants outgrow beetle damage.

Bertha armyworm is native to North America. This pest, along with the true armyworm and variegated cutworm, belongs to a group of insects called the "climbing cutworms." Bertha armyworm can be a significant pest in canola; however, adverse environmental conditions and natural enemies help to keep this pest insect at low population levels during most years. There are a number of diseases and parasites that attack the bertha armyworm including: a nuclear polyhedrosis virus, an ichneumon parasitic wasp, *Banchus flavescens*, and a tachinid parasitic fly, *Athrycia cinerea*. Populations of these natural enemies build up slowly and have their greatest impact a year or two after the peak of an outbreak of bertha armyworm. Therefore, severe infestations only last two or three years.

Diamondback moth was introduced from Europe about 150 years ago and has since established throughout North America wherever its hosts plants are grown. Larvae are the damaging stage, and they feed on plants in the mustard family (canola, mustard), cole crops (broccoli, cabbage), and several greenhouse plants. Diamondback moth does not overwinter well in the northern states, and the severity of an infestation in a given year depends on overwintering populations in southern states and southerly winds to transport adult moths northward. Natural controls, including weather and beneficial organisms, can have a significant impact on diamondback moth population levels. Fungal diseases in the class *Entomophthorales* cause natural disease outbreaks in larval populations (Figure 18). Disease outbreaks usually occur later in the season after populations have reached higher levels. Infection at higher rates can limit development of additional generations late in the season. Three parasitic wasp species are known to attack the diamondback moth in western Canada. *Diadegma insulare* and *Microplitis plutellae* attack the larvae, and *Diadromus subtilicornis* attacks the prepupa and pupa stages. In addition to the parasitic wasps, other beneficial organisms that attack diamondback larvae include lacewings, predaceous plant bugs and ground beetles, minute pirate bugs, spiders and birds.

Lygus bugs have been observed during the past few production seasons in North Dakota, and yield losses may have been attributed to lygus bug populations in northwestern Minnesota during the 1999 production season. Lygus bugs are a major pest of canola in Canada. The parasitic wasp *Anaphes iole* can be used in an augmentative approach against lygus bugs. This wasp attacks lygus bug eggs on the flowers and buds. Releases are made when lygus bugs are found laying eggs during the flowering stage. *Anaphes iole* does well in warm and dry to humid environments. Some commercial insectaries may provide *A. iole* at a reduced rate for growers interested in experimenting on untested cropping systems.

Green peach aphid (*Myzus persicae*) and turnip aphid (*Lipaphis erysimi*) also have recently been observed in canola fields during the flower and pod development periods but have not reached levels that would be damaging to the canola crop. This may be attributed to the presence of natural enemies in the canola fields when aphids occur. Lady beetles are usually the dominant beneficials in canola fields when aphids are present and probably are maintaining aphids at low levels, although fungal pathogens play an important role as aphid densities increase.

Potato Insect Pests

The Colorado potato beetle (*Leptinotarsa decemlineata*), green peach aphid and potato leafhopper (*Empoasca fabae*) are the major pests of potato crops in the upper Midwest. Predators (lady beetles, nabids, lacewing larvae and syrphid fly larvae), parasites (aphid parasites) and fungal diseases can effectively maintain aphid populations below damaging levels.

Insecticides and fungicides are commonly used in potato production. Because the green peach aphid is resistant to most insecticides used in potato production, their numbers increase substantially in the absence of their natural enemies. In addition, regular fungicide applications appear to reduce the effectiveness of beneficial fungal diseases that play an important role in keeping green peach aphid populations in check in potato fields.

The Colorado potato beetle is the major insect pest in potato crops and often determines the method of pest management. Microbial insecticides provide an option for beetle management and are less harmful to most natural enemies. Microbial insecticides give adequate control of the beetle and allow natural enemies to effectively reduce green peach aphid populations below damaging levels. Proper application timing is important to ensure adequate control of the beetle. Microbial insecticides have a short residual life and must be applied frequently. In addition, they are not effective against larger larvae (third and fourth instars) and adults and must be targeted toward the smaller larvae. The microbial insecticides should be applied between 15 and 30 percent egg hatch for best control. Frequent application should be continued because beetle eggs are laid over several weeks.

Sunflower Insect Pests

Sunflower is native to North America and, although hundreds of insects have been recorded on sunflower, only a small number have achieved pest status. Indigenous natural enemies have been a significant factor in preventing many plant-eating insects from becoming economic pests. Even the insect species that have become pests are subject to attack by numerous natural enemies. Insects of main concern to cultivated sunflower in the northern Great Plains include the red sunflower seed weevil (*Smicronyx fulvus*), the banded sunflower moth (*Cochylis hospes*), the sunflower beetle (*Zygogramma exclamationis*), the sunflower stem weevil (*Cylindrocopturus adspersus*), and the sunflower midge (*Contarinia schulzi*).

