Biological Control of Insect Pests on Field Crops in Kansas

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Biological Control

In the simplest terms, biological control is the reduction of pest populations brought about through the actions of other living organisms, often collectively referred to as natural enemies or beneficial species. Virtually all insect and mite pests have some natural enemies, although not all are effective in suppressing pest populations. Learning to recognize, manage, and conserve natural enemies can help reduce pest populations and maintain them below economic levels, thus reducing crop losses and the need for more costly control measures that may also have undesirable environmental side-effects.

Biological control is often most effective when coupled with other pest control tactics in an integrated pest management (IPM) program. Practices that are often compatible with biological control include cultural controls, crop rotation, planting pest-resistant varieties, using insecticides with selective modes of action, or spot treatments that leave untreated areas to serve as refuges for natural enemies.

Effective biological control often requires a good understanding of the biology of the pest and its natural enemies, as well as the ability to identify various life stages of relevant insects in the field. Field scouting usually is necessary to monitor natural enemy activity, evaluate impact on pest populations, and anticipate the need for additional control measures. Although three distinct approaches to biological control are recognized (conservation, importation, and augmentation), the principles of conservation biological control are by far the most important for producers of field crops in Kansas to understand.

Conservation of Natural Enemies

Natural enemy conservation is at once the most straightforward concept of biological control in the context of field crops, and the most complex. At the simplest level, conservation biological control means avoiding cultural practices that harm natural enemies and implementing practices that attract, encourage, or benefit them. Although this may seem like common sense, the challenging part is understanding exactly what practices are harmful to natural enemies and how beneficial practices can be integrated into production systems in a cost-effective and convenient manner. This requires not only a good understanding of the biology and ecology of natural enemies, but also a willingness to modify production practices to accommodate their needs. Complicating matters is the fact that many beneficial insects feed not only on pest insects, but also on each other, a phenomenon referred to as **intraguild predation**. In a healthy agroecosystem with a high degree of plant and insect diversity, naturally-occurring biological control can go almost unnoticed because natural enemies are effectively maintaining a plethora of potential pests at low densities.

The most obvious harmful practice is the use of insecticides at times when natural enemies are active. Insecticides have a wide range of adverse effects on natural enemies, killing them directly, impairing their foraging and reproductive abilities, and depriving them of food. Nevertheless, there are various ways that insecticides can be successfully integrated into a production system while minimizing their impact on beneficial species.

Materials such as certain varieties of *Bacillus thuringensis* (Bt) are selectively toxic to particular groups of pest insects such as caterpillars and leave natural enemies unharmed. Unfortunately, most Bt formulations currently available lack good residual efficacy under field conditions. The in-plant expression of Bt toxin in genetically-engineered corn and cotton varieties has revolutionized the management of moth pests on these crops and has so far proven compatible with biological control of other pests, primarily through reduced applications of hard insecticides.

Several recently developed **biorational** materials such as spinosad and indoxacarb achieve selectivity through low contact toxicity; they must be consumed by the insect to be activated. Since natural enemies typically don't eat plant material with the chemical on it, they are spared direct mortality. However, even materials with high contact toxicity can be applied in ways that minimize their impact on beneficial species. Insecticides with good plant systemic activity (e.g., clothianidin, imidacloprid, thiamethoxam) can be used as seed treatments, in-furrow, or as soil drench applications to be taken up by the plants while causing little direct mortality to natural enemies. Finally, damaging pest populations are often confined to portions of a field, rather than being evenly distributed throughout it. Selective spot-treatment of affected areas will not only reduce application costs, it will leave untreated areas to serve as reservoirs for natural enemies. These survivors can then recolonize treated areas following degradation of the insecticide, accelerating the restoration of biological control and sometimes averting the need for subsequent treatments. Nevertheless, situations arise where the preservation of biological control requires avoiding the broadcast application of any insecticide. When biological control is widely disrupted by insecticide applications, minor pests can become major pests (secondary pest resurgence), and a farm can develop dependency on chemical control measures once natural enemies are no longer resident in the fields (the pesticide treadmill effect).

