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Biological Control of Insect and Mite Pests

Robert J. Wright, Extension Entomology Specialist

The advantages and disadvantages of the three forms of biological control of insect and mite pests — classical, augmentation and conservation — are discussed.

Biological control is the conscious use of living beneficial organisms, called natural enemies, to control pests. Biological control should be an important part of any integrated pest management program, an approach which combines a variety of pest control methods to reduce pest levels below an economic threshold. Virtually all insect and mite pests have some natural enemies. Managing these natural enemies can effectively control many pests. Often the use of insecticides or other practices can injure or kill natural enemies, increasing the survival of the remaining pest insects. There are three basic components of biological control: importation, conservation and augmentation.

Classical Biological Control: Importation of New Natural Enemies

Many insects are serious pests because they are not native to Nebraska; they were accidentally introduced through commerce or the transport of personal belongings (*Table I*). Many of these pests were introduced from overseas with early settlers who unwittingly brought infested foodstuffs or even plant material destined to start new crops in the New World. Modern quarantine laws are intended to eliminate the introduction of new pests, but even now, serious new pests, such as the Russian wheat aphid, find their way into the United States, become established and cause damage.

Figure 1. The seven-spotted lady beetle, *Cocinella septumpunctata*, was imported from Europe by USDA, and is now established throughout Nebraska.

When a non-native pest is accidentally introduced in a new area, it usually arrives without the many natural enemies that control it in its native location. Often some of the most effective natural enemies of an organism are those that have coevolved with it in its native habitat. Therefore, some of the most dramatic successes in biological control have resulted from importing natural enemies from other countries, a practice often called classical biological control. The first major successful example of this method occurred over 100 years ago and involved the control of cottony cushion scale, a serious pest of the California citrus industry, by introducing a lady beetle, the vedalia beetle, from Australia.

Table I. Important non-native insect pests in Nebraska.

Insect pest	*Original home*
Russian wheat aphid	Russia
European corn borer	Europe
Hessian fly	Europe
Colorado potato beetle	Mexico
alfalfa weevil	Europe
greenbug	Europe
imported cabbageworm	Europe
Mexican bean beetle	Mexico
codling moth	Southeastern Europe
elm leaf beetle	Europe
euonymus scale	Asia
mimosa webworm	China
cabbage maggot	Europe
Japanese beetle	Japan

Adapted from Mahr & Ridgway (1993), NCR Publ. No. 481.

The goal of classical biological control is to find useful natural enemies, introduce them into the area of the target pest, and permanently establish them so that they will provide continuing pest control with little or no additional human intervention.

Classical biological control differs from the other two general methods (conservation and augmentation) because it is not directly conducted by the farmer or gardener. International agencies, federal agencies (especially USDA), and state agencies (state departments of agriculture and land-grant universities) are responsible for identifying potential target pests, locating their natural distributions, searching these areas for candidate natural enemies, and introducing selected natural enemies into the necessary areas. Indeed, specific quarantine laws prohibit private individuals or agencies from introducing non-native organisms (including natural enemies) without proper authorization from USDA.

Natural enemies must be carefully screened by trained personnel under rigid quarantine conditions to be certain that (1) they will provide benefit in controlling 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 natural enemies. Many of the past successes in classical biological control have occurred in tropical and subtropical locations. California, Hawaii, Texas and Florida have achieved significant successes by introducing exotic (foreign) natural enemies.

In Nebraska, USDA efforts have resulted in establishment of a European lady beetle, the seven-spotted lady beetle, now found in all Nebraska counties (*Figure 1.*). USDA also introduced natural enemies of the alfalfa weevil and European corn borer in Nebraska. There are over 75 non-native pests of crops, livestock, human health, forests and landscape in the Midwest; many of these are candidates for classical biological control.