Larvae and pupae of the red sunflower seed weevil overwinter in the soil and are reported to be attacked by three different predators in North Dakota, including larvae of two species of predaceous flies in the family Therevidae, *Thereva candidata* and *Fucifera rufiventris*. In addition, ants of the species *Formica cinera* also attack and consume overwintering seed weevil larvae in the soil. Larvae of the red sunflower seed weevil have been reported as hosts for a number of parasite species, including the pteromalids *Trimeromicrus* sp. and *Pteromalus* sp. and three species of braconids, *Bracon mellitor*, *Nealiolus curculionis*, and *Triaspis aequoris*. Female *T. aequoris* deposit eggs singly in weevil eggs and early-instar larvae and overwinter within the larva, killing it the following spring.

Predation is reported to be important in reducing populations of the banded sunflower moth. Eggs and larvae of the banded sunflower moth are consumed by minute pirate bugs, nabids, green lacewings, and several species of lady beetles (*Hippodamia* spp.). A number of species of predaceous ground beetles are present in the fields and probably consume overwintering larvae. Analysis of gut contents of beetles showed that the carabid beetle, *Pterostichus lucublandus* (Figure 19), attacks and feeds on banded sunflower moth larvae. Studies in Canada revealed that at least two species of parasites attack banded sunflower moth larvae and are often able to maintain the pest below economic levels. Studies in North Dakota, Minnesota, and South Dakota on cultivated sunflower showed that the banded sunflower moth is parasitized by the braconids *Chelonus phaloniae* and *Macrocentrus ancylivorus* and the ichneumonid wasps *Glypta prognatha* (Figure 20), *Mastrus* sp., and *Trathala* sp. The most abundant parasites of the banded sunflower moth in cultivated sunflower fields are *C. phaloniae* and *G. prognatha*, and the relative impact of each parasite species on the banded sunflower moth appears to vary from year to year, with a total of 40-70 percent of overwintering larvae parasitized.

Based on a multiple-year study of the sunflower beetle in Manitoba, Canada, a number of predators were determined to be feeding on the different life stages of the sunflower beetle. Adult beetles were attacked by redwinged blackbirds and the stinkbug, *Podisus maculiventris*. The latter species also attacks larvae in North Dakota sunflower fields. Sunflower beetle eggs are consumed by the melyrid beetle, *Collops vittatus*, and the lady beetles, *Hippodamia tredecimpunctata* and *H. convergens*, and green lacewings consume both eggs and larvae. Sunflower beetle larvae are also fed on by the stink bugs, *Perillus biocolatus* and *P. circumcinctus*. The carabid beetle, *Lebia atriventris*, which was reported feeding on sunflower beetle larvae in Manitoba, is a common inhabitant of sunflower fields in North Dakota and Minnesota. Nabids are common predators in sunflower fields and also are suspected of feeding on sunflower beetle larvae. Parasites have been reported to attack three stages of the sunflower beetle. Studies in North Dakota, Minnesota, and Manitoba have shown eggs are parasitized by the pteromalid *Erixestus winneman* and larvae are attacked by the tachinid fly *Myiopharus macellus*. The life history of *M. macellus* is well synchronized with the life history of its host, and the rate of parasitization is high in both Canada and the U.S. (up to 70 and 100 percent, respectively). Adult sunflower beetles are parasitized by the tachinid, *Myiopharus* sp. Approximately 0.2 to 17 percent of adults in Manitoba are attacked, but less than 2 percent of adults are parasitized in North Dakota and Minnesota.

No predators have been reported to attack the sunflower stem weevil. However, this is probably due to a lack of research rather than an absence of predators. The sunflower stem weevil is parasitized by a number of wasp species. *Anaphes pallipes* (Hymenoptera: Mymaridae) was reared from eggs of the weevil. Larvae are attacked by the following Hymenoptera in the northern Great Plains: *Nealiolus curculionis* (Braconidae); *Quadrastichus ainsliei* (Eulophidae); and *Mesopolobus* sp. (Pteromalidae). *Nealiolus curculionis* represented over 96 percent of the parasites attacking sunflower stem weevil larvae from 1980 to 1991 in North Dakota and is a consistent mortality factor even when the weevil density is low.

No predators have been reported to attack the sunflower midge. However, a number of generalist insect predators are on the sunflower heads when midge eggs and larvae are present. The parasites of the sunflower midge are largely unknown. Only one undescribed species has been discovered, *Inostemma* sp., and the impact of this larval parasite has not been studied.