Certain cultural practices also can be detrimental to natural enemies. Plowing, cultivation, mowing, or harvesting operations can be disruptive to natural enemies if they coincide with critical stages of their life cycle. While the adoption of no-till and minimum tillage agriculture has favored the resurgence of some pests such as false wireworms that utilize crop residues for food or harborage, such practices also favor various beneficial insects such as ground beetles, spiders, and other generalist predators that rely on crop residues for cover, which encourages their persistence in the field. Dust raised by traffic along dirt roads or cultivation operations carried out during dry weather can impede the foraging activities of beneficial insects when it is deposited in sufficient amounts on leaf surfaces. The burning of crop residues can also kill large numbers of beneficial insects, as can inappropriately timed flood irrigation. Other practices such as excessive herbicide applications on pastures and fallow fields reduce both plant and insect diversity in non-crop habitats that normally serve as important reservoirs of many natural enemy species. These beneficial species are then no longer available to colonize annual crops in adjacent fields as pest populations develop.

One of the biggest hurdles for sustainable biological control in field crops is the loss of plant and insect diversity associated with large scale monoculture, a configuration that tends to favor pests over their natural enemies. Conservation of natural enemies can be generally improved by avoiding a completely clean farming approach and by taking steps to encourage plant and insect diversity in non-cultivated areas and wherever else this may be feasible. Strip-harvesting of alfalfa, where alternating rows of alfalfa are left uncut until the cut areas begin to grow back, is an excellent example of conservation biological control because this modified harvesting practice provides a continuous refuge and food supply for beneficial insects.

Importation of Natural Enemies

Today's high volumes of international trade and airline traffic have increased the frequency of arrival of exotic pests from other regions of the world. When immigrant pests succeed in establishing in a new geographic location they can rapidly reach very high populations and cause serious economic losses, largely because they lack the complex of natural enemies that limits their population growth in their country of origin. Examples of serious pests in Kansas of foreign origin include the Hessian fly, the European corn borer, the Russian wheat aphid, and the alfalfa weevil. The selective importation and release of natural enemies from the pest's country of origin is also known as **classical biological control**. This approach gained impetus early in the last century following several dramatic successes, notably the importation of the vedalia beetle to control cottony cushion scale in California. However, only a small proportion of importations have met with this level of success and the general applicability of this approach to all new invasive pests is currently a subject of considerable debate. Although large populations are often observed when an exotic pest first invades, these often decline over a period of years as the native community of natural enemies gradually evolves to exploit them. Evidence is growing that many invasive pests ultimately come under adequate biological control solely through the action of native beneficial species. However, there are other examples where native natural enemies do not — or cannot — provide required levels of biological control.

Classical biological control involves exploring a pest's country of origin for a potentially effective natural enemy, importing it to the pest's adopted country, and mass-rearing it in the laboratory for subsequent release in regions where the pest is active. The goal is to ultimately establish a self-sustaining population of the natural enemy that maintains the pest population below economic threshold levels for perpetuity. In this regard, classical biological control differs from other forms of biological control in that it is not carried out by the farmer or gardener, but only by scientists with appropriate authorization from federal agencies, in particular the United States Department of Agriculture. Non-native insects must be held under strict quarantine conditions until it can be ascertained that (1) they have some potential to control the target pest, (2) they will not themselves become pests, and (3) they do not harbor their own natural enemies that might interfere with their effectiveness or that of other beneficial insects. In addition, prospective natural enemies are evaluated to determine their potential to attack and/or feed on other beneficial species. Growing awareness and concern about potential non-target effects of released natural enemies has led to increasingly stringent criteria for introductions. These restrictions are justified given that other, far more complex, ecological impacts of introduced species are exceedingly difficult to predict. A good example is the multicolored Asian lady beetle, *Harmonia axyridis*. Although this species is an excellent biological control agent and a voracious predator of aphid species on many crops, it appears to have displaced many native lady beetles from their habitats and become a serious urban pest in many regions.

Augmentation of Natural Enemies

To some people, biological control means buying and releasing natural enemies to control pests. This approach is generally known as **augmentation**, although in the strictest sense, augmentation refers to situations whereby natural enemies are released to supplement an existing population, something that is rarely done in field crops. Augmentative biological control is widely recognized by the public because many commercially available insects are advertised for sale in magazines and publicized in the media. Further, the use of pesticides has conditioned us to think about pest management in the context of purchased products. However, in contrast to the other two forms of biological control, augmentation is less sustainable because it relies on regular or periodic releases of purchased products, something that sometimes benefits producers of these products more than consumers. Situations do exist where augmentation can be highly efficacious, cost effective, and a desirable alternative to pesticide applications, but these occur mostly in enclosed settings such as greenhouses and interior plantscapes.