Although farmers and gardeners are not directly involved in the classical biological control process, they need to be involved in the management of the exotic natural enemies that become established. Recognizing these natural enemies, and understanding their benefits and use in an overall integrated pest management program, are important considerations in both the conservation and augmentation of natural enemies.

Augmentation: The Periodic Release of Natural Enemies

To many people, "biological control" means buying and releasing beneficial natural enemies to control insect and mite pests. This approach is known as augmentation. The underlying reason for the wide recognition of this technique is that it relies on commercial products, which may be advertised in magazines and publicized in the media. Further, the use of pesticides has trained people to think about pest management in the context of purchased products. However, of the three general approaches to insect biological control, augmentation is the least sustainable because it requires regular or periodic purchase of products. Nonetheless, in some pest situations it is a highly efficacious, cost effective, and environmentally sound approach to pest management.

The practice of augmentation is based on the idea that in some situations there are inadequate numbers or species of natural enemies to provide optimal biological control, but that the numbers can be increased (and control improved) by releases. This requires a readily available source of large numbers of natural enemies. This need has fostered the development of companies to produce and sell these organisms. Many companies (called insectaries) produce a variety of predatory and parasitic insects; other companies produce and market insect pathogens for use as microbial insecticides.

There are two general approaches to augmentation: inundative releases and inoculative releases. Inundation involves releasing large numbers of natural enemies for immediate reduction of a damaging or near-damaging pest population. It is a corrective measure; the expected outcome is immediate pest control. Because of the nature of natural enemy activity, and the cost of buying them, this approach using predaceous and parasitic insects is recommended only in certain situations, such as the mass release of the egg parasite *Trichogramma* to control moth eggs. The use of some microbial insecticides (such as those containing *Bacillus thuringiensis*) also is an example of inundation. Inoculation involves releasing small numbers of natural enemies at intervals throughout the period of pest activity, starting when the pest population is very low. The natural enemies are expected to reproduce to provide more long-term control. The expected outcome of inoculative releases is to keep pest numbers low, never allowing the number to approach an economic injury level; therefore, it is more of a preventive measure. Two examples are the release of predatory mites to protect green house crops, and the inoculation of soils with the milky spore pathogen (*Bacillus popillae*) to control Japanese beetle grubs.

Targets of augmentation. Augmentative biological controls have not been developed for all pest problems. Indeed, relatively few situations are amenable to this approach. One of the most frequent uses of augmentation is to protect greenhouse crops, a practice that was started in Europe over 30 years ago in response to widespread insecticide resistance to greenhouse pests. Today, commercial natural enemies are available for controlling aphids, mites, scale insects, mealybugs, leafminers, thrips, caterpillars and other greenhouse pests.

Augmentation, other than the use of microbial insecticides, has not been widely used in Midwest crops. It is heavily used in some areas of California, where citrus growers have their own insectaries for natural enemy production. In row crops, generalist natural enemies frequently are used, such as the egg parasite *Trichogramma*, green lacewings and microbial insecticides. In the United States, augmentation probably has been used the least on field crops, partly because of the lack of effective natural enemies and partly because the expense may be unacceptable on low-value crops.

Bacillus thuringiensis is commonly used for controlling European corn borer larvae, and considerable research is aimed at making the release of *Trichogramma,* which parasitizes corn borer eggs, a viable option. Home gardeners increasingly are using natural enemies to protect food crops and landscape plants. Commercial natural enemies may be used in several other areas, and some companies target specialized markets, such as the gypsy moth, fire ant and stored product pests.

Types of natural enemies available. More than 100 types of natural enemies are commercially available, including predatory insects and mites, parasitic insects, insect-parasitic nematodes and insect pathogens. Although this sounds like a high number, it is small compared to the total number of pests in the United States. Further, many of these natural enemies are specialized for pests on crops such as cotton and citrus not grown in the Midwest. Other commercial natural enemies, such as lady beetles and praying mantids, are of questionable value, even though they have been highly popularized.