Figure 19. Carabid beetle feeding on sunflower beetle larva.

Figure 20. *Glypta prognatha,* a parasite of the banded sunflower moth larva.

Sugarbeet Insect Pests

Sugarbeet root maggot, *Tetanops myopaeformis*, is probably the most destructive insect pest of sugarbeets in the Red River Valley of North Dakota and Minnesota. Damage depends on degree of infestation but can range from 10-50 percent if not managed. This native pest appears to have few natural enemies. Although no parasites have been reported, ground beetles and birds have been observed feeding on the root maggot. Research into the role of diseases may eventually assist in managing this pest.

A number of strains of entomopathogenic nematodes of the genus *Steinernema* (Figure 21) were effective in killing maggot larvae in the laboratory, but results were poor in field trials. A fungus, *Syngliocladium tetanopsis*, was discovered attacking the maggot larvae collected from sugarbeet fields in North Dakota. This species may be specific to the root maggot and killed 95-100 percent of newly hatched maggots in laboratory experiments, but more research is needed to discover if this disease could be developed into a biopesticide. Recent work with another entomopathogenic fungus, *Metarhizium anisopliae*, has shown promise in controlling the maggot in the field, but additional research is needed on the application rates, timing, and formulation.

Corn Insect Pests

The European corn borer (*Ostrinia nubilalis*), corn rootworm (*Diabrotica* spp.), and corn leaf aphid (*Rhopalosiphum maidis*), are the most common insect pests of corn in the northern states. There are many infrequent pests such as cutworms, armyworm (*Pseudaletia unipuncta*), white grub (*Phyllophaga* spp.), wireworms and grasshoppers.

European corn borer (ECB) has many natural enemies. Predators that feed on eggs and larvae include lady beetles, lacewings, bigeyed bugs, damsel bugs, minute pirate bugs and others. There are numerous parasitic insects associated with European corn borer. The most significant parasitic wasps are *Macrocentris grandii*, a braconid larval parasite introduced from Europe, and the *Trichogramma* wasps which are egg parasites. Parasitization levels by *M. grandii* have been reported as high as 45 percent; *Trichogramma* levels are quite variable, ranging from less than 1 to 70 percent. Pathogens of ECB include *Nosema pyrausta*, *Beauveria bassiana* (Figure 22), *Bacillus thuringiensis*, the bacteria source for the gene inserted in genetically modified *Bt*-corn for producing an ECB toxin, and others.

Natural enemies fail to play a major role in affecting corn rootworm populations. The fungi *B. bassiana* and *Metarhizuium anisopliae* have been tested against rootworm larvae with poor results. A subspecies of the bacterium *B. thuringiensis* kills beetles and is a potential source of proteins useful in developing genetically modified corn resistant to rootworms.

Numerous predators and parasites help to regulate populations of the corn leaf aphid and other cereal aphids. Lady beetles, lacewings, and syrphid fly maggots feed on all species of aphids. The wasps *Lysiphlebus testaceipes* and *Aphelinus mali* are common aphid parasites that help regulate populations. Numerous fungal diseases affect aphids. Infected aphids take on a fuzzy appearance as the fungus grows outside the dead aphid's body (Figure 23). Rapid declines in aphid populations can occur when environmental conditions favor fungal infection.

Small Grain Insect Pests

The most important insect pests of wheat in the region are the cereal aphids, orange wheat blossom midge (*Sitodiplosis mossellana*), wheat stem sawfly (*Cephus cincta*), grasshoppers, and wireworms. Occasional pests

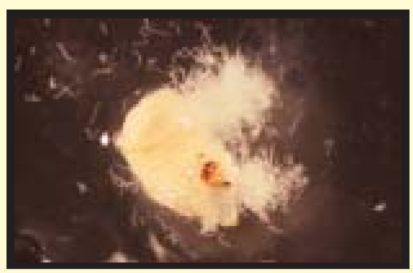


Figure 21. Entomopathogenic nematodes released from the body cavity of killed larva. (USDA)

Figure 22. Corn borer larva killed by *Beauveria bassiana.* (USDA)

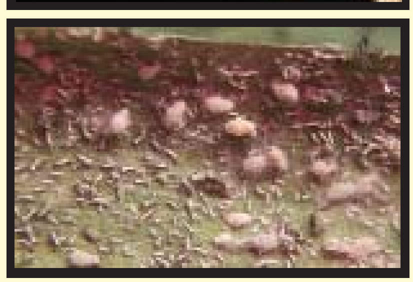


Figure 23. Corn leaf aphids killed by a fungal pathogen.

include armyworms (*P. unipuncta*), cutworms, and wheat stem maggot (*Meromyza americana*).