Natural enemy augmentation is based on the assumption that, in some situations, there are not adequate numbers of natural enemies to provide sufficient biological control (even though some may be present), or that their immigration is not timely enough to suppress the pest before it reaches economic levels. One requirement for augmentation to be feasible is a source of large numbers of natural enemies that are readily available for an affordable price. In response to demand, many companies have developed insectaries capable of producing large numbers of predatory and parasitic insects and others produce and market nematodes and microbial pathogens as other forms of biological insect control. Unfortunately, while these companies may have developed good techniques for rearing and disseminating their beneficial insects, they typically have limited experience with regard to how, where and when to release these insects into the crop for greatest impact. Likewise, only rarely do recommendations identify circumstances when releases of natural enemies should not be made.

There are two general release strategies in augmentative biological control: inundative and inoculative. Inundation involves releasing large numbers of natural enemies for immediate reduction of a damaging or near-damaging pest population. This strategy is used mainly for short-term control and is only feasible for natural enemies that can be produced in large numbers very cheaply. It is applied as an immediate, corrective measure; successful reproduction and continued survival of the natural enemy population is neither presumed nor expected. Inundative releases are often used as a substitute for a chemical spray that might be undesirable because of unwanted side-effects, hence the term **biopesticide**. In contrast, inoculation involves releasing small numbers of natural enemies once or more throughout the period of pest activity, usually beginning when the pest is still at low density. It is therefore more of a preventative measure, in that the natural enemy is expected to reproduce and build a population that will prevent the pest from reaching the economic injury level.

Augmentative biological control is only reliably effective when it rests on a solid foundation of research derived from the specific context of application. Although many purveyors of natural enemies recognize the need to provide an insect + information package to their clientele to maximize the chances for success, many others are primarily concerned with selling insects, with the result that many are sold for inappropriate applications, sometimes generating consumer dissatisfaction with biological control in general. A prime example is the sale of adults of the lady beetle, *Hippodamia convergens*, to control aphids. Dozens of outlets offer these insects for sale, including some of the largest agricultural supply companies, despite general agreement among entomologists that they are not effective in this application. Most commonly, the adult beetles are collected in buckets en masse from overwintering aggregations in the mountains of California. This practice is fraught by at least two problems. As they emerge from hibernation, the beetles instinctively disperse rather than feed and lay eggs. Consequently, most fly away from their release sites immediately, regardless of the presence of aphids. Secondly, beetles collected from hibernation are typically in reproductive diapause, a dormant state in which eggs are not laid and adult feeding may be minimal, resulting in poor performance. A general problem, not specific to lady beetles, is that populations reared in the insectary, or field-collected from certain localities, may be adapted to specific environmental conditions substantially different from those where they are released. If local climate or food sources are considerably different from those to which the populations is adapted, survival and reproduction may be greatly diminished at release sites.

Even when an appropriate natural enemy is selected, failures to achieve satisfactory control can result from a number of causes, most commonly a user's lack of information on the biological requirements of the insect, the biology of the target pest, and effective modes of application. Another problem is that appropriate release rates are difficult to determine for a given situation and depend on many factors, not least of which is the actual pest density at the time of release. The best advice for pest managers considering an augmentation approach is to do their own research and obtain as much information as possible to maximize the probability of success. Well-researched projects can and do result in very effective augmentative biological control programs, including those involving applications of microbial insecticides.

The cost of commercially supplied natural enemies is a major consideration in assessing their potential suitability as an alternative for pesticides in any situation. Prices vary widely because of differences in the degree of difficulty and expense in rearing different species. Sometimes it is justifiable to pay a higher cost for natural enemies relative to an insecticide, provided adequate control of the pest is obtained. This may be the case where pests have developed insecticide resistance, where worker protection standards are a concern, where there are risks of disrupting biological control programs for other pests with insecticides, or where a premium price can be obtained for certified organic production. In general, the inoculative approach is more cost effective provided that correct release rates and timing are used. Inundative releases can be justified on high-value crops where the cost of production is already substantial. Managers should carefully evaluate the cost of a natural enemy as they would any other production cost before making a decision on augmentative release.

Important questions to ask before considering an augmentation program:

1. Has research shown that a release program can be effective for a particular pest, crop and local situation?
2. What is the best time to release the natural enemy in relation to the pest's life cycle?
3. Are releases compatible with other crop production practices that are anticipated, including the possible need to apply pesticides against other pests?
4. Does the supplier provide a comprehensive information package with clear instructions on handling, releasing, and evaluating the effectiveness of the natural enemy?
5. What quality control practices does the supplier use to ensure that insects arrive alive and in good condition?
6. How does the overall cost of a release program compare with alternative control strategies when all ancillary costs and benefits are factored in?

