Biological control of pests requires a change in thinking for the grower as well as the supplier of the biological products. The concept of maintaining a balance of pests and predators or parasitoids does not work in crops where any insect or mite found on the plant is not acceptable, as in most food crops. However, some woody and herbaceous landscape plants and situations may tolerate low levels of certain insects on the plants. Consequently, biological insects have been successful in controlling certain pests in North America and Europe. Dutch growers have realized that biological controls do work, plus they also obtain larger plants as a result of a simple IPM program where chemicals are sprayed only as needed and biological controls are used when possible. Most growers have progressed even further using biological controls because, if properly used, they are less expensive and they may enhance the effectiveness of chemical sprays that are used. The traditional view of using biological controls, where a balance of pest and predator is achieved is now being replaced with the goal that a successful program is based on the prevention of critical insect infestations.

Applied Bio-nomics, Ltd. in Sidney, B.C., Canada reports that “fresh” beneficial insects and mites provide better and faster pest control than some refrigerated or “stored” specimens. Therefore, it is necessary to minimize or eliminate the storage of the products that may degrade their performance quality over time. Fresh products fly farther, live longer, and lay more eggs than stored products. Fresh beneficial insects provide pest control with low, regular introductions to a crop.

The movement of animals or people throughout the greenhouse or field is a major form of dispersal for crawling pests such as spider mites. Whenever possible, restrict the movement of people in known insect infested hot spots or enter these hot spots less often and at the end of the day and then directly leave the greenhouse, nursery or site. Clothing should be frozen overnight or washed each day for people that work in known infested areas.

Prior to planting in a greenhouse, the house should be thoroughly cleaned. Walls, floors, posts and wires should be washed with soap or another suitable cleaning product. Whiteflies and aphids will persist in cool greenhouses for over a week without any plant material available, but they will be killed with a thorough cleanup.

Upon planting in a field or landscape where insect problems are anticipated, release Hypoaspis miles at a rate of ten to 20 liters per acre. Hypoaspis will establish permanently and will control fungus gnats, springtails, over wintering spider mites, soil pupating thrips and several other pests.

Biological Control of Fungus Gnats
Fungus gnats can have a significant impact on the growth rate of plants, therefore, it is essential that the gnats be controlled immediately. Apply the beneficial mite Hypoaspis miles at a rate of five milliliters per plant, which is approximately 125 mites per plant. Hypoaspis can be diluted with sawdust or vermiculite to obtain a better distribution of the mites. Another technique is to broadcast them over a crop using a whirlybird hand spreader, or a modified Echo blower, with the optional hopper. Skipping a few plants in low pest populated areas is acceptable, as the Hypoaspis will disperse themselves throughout the area. Within one week of the Hypoaspis application, apply biological nematodes which will have two positive effects:

1. They will kill some of the fungus gnats.
2. They will serve as a food source for the Hypoaspis.

This will help the beneficial mites disperse into the entire crop and become established. If there is a very high count of fungus gnats, it may be necessary to alter the growing medium slightly, as a very small variation in the growing medium will have a significant impact on whether or not the fungus gnats will explode in population. Raw potato slices can be used to monitor the relative numbers and stages of fungus gnat larvae. Place a slice of potato on the growing medium surface for a known period of time. The fungus gnat larvae will be attracted to the potato, which then provides a relative population count.
Repeated monitoring for the same duration of exposure will provide an indication whether the problem is getting better or worse. If the growing medium is loose, a single application of Atheta coriaria, the Rove beetle, should also be made at 0.1 to 1.0 units per square yard.

**Biological Control of Spider Mites**

Spider mites must be readily diagnosed, as their damage is permanent. Cleanliness in the greenhouse or field is essential. If a greenhouse has a history of spider mite problems, they can be found in the ground around posts and walls. An introduction of *Hypoaspis miles* at 25 beneficial mites per square foot, or more if higher levels of spider mites exist, at each post and along the walls will help kill the over-wintering spider mites. Cleanup must occur before fall weather since once spider mites begin developing the “red phase”, they become unattractive to predatory mites and more resistant to chemical sprays. Physically spraying with high-pressure water, chemical spraying, and the application of *Hypoaspis* are all effective treatments. Overhead irrigation also helps, to a limited extent, in the prevention of spider mite establishment. When growers switch from overhead irrigation to drip irrigation, spider mite problems increase.

Greenhouse fans should be carefully directed to achieve the desired effect, but they should not blow directly onto the plants. Increased air movement lowers the humidity at the leaf surface, which is unattractive to the predators. The result is that the spider mites will enjoy a predator free area, which will lead to plant injury and a spider mite hot spot.

Spider mites can be prevented and chronic infestations can be cured by the release of *Neoseiulus fallacis*. A general release rate of 10,000 per acre should be modified so that 5,000 are evenly dispersed and the other 5,000 are used directly on infested or susceptible plants. This is usually a one-time introduction, as the *N. fallacis* will establish themselves, feed on pollen and mites, and persist in the plants for many years, even after the pests are eliminated. *N. fallacis* has the added advantage in that they will over winter and persist in any indoor or outdoor environment. Preventive releases of *N. fallacis* in a granular carrier should be made prior to the arrival of spider mites. If spider mites present a continuous problem in a greenhouse, bean plants can be grown around the walls and table legs. The beans will attract the spider mites and display damage very quickly, which helps with monitoring the mites. Once spider mites are present, apply *Phytoseiulus persimilis* to the beans at an approximate ratio of one *P. persimilis* to 100 spider mites. The beans will become beneficial banks which release *P. persimilis* as long as the spider mites survive. In most cases, this will be a long time, as the spider mites come out of hibernation over a very long period of time. Bean leaves that display a ratio of one *P. persimilis* to ten spider mites can be used to treat remote infestations. *Feltiella*, another predator, may volunteer in a cool season crop, but their habit of pupating on the plant leaves may cause additional problems. If the spider mites are under control, it is unlikely that *Feltiella* will populate the crop.