Four cereal aphids, English grain (*Macrosiphum avenae)*, greenbug (*Schizaphis graminum*), bird-cherry oat *(Rhopalosiphum padi)*, and corn leaf (*R. maidis),* can be found in small grains. Lady beetles, lacewings, and syrphid fly maggots feed on all species. The parasitic wasps *L. testaceipes*, *A. mali*, and *Aphidius avenaphis* are common aphid parasites that help regulate populations. Numerous fungal diseases affect aphids. Infected aphids take on a fuzzy appearance as the fungus grows outside the dead aphid. Rapid declines in aphid populations can occur when environmental conditions favor fungal infection.

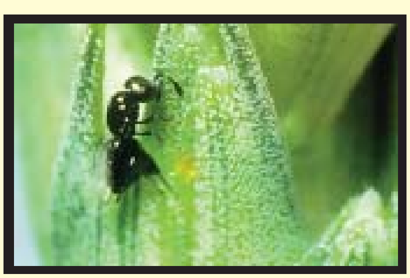
The orange wheat blossom midge is parasitized by the parasitic wasp *Macroglenes penetrans* (Figure 24)*,* which is an egg-larval parasite. Eggs are laid in the egg of the wheat midge. The parasite larva develops in the midge larva, killing the larva in the late spring of the next year. This parasitic wasp controls about 40 percent of the overwintering midge larvae.

The wheat stem sawfly has four different parasitic wasps that attack it, but normally they do not kill enough sawfly larvae to have a great impact. The most common parasitic wasps are *Bracon cephi*, *B. lissogaster*, and *Eupelmus allynii*.

The armyworm is preyed on by ground beetles and many vertebrate predators. Important parasitic wasps include the redtailed tachinid fly, *Winthemia quadripustulata*, and the braconids *Apanteles marginiventris* and *A. militaris*. Activity by some of these parasites is apparent when clusters of the parasite's fuzzy, pupal cocoons are seen on wheat heads.

The wheat stem maggot has two parasitic wasps, *Bracon meromyzae* and *Coelinidea meromyzae*, that are important in maintaining the pest populations at low densities.

Figure 24. *Macroglenes penetrans,* egg-larval parasite of the wheat midge. (Saskatchewan Agriculture and Food)



Weeds

The scope of biological control extends beyond the use of predators, parasites, and pathogens for management of insects. Herbivory is common among insects and many phytophagous insects feed exclusively on weed pests. Many noxious invasive weed species in the United States are being managed using herbivorous insects introduced through importation programs. Leafy spurge and purple loosestrife are two introduced noxious weed pests of the upper Midwest region including North Dakota and Minnesota. Insects that feed on these weeds have been located in the countries where the weeds originated and introduced into the United States to establish control.

Leafy Spurge

Nine insects have been released in the United States against leafy spurge. Six insects have become established in North Dakota, including a gall midge, a stem/root boring beetle and flea beetles (*Aphthona* spp., Figure 25). Of these, the flea beetles have been the most important in reducing leafy spurge density. Releases of five species of flea beetles (*A. flava, A. czwalinae, A. lacertosa, A. abdominalis*, and *A. nigriscutis)* began in 1985 in North Dakota. By 1996, *A. lacertosa* and *A. nigriscutis* had established in almost every county and are the most important in reducing leafy spurge infestations. Adult flea beetles feed on the foliage; however, it is larval feeding on the roots that results in the major damage to the plant. Small larvae feed on the fine root hairs, reducing water and nutrient absorption. Larger larvae feed on the root crown, destroying the root tissues directly and indirectly causing the plant to become more susceptible to herbicides and soil borne pathogens. *Aphthona* flea beetles have established throughout the north central Great Plains region and have substantially reduced spurge infestations at locations that provide the necessary environmental conditions for flea beetle development. Flea beetles do not always provide predictable and consistent levels of control. Under less than optimal conditions, they may take several years to establish and reduce a spurge stand to a tolerable level. When using flea beetles, land managers should not expect a "quick fix" and need to practice patience to ensure long term benefits. Flea beetles are collected and redistributed from mid-June to early July. Land managers interested in collecting and releasing flea beetles on their lands should contact the local county weed officer for information on date, time, and locations of flea beetle collection and redistribution programs in their area. Refer to NDSU Extension Service Circular W-1183, “Leafy Spurge Control Using Flea Beetles (*Aphthona* spp.),” for more information on *Aphthona* flea beetles for biological control of leafy spurge.