To summarize, augmentation is perhaps the most publicly recognized form of biological control, but also one of the least understood and most often misapplied. It can provide a safe alternative for controlling certain pests in some situations, but a significant investment in research is required for it to provide reliable control in any given situation. It is the responsibility of the end user to obtain and assimilate the relevant information necessary for effective implementation of a release program and ensure that the product purchased is appropriate for the particular pest and situation. There are no commercially available natural enemies that are currently recommended for augmentative biological control applications in large-scale commercial production of field crops in Kansas.

Recognition of Common Beneficial Insects in Kansas Field Crops

Predators

By **predators** we refer to insects or other arthropods (spiders and mites) that feed on other insects (prey) by hunting, killing and directly consuming them. Although more than 100 families of insects contain predaceous species, about 12 of these contain the major biological control agents of field crop pests. Here we summarize the biology and description of some of the most important families.

Lady Beetles (Coleoptera: Coccinellidae)

Lady beetles, or ladybugs, are possibly the most universally recognized group of beneficial insects. They are found almost anywhere and usually feed on aphids and a variety of other soft-bodied insects. Some will also feed on mites and the eggs and larvae of moths and beetles. Currently there are about five species that can be commonly encountered in field crops in Kansas.

Probably the most abundant species in Kansas field crops is the convergent lady beetle, *Hippodamia convergens*, a native species. This lady beetle is recognizable by the two convergent white lines on the black portion of the body immediately behind the head (Fig.1). Coloration ranges from pale orange to red with a series of black spots that may only be faintly visible, or entirely absent. Aphids are the preferred food, although adults may supplement their diet with other prey items and certain vegetable food

Fig. 1

sources. Overwintered adults produce one generation in early spring that is typically completed around the time wheat is harvested, leading to the mass exodus of large numbers of beetles from maturing wheat fields. First-generation females mate within days of emergence, but produce very few mature eggs right away unless they are able to encounter a large supply of aphids. Rather, the majority produce fat bodies to store the energy gleaned from whatever prey they find and forgo reproduction for the duration of summer, surviving dry periods by drinking the sap from various plant species, especially sunflower. As fall brings cooler weather, aphids once again increase in abundance and the over-summered females lay their bright yellow or orange eggs in clusters near aphid colonies to begin the next generation. The number of generations is variable, depending on the food supply, but the majority of adults maturing late in the season delay reproduction and conserve their resources for hibernation. They crawl into protected sites, typically at the base of grass tussocks, and remain dormant through winter months until they are awakened by the warm temperatures of spring. These abilities to hibernate in winter and forgo reproduction during summer when prey are scarce represent adaptations that are likely key to this species' success and abundance in prairie habitats.

Another common species is the twelve-spotted or pink lady beetle, *Coleomegilla maculata*. The adults are pink with six black spots on each wing cover (Fig. 2). Aphids are also the preferred food of this species, but a very wide range of insect prey may be consumed. The larvae of this species are unique among lady beetles in their ability to complete development on an exclusive diet of pollen.

Fig. 2

Pollen is also attractive to adults and many can be found in corn fields at tasseling, although they also like to feed on the eggs and small larvae of many moth species that are abundant in corn, including economically important corn borers. This species is often abundant in proximity to water sources such as rivers and lakes. It hibernates in aggregations during winter months but, unlike the convergent lady beetle, probably continues to reproduce throughout summer months, typically producing 3 or 4 generations per year.

A species becoming increasingly common in the Midwest with the advent of soybean aphid is the multicolored Asian lady beetle, *Harmonia axyridis* (Fig. 3). Adults are highly variable in coloration (pale orange to red) and spotting patterns (males often have none). The key to identifying this species is the prominent black 'W' on the part of the body behind the head. This

Fig. 3

invasive species is a voracious predator of aphids and many other insects, including the larvae of alfalfa weevil. Unfortunately, it can also complete development feeding on the eggs and larvae of many other lady beetles and has been implicated in the declining abundance of a number of native species, a fact that has marred its reputation as an otherwise effective biological control agent in many types of agricultural production. Another habit contributing to the potential pest status of this beetle is a propensity for entering houses in fall and winter, often forming large aggregations that can be very distressing to homeowners.