Efficacy. "But do they work?" This is a frequently asked question about commercially produced natural enemies. The short answer is "Yes..., and no." There is no doubt that well-researched applications of natural enemies can be very effective. This includes the use of microbial insecticides as well as many specific uses of predators and parasitic insects. There is also no doubt that many natural enemies that are sold do not control the intended target pest(s). The reasons for the latter

scenario are multiple and complex. They range from the ridiculous (e.g., a community that bought and released lady beetles for mosquito control) to the obscure. Probably the common thread that exists with "failures" is a lack of knowledge. This encompasses both a lack of research needed to make recommendations for successful implementation, and the user's lack of knowledge about the biology of the pests, their natural enemies and their environment, all of which are crucial to making augmentation work. The best advice for pest managers interested in starting an augmentation program is to get as much information as possible to assure a reasonable chance for success.

Cost effectiveness. Some natural enemies are much easier and less expensive to produce than others; this is reflected in their prices. Because of the differences in prices and usage patterns, it is hard to generalize on the cost effectiveness of purchased natural enemies. Other less obvious factors also have to be considered, especially when comparing the release of natural enemies to the use of pesticides. These include pesticide resistance management, worker protection, impacts on non-target pests, environmental considerations and marketing practices (such as conventional vs. organic). Another problem is that, for many commercial natural enemies and their potential target pests, there is inadequate research to recommend specific release rates based upon pest population levels. There are, however, many situations where augmentative biological control is cost competitive with the use of pesticides or other pest management practices. On high value crops, the expense of biological control may be relatively low when compared to overall production costs. On low value crops, the use of natural enemies must be inexpensive to be justified. This does not preclude the use of augmentation in field crops; inundative controls such as *Bacillus thuringiensis* and *Trichogramma* may be cost effective, as can be inoculative releases that rely on relatively low numbers of natural enemies. The cost of natural enemy releases should be carefully evaluated, as with any other production cost.

In summary, extension personnel get more questions about the release of purchased natural enemies than all other approaches to biological control. And in some cases, it is the area where there are the fewest answers. Many augmentation programs do work and are cost effective, but augmentation cannot be considered "the silver bullet" of biological control. It is not foolproof, and it requires a certain level of knowledge and understanding to make it work. Additionally, effective commercial natural enemies are available for only a small percentage of all the types of pests we must manage. It is the most costly and least sustainable form of biological control. However, where it does work and is cost effective, augmentation can be very useful.

Conservation of Natural Enemies: Keeping Your "Livestock" Happy and Productive

Conservation of natural enemies is arguably the most important concept in the practice of biological control and fortunately is also one of the easiest to understand. Simply put, conservation of natural enemies means avoiding practices that harm natural enemies and implementing practices that benefit them. It may sound like good common sense, but the tricky part comes in understanding exactly what practices are harmful and how beneficial practices can be integrated into a production system. This requires understanding the biology of natural enemies and being willing to modify practices to accommodate them.

Natural Enemies as Livestock. Everyone understands that a dairy cow needs food, water, shelter and protection from adverse conditions. To perform her best she also needs protection from biting flies, diseases and in some cases, predators that may injure or kill her. The dairy producer knows her requirements change through the year and makes provisions to provide for these needs. In the winter, shelter is critical, while in the summer adequate water and shade are necessary. In some months, grazing may provide her total food requirements, but as pasture growth slows, supplemental food may need to be provided.

Natural enemies have exactly the same types of needs as the dairy cow. To perform their best, they need food, shelter and protection from adverse conditions. Frequently, we do not fully understand or provide for these needs. The result is many instances where biological control could be effective, but has failed or resulted in less than adequate control because humans did not provide for the natural enemies' basic requirements. So what do natural enemies need and how can we help them?