Purple Loosestrife

Four insects have been released in the United States for the control of purple loosestrife: two leaf feeding beetles, the black-margined loosestrife beetle (*Galerucella calmariensis*) and the golden loosestrife beetle (*Galerucella pusilla,* Figure 26); a root-boring weevil (*Hylobius transversovittatus*); and one flower-feeding weevil (*Nanophyes marmoratus*). The two leaf-feeding beetles and the root-boring weevil have recently been released on a few small areas in North Dakota. The two *Galerucella* species have established in two loosestrife infestations along the Sheyenne River at Valley City, and none of the biological control agents have yet established along the English Coulee in Grand Forks. Biological control has played a more important role in reducing loosestrife infestations in Minnesota, where this weed is a larger problem (several thousand acres infested at nearly 2,000 locations statewide) and herbicides are ineffective in areas of severe infestations (more than an acre with 75-100 percent loosestrife). *Galerucella calmariensis* and *G. pusilla* have been released on over 400 sites in Minnesota with an 85% establishment rate. The leaf-feeding beetles have significantly reduced the loosestrife infestation on many of these sites, including ones of up to 40 acres in size. There were approximately 20 sites that produced roughly 2 million beetles during the 2000 growing season. These sites serve as insectaries from which beetles can be collected and redistributed to other infested areas. A cooperative rearing program that enlists volunteers to rear the leaf-feeding *Galerucella* beetles has allowed Minnesota to rapidly expand the number of sites with biological control agents. A rearing method has recently been developed for the root weevil, and now this biological control organism can be produced on artificial diet. The Minnesota Department of Natural Resources will be releasing the loosestrife root weevil on only a few sites initially. As production increases, more sites will be established with this biological control agent.

Conclusions

The best approach to preserving effective biological control by natural enemies is a combination of management tactics. By conserving and protecting natural enemies, we provide an opportunity for them to operate at their full potential as naturally occurring sources of biological control in the agricultural environment.

Challenges for the future in biological control include additional studies to identify the complex of natural enemies in cultivated crops, understand the biology and population dynamics of the natural enemies associated with the major pest species, and determine how the different IPM practices can best be used to ensure their compatibility with the natural enemies. Also needed are studies to evaluate the impact of predators, parasites, and diseases to find ways to improve biological control through conservation, augmentation, and importation.

Figure 25. *Aphthona flava,* leafy spurge flea beetle. (USDA)

Figure 26. Golden loosestrife beetle, an herbivore or purple loosestrife, *Lythrum salicaria.* (MN Dept. of Nat. Res.)

Biological Control References

Bellows, T. S. and T. W. Fisher (editors). 1999. Handbook of biological control. Academic Press, San Diego, CA. 1046p.

Flint, M. L. and S. H. Dreistadt. 1998. Natural enemies handbook — the illustrated guide to biological control. Univ. of California Press, Berkeley, CA. 154p.

Hunter, C.D. 1997. Suppliers of Beneficial Organisms in North America. California Environmental Protection Agency, Dept. of Pesticide Regulation, Environmental Monitoring and Pest Management Branch, 1020 N St., Rm 161, Sacramento, CA 95814-5624. www.cdpr.ca.gov

Lee, J. C. and D. A. Landis. 2001. Natural enemies in field crops: a guide to biological control. Michigan State Univ. Ext. Bull. 2721. 65p.

Mahr, D. L. and N. M. Ridgway. 1993. Biological control of insects and mites. North Central Regional Publication 481. Univ. of Wisconsin, Madison, WI. 92p.

Ryan, J. M., D. A. Landis, and E. J. Grafius. 1993. Biological control of insects. Michigan State Univ. Ext. Bull. E-2453. 8p.

Sloderbeck, P. E., J. R. Nechols, and G. L. Greene. 1996. Biological control of insect pests on field crops in Kansas. Kansas State Univ. Coop. Ext. Serv. MF-2222. 18p.

Van Driesche, R. G. and T. S. Bellows, Jr. 1996. Biological control. Chapman & Hall, New York, NY. 539p.

Biological Control News
www.entomology.wisc.edu/mbcn/mbcn.html

For more information on this and other topics, see: www.ag.ndsu.nodak.edu

NDSU Extension Service, North Dakota State University of Agriculture and Applied Science, and U.S. Department of Agriculture cooperating. Sharon D. Anderson, Director, Fargo, North Dakota. Distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914. We offer our programs and facilities to all persons regardless of race, color, national origin, religion, sex, disability, age, Vietnam era veterans status, or sexual orientation; and are an equal opportunity employer. 3M-01-02

This publication will be made available in alternative format upon request to people with disabilities (701) 231-7881.

E-1225