The seven spotted lady beetle, *Coccinella septempunctata*, is another imported species, one that originates in Europe. It is a large beetle that can be recognized by the distinctive seventh black spot that spans the front edge of both wing covers and is flanked by two small white triangles (Fig. 4). It prefers to feed on aphids infesting grasses and herbaceous plants.

Fig. 4

Other, smaller species of ladybeetles can also be abundant in Kansas fields, but may go unnoticed because of their small size and more secretive habits. Many are important for feeding on the eggs of moth pests such as the European corn borer. S*cymnus spp.* (Fig. 5) have larvae that produce waxy secretions that serve to defend them against ants, causing them to resemble mealy bugs

Fig.5

(Fig. 6). Others such as *Stethorus spp.* are even smaller and specialize in feeding on mites (Fig. 7).

Most aphid-feeding species lay bright yellow or orange eggs in clusters of 15 to 40, usually near, but not directly in, aphid colonies. The larvae of ladybeetles are more difficult to identify to species than adults, but larvae of most of the larger species resemble little alligators. There are four larval instars (molts) before the pupal stage is reached.

Fig.6

Fig. 7

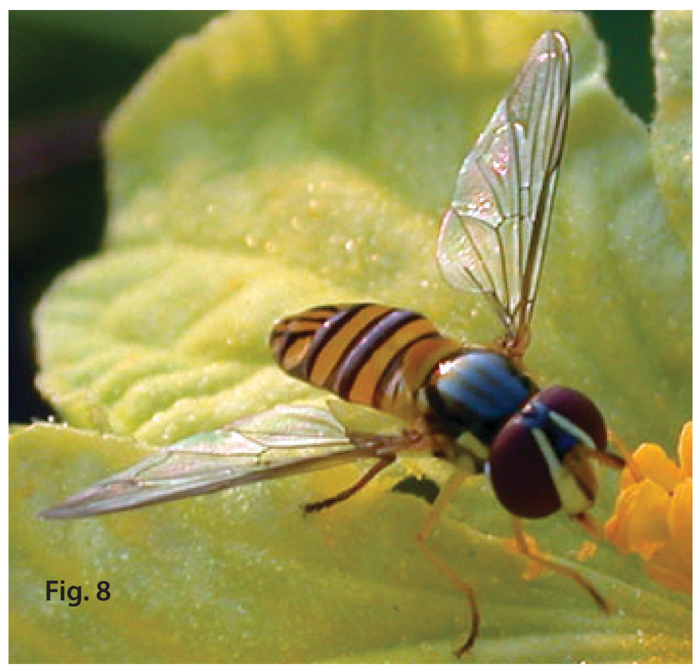

Fig. 8

Hover Flies (Diptera: Syrphidae)

Hover flies (Fig. 8) are also known as flower flies and are most easily recognized by their hovering flight above flowers or aphid-infested plants. Many resemble bees or wasps, but different species vary greatly in size and appearance. The larvae (Fig. 9) are voracious predators of aphids and, in some cases, other small, soft-bodied insects.


Fig. 9

Adult hover flies require access to flowers as they need sugar from nectar to fuel their flight. In addition, female flies must consume pollen as a source of protein before they can mature their eggs. Adult females find aphid colonies by orienting to the smell of honeydew excreted by the aphids. Many studies have shown that planting mixed borders of wildflowers around gardens can attract hover flies and increase the rate of egg-laying on aphid colonies on adjacent vegetables and other crops. This is an example of conservation biological control by habitat management and is the only effective means of encouraging these insects.

Different species of hover fly vary in the kinds of aphid colonies they select for laying their eggs and many are quite specific to certain aphid species. The white, oblong eggs (Fig. 10) are usually laid singly in among the