Avoid Harmful Practices. The most obvious practice is the use of insecticides at times when natural enemies will be harmed. Insecticides can have direct effects on natural enemies by killing them or indirect effects by eliminating their hosts and causing starvation. In some cases, insecticides can be successfully integrated into the system without harming natural enemies. This may be through the use of a selective insecticide such as B.t., timing the application to avoid periods when important natural enemies would be exposed, or placing the insecticide in a location where natural enemies will not contact it. In other cases, adequately protecting natural enemies may require not using an insecticide.

Certain cultural practices also can be detrimental to natural enemies. Plowing, cultivation, mowing or harvesting operations that disrupt natural enemies at critical points in their life cycle should be avoided. Excessive amounts of dust from roads or cultural operations also can disrupt the activities of predators and parasitoids resulting in reduced control. Burning crop residues or inappropriately timing irrigation also can kill many natural enemies.

Finally the ambiguous category of "clean farming," which includes removing weeds and noncrop habitats, has been identified as detrimental to many natural enemies.

Incorporate Beneficial Practices. Here is where a detailed understanding of the biology of the important natural enemies in your system becomes extremely critical. If you do not know what natural enemies you want to manage, success is doubtful. The first step is to gather information on the types of natural enemies to conserve. Then consider these points:

- **Where does the natural enemy overwinter?** In England, a group of researchers discovered that important predators of aphids in wheat overwintered in areas of grasses in hedgerows on the edges of fields. The predators migrated into the fields in the spring, but got there too late to control aphids in the center of the fields. By planting a one meter strip of tussock grasses in the center of the field,

overwintering predator numbers soared and aphid damage was controlled.

- **What alternate food sources do the natural enemies need? Are these close by and available at the right times?** After emerging from overwintering, pink-spotted lady beetles feed on plant pollen (dandelion, spring beauty, etc.) for several weeks before moving into alfalfa and wheat fields to feed on aphids. Many parasites also require the protein-rich pollen to develop new eggs. Sources of sugar (carbohydrate) are needed by many parasites, which they frequently obtain from the nectar of flowering plants or from aphid honeydew. Having a diversity of plants in and around fields has been shown to improve biological control.
- **Do my natural enemies need alternative prey/hosts?** Many predators and parasites require alternative hosts during their life cycle. *Lydella thompsoni* is a tachnid fly that parasitizes European corn borer. It emerges before borer larvae are present in the spring and completes its first generation on common stalk borer instead. Clean farming practices, which eliminated stalk borer hosts, are thought to have contributed to the decline of this parasite. Alternative prey also may be important in building up predator numbers in a field prior to the appearance of the target pest. Lady beetles and minute pirate bugs can consume many European corn borer eggs, but alternative prey must be present in the field prior to European corn borer egg laying to maintain high predator numbers.
- **What shelter is needed by my natural enemies during the growing season?** The activity of ground dwelling predators (e.g., spiders and ground beetles) may be limited by high soil temperatures during the day. Incorporation of cover crops or intercrops may help reduce soil temperatures and extend the activity period of these organisms. Increased crop residue from reduced tillage or use of grassy field borders also may benefit ground dwelling predators. Similarly, many parasites require moderate temperatures and higher relative humidity and many need to leave fields in the heat of the day to seek shelter in shady areas. For example, the activity of a parasitic wasp attacking European corn borers was found to be highest at field edges with wooded areas which provided shade and reduced temperatures, and contained flowering plants which provided nectar or honeydew for the wasps.

Conclusion

Consideration of the biological and ecological needs of natural enemies is critical for the success of any biological control effort. It is one of the easiest ways for producers to initiate biological control on their farms and should be a major consideration in any importation or augmentation program. While there are innumerable practices in your production system that may benefit or harm the natural enemies you are seeking to manage, understanding the biological and life cycle of the desired specific natural enemies to conserve is the first step to achieving the best results.

This publication was adapted from material published in the Biological Control Newsletter, which is available online at *http://www.entomology.wisc.edu/mbcn/mbcn.html*.

Sources

For more information on biological pest control:

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