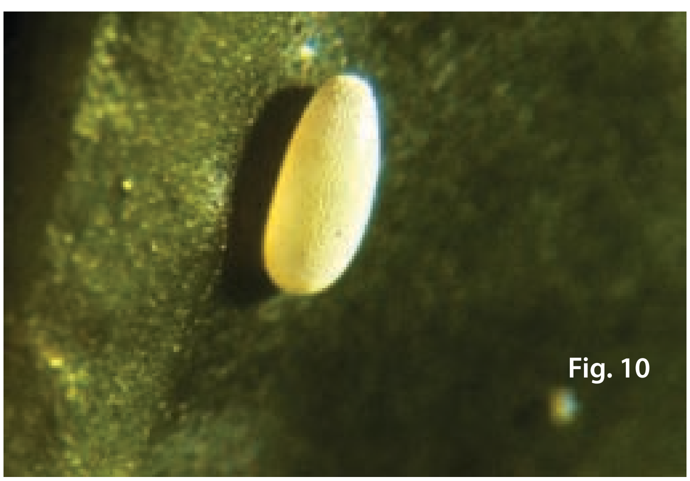
Fig. 10

aphids. A maggot hatches from the egg in 2 or 3 days and begins to feed on aphids voraciously, growing at a truly remarkable rate. The larvae are slug-like, tapered toward the head, and use a film of their own saliva to adhere to the leaf surface. There are typically three instars that may be completed within 7 to 14 days, depending on temperature, and as many as 400 aphids may be consumed by the larva in its period of development. The pupae are typically teardrop-shaped (Fig. 11) and may form on plant parts below the aphid colony, or in the soil, depending on


Fig. 11

species. The pupa is also the overwintering stage. Syrphid flies comprise an important, if often overlooked, source of aphid mortality that, acting in concert with other predators and parasitoids, is important in keeping aphid populations below damaging levels.

Lacewings (Neuroptera: Chrysopidae and Hemerobiidae)

All lacewings are predaceous as larvae, and adults of some species are predaceous as well. Lacewing larvae (Fig. 12) prefer aphids as prey but also consume a range of other soft-bodied pests such as mites, thrips, leafhoppers and mealybugs. The most common species in Kansas field


Fig. 12

crops is the green lacewing, *Chrysoperla carnea*, although other species also occur. Adults have large, lacey wings, thread-like antennae, and protruding eyes (Fig. 13). They are primarily nocturnal, but when disturbed, they will leave their resting places on the undersides of leaves in an erratic, fluttering flight. Despite their fragile appearance, lacewings are among the very few insects capable of extricating themselves from a spider's web. The white,

Fig. 13

Fig. 14

oval eggs are laid on the end of long stalks (Fig. 14). The relative length of the stalk and the pattern in which the eggs are laid (singly versus in groups, in line or in a spiral) can be characteristic of particular species.

Lacewings are among the beneficial insects that are available commercially. Usually, the eggs are shipped mixed with a substrate such as rice hulls and some moth eggs for food. However, because the larvae are highly cannibalistic and immediately begin to kill and eat each other upon hatching, they require immediate distribution in the field. Even then, lack of biological information on habitat preferences, climatic tolerances, dormancy, and the behavioral responses of particular species, as well appropriate release rates and suitable release techniques, have severely limited the usefulness of these insects in augmentative biological control programs.

True Bugs (Hemiptera: Anthocoridae, Nabidae)

Numerous species of 'true' bugs are predators of insect pests. These include damsel bugs, (*Nabis spp.*, Fig. 15), big-eyed bugs (*Geocoris spp.*), minute pirate bugs (*Orius spp.*) and assassin bugs. Predatory bugs skewer their prey with piercing and sucking mouthparts, inject enzymes to digest the internal organs, and then drink the liquefied body

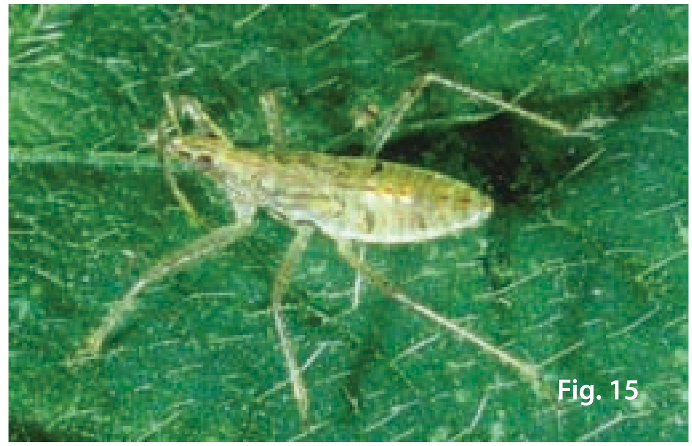

Fig. 15

contents like soup through a straw. This process is known as **extraoral digestion** (which is also used by lacewing larvae). A wide range of prey are taken depending on the size and species of bug. Minute pirate bugs are partial to thrips, but other bugs will feed on aphids, caterpillars, and insect eggs. The larger assassin bugs (*Reduviidae*) are top predators in the food chain and feed on many kinds of insects, even lady beetles. This is an example of **intraguild predation** – predators eating each other as well as feeding on pest species, a phenomenon that often adds complexity to biological control systems.

Ground Beetles (Coleoptera: Carabidae)

Ground beetles are commonly found in all cultivated field crops. Both larvae and adults are predaceous on many ground-dwelling insects, but their actual contribution to biological control of crop pests is not well understood. Most species are large, shiny and black, with ridged wing covers. They have threadlike antennae and a head that is smaller than their thorax. Adults of most species rarely fly and are most often seen running across the soil surface. Most adult feeding occurs on the soil surface, and most larval feeding under the soil surface, so they feed on root maggots, rootworms, caterpillars, and other soft-bodied insects that might be dislodged from plants. For example, ground beetles have been studied for their contribution to biological control of cereal aphids, even though most will not climb a plant to reach the aphids. However, as lady beetles and other predators attack an aphid colony, they often dislodge more aphids than they actually eat, and carabid beetles foraging on the soil surface reap the rewards, and ensure that these aphids are not able to climb back onto the plants.

Spiders

Although spiders are not insects, they play an important role as generalist predators of many insect groups. As such, their role as biological control agents is perhaps greater than previously thought. Their presence also is considered by many to be indicative of a healthy agroecosystem. Spiders comprise a very diverse group that can be broadly categorized by their hunting strategies. Web-spinners, including orb-weavers, and garden spiders, use silk to trap their prey in various ways. Species such as crab spiders are highly cryptic 'sit and wait' predators that hide in flowers to ambush pollinators. Hunting spiders are typically hairy, robust species that do not build webs, but actively seek out their prey. These include jumping spiders, wolf spiders and the large tarantulas.

Parasitoids

Parasitoids are like the vampires of the insect world. As immatures, they obtain their nutrition by feeding in or on the body of another insect, ultimately killing it. The adults are typically free-living and the females are responsible for finding host insects for their progeny. The two major groups discussed here are parasitic wasps and tachinid flies.

Parasitic Wasps

Parasitoid wasps comprise one of the most diverse and important groups of beneficial insects. Almost all insects are attacked by at least one species of parasitoid, and most by more than one. Some species attack only one insect host and many successful classical biological control programs have involved the introduction of highly specific parasitoids. Many species are large and colorful, but most of the economically important ones are small and very inconspicuous. For example, those attacking aphids are smaller than their aphid hosts (Fig. 16), and those developing within a single moth egg or scale insect are barely visible to the naked eye. Some are solitary, with only a single individual completing development in a host insect, whereas others are gregarious, with as many as several hundred siblings feeding and developing on the same host. This condition most often results from the female laying many eggs on the same host, but in some species a single egg undergoes a series of divisions before development begins, a condition known as polyembryony.


Fig. 16

Parasitoid biology is distinct from that of many other insects. Although reproduction is typically sexual, most females can manipulate the sex of their progeny by controlling the fertilization of eggs; males are produced from unfertilized eggs and females from fertilized ones. In some species, all-female lines persist for many generations without sexual reproduction. The female uses an ovipositor to lay eggs in a host insect (the stinger of a honey bee is a modified ovipositor that delivers only venom). In some species the ovipositor is held internally when not in use; in others it is not retractable and may be as long, or longer than, the entire wasp body. Venom that serves to immobilize, paralyze or otherwise subdue the host may also be delivered via the ovipositor. Some female parasitoids also use the ovipositor to puncture a host and then feed on the body fluids before selecting other hosts for oviposition, thus causing two different types of mortality in the pest population. In some cases, the egg is laid externally on the body of the host and the larvae may also feed externally (ectoparasitism). More commonly, the larva develops and pupates within the host body, feeding selectively on the host's internal tissues and leaving the digestive tract and nervous system to the very last (endoparasitism). Another important distinction is whether the host is allowed to develop and grow with the parasitoid larva inside it, or whether it is killed or permanently paralyzed by the attacking females so that it remains a static, rather than dynamic, food source for the developing larva.

Tachinid Flies

This group represents a very large family of flies with more than 1,000 species in North America, all of which have a parasitic lifestyle. They vary considerably in appearance, but most have bristled bodies and resemble house flies, although they can be substantially larger or smaller (Fig. 17). The adult female typically lays an egg on the surface of the host insect cuticle, and the hatching larva then bores into the body of the host and develops internally. In other cases, the fly egg is consumed by the host insect while it feeds. Some species give birth to live larvae that are placed directly onto the host. A wide range


Fig. 17

of moth and butterfly larvae are attacked, and so are a number of beetle species. The host may be killed in the adult stage, but more commonly in the pupal stage.

Nematodes

Nematodes are a phylum of roundworms that are among the most abundant multicellular organisms on earth. Although many families of nematodes feed on plants and include many important pest species, some are free-living whereas others are obligate parasitoids of insects and include many important biological control agents. Some are produced and sold commercially for control of soil and foliar insects. Nematodes are normally applied as either a spray suspension or a soil drench, but their survival and efficacy is often dependent on soil type and adequate moisture. They are associated with a number of different commensal and symbiotic bacteria that aid them in killing and digesting their host insects.

Microbial Pathogens

A variety of microbial pathogens, including bacteria, protozoans, viruses and fungi are specifically pathogenic to insects and completely harmless to other forms of life. This selective pathogenicity renders many of them valuable as biological control agents of insect pests. Some, such as *Bacillus thuringensis*, have been the source of natural insect toxins that are now synthesized as biopesticides, or engineered directly into crop plants. Many insect diseases caused by pathogens are very important sources of mortality in pest populations and lead to precipitous population declines when they become epizootic (analogous to an epidemic in a human population). However, many attempts to induce epizootics in pest populations by means of distributing spores or other types of inoculum fail because stringent environmental conditions are often necessary for successful infection and/or transmission of the disease. For example, many fungal diseases of insects require high humidity or prolonged leaf wetness in combination with particular temperatures to infect their hosts. Some success has been obtained with baculoviruses commercially formulated with sunscreens to protect them from solar radiation when sprayed onto plant surfaces. However, most insect epizootics proceed without human assistance when suitable environmental conditions arise. Conservation is also a consideration when epizootics are a significant natural mortality factor in pest populations. For example, excessive use of fungicides to control powdery mildew and other foliar diseases in potatoes can also eliminate insect-pathogenic fungi, thus favoring aphid outbreaks.

Conclusions

Biological control is a natural process that plays an important role in the suppression of field crop pests in Kansas. A lot of the best examples of biological control proceed completely unnoticed by the farmer, simply because both the pest and its natural enemies coexist at such low densities that there is no perceptible problem in the crop, even thought the pest is present. This fact has been demonstrated by using pesticide treatments to disrupt natural enemy populations and then observing formerly insignificant insect populations rise to the status of major pests. It is generally agreed that integrated pest management (IPM) is the preferred approach to sustainable pest control in agriculture. Whenever possible, IPM programs for field crops should be constructed on a foundation of biological control, with additional control measures applied only as needed and selected to conserve natural enemies and all non-target insects to the greatest extent possible. The best way a farmer can improve his chances of benefiting from biological control (e.g. saving the expense and hazard of pesticide applications) is by learning to recognize those beneficial insects that are important natural enemies of the key pests attacking his crops. These insects should be thought of as farm laborers that work for free — the only wages they demand are the pests that they consume. While more research is needed to better understand the needs and requirements of many beneficial species so that their effectiveness might be enhanced, there are many recognized techniques available to generally conserve natural enemies and encourage their activities. The advent of no-till agriculture has likely had a net positive effect on the abundance of beneficial insects in field crops. Crops genetically modified to express natural insect toxins have, to date, proved either neutral or favorable to biological control by virtue of reducing overall pesticide usage. Fallow areas around fields can serve as reservoirs of many natural enemies, especially if weed species are allowed to flower. If a pesticide treatment becomes necessary, leaving less-affected portions of a field untreated can provide a refuge for natural enemies and accelerate the field-wide restoration of biological control post-treatment. Some newer pesticide formulations are designed to be more selective for particular pests and will spare natural enemies. In short, whenever biological control has a role in pest population reduction, pest control decisions should be weighted by considerations of how natural enemies will be impacted, and what tactics might be feasible to conserve them.

Other Resources

Insect Biocontrol Laboratory U.S. Department of Agriculture: *http://www.ba.ars.usda.gov/psi/ibl/*

Biological Control Information Center, University of North Carolina: *http://cipm.ncsu.edu/ent/biocontrol/*

Biological Control: A Guide to Natural Enemies in North America: *http://www.nysaes.cornell.edu/ent/biocontrol/*

Nematodes as Biological Control Agents of Insects: *http://nematode.unl.edu/wormepns.htm*

The Association of Natural Biocontrol Producers: *http://www.anbp.org/*

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