*P. persimilis* is the main beneficial predator for mites, but only for the two-spotted spider mite if the plants are outdoors. Generally the leaf form of the beneficial predator will work twice as fast at half the inoculum rate, as a beneficial predator in a granular carrier. Spider mites should be surrounded by *P. persimilis*. Treat the hot spot plus two or more unaffected plants, as the spider mites are probably also on these visually unaffected plants. *P. persimilis* should be placed low on the treated plants as they instinctively move upward on the plant. A ratio of one *P. persimilis* to 100 spider mites will achieve control in two weeks. A typical attack on a single plant hot spot would be 1000 *P. persimilis* per affected plant, plus 500 *P. persimilis* per immediately adjacent plants, plus 200 *P. persimilis* on all plants within the treatment circle. The hot spot should be flagged and traffic should be diverted from the area. In areas of low humidity, volunteer *Feltiella* will disappear and hot spots may flare up more frequently due to the decline in flying predators. *Stethorus punctillum* should be released at a rate of 200 per acre every two weeks. The *Stethorus* are not intimidated by low humidity or high temperature and they will easily be seen feeding on the upper portions of the plant. During hot weather, the *P. persimilis* will avoid the exposed tops of the plants to prevent drying out. Although *Stethorus* will quickly move into the exposed tops of the plants and feed on a tremendous number of spider mites, *Stethorus* must be applied before the plants are damaged. This damage is permanent and it will reduce the humidity so that the *P. persimilis* will still avoid the area after it has moved down into the canopy. Therefore, preventive control is the key to spider mite management.

Late summer is the most important time of the year for spider mites. Mite populations at this time will determine how severe next year’s infestation will be. Every effort should be made to eliminate all of the spider mites before the beginning of September. Once day length noticeably decreases and evening...
temperatures drop, spider mites begin diapausing. In a diapaused state, spider mites are more resistant to chemicals and are not as attractive to beneficial predators. If chemicals can be used, an application of Avid would be effective at this time. Be aware that in a greenhouse, a whitefly outbreak could occur following an application of Avid.

**Biological Control of Aphids**

In recent years, the range and species of aphids have dramatically increased, therefore, regular scouting for aphids must occur in the greenhouse, field and landscape. Regular low releases of *Aphidoletes aphidimyza* will prevent the establishment of all species of aphids. A rate of 1200 per acre per week will protect a crop from aphids. For general protection, they should also be released away from any known hot spots, which will force them to disperse and seek out new infections. However, aphid infestations in the field or landscape should be attacked with direct releases of 100 adult *Aphidoletes* to an infestation, as they will cycle and over winter for prolonged control resulting in fewer aphid hot spots in subsequent years. All summer infestations and all aphid hot spots should always be treated with direct releases of adult *Aphidoletes*. *Aphidoletes* should be released at dusk, after the wind has subsided. Control of the Melon Aphid will only occur by prevention, as the Melon Aphid reproduces and disperses faster than the biological predators can consume this aphid. For major infestations, rates of 2400 per acre per week should be released until the numbers of aphids are reduced to manageable levels. In order to achieve recovery within three weeks, the ratio of *Aphidoletes* to aphids must be approximately one *Aphidoletes* to 100 aphids. This would require extremely large numbers of *Aphidoletes* for a quick cure or fewer numbers for a longer time period for recovery. Although all species of aphids are controlled by *Aphidoletes*, *Aphidius matricariae* will also control and cycle with the Green Peach aphid. However, *A. matricariae* has the disadvantage of leaving “mummie” casings on the plant leaf surface. Also, during the summer, aphid control should be entirely by *Aphidoletes* as *Aphidius* can become infested with hyperparasites. Any aphid banking system should be converted to *Aphidoletes* by introducing *Aphidoletes* directly onto the banks. However, banking systems are not recommended for aphids due to the high costs.

Aphids must be under control going into fall, as the *Aphidoletes* will stop cycling due to diapause. However, preventive releases will continue to be effective, but they would not be expected to cycle. *Aphidius* can work very well in the fall, especially if they were not used in the summer. Using *Aphidius* only in the fall reduces the pressure from hyperparasites.

**Biological Control of Whiteflies**

The whitefly is an insidious pest and low numbers can give a false sense of security. The longevity and fecundity of the whitefly can lead to overwhelming situations very quickly, so they should never be given the chance to increase in numbers. However, at temperatures over 85°F, whitefly adults will live for just a few days instead of months, and will not lay eggs. The only sure way to control the whitefly is to start clean and prevent any significant buildup of the insect. Apply *Encarsia Max* at a rate of 0.25 units per square yard if no whiteflies are detected per yellow trap card. If one to two whiteflies per yellow card per week are trapped, immediately increase the application rate to one unit per square yard. A count of over two white flies per card per week requires an immediate release rate increase to six units per square yard per week of *Encarsia Max* or eight units of refrigerated *Encarsia*. If refrigerated *Encarsia* is used rather than *Encarsia Max*, the application rate should be doubled. Weekly releases of preventative *Encarsia* should be considered similar to an insurance policy. The use of *Encarsia Max* rather than the refrigerated *Encarsia* will reduce the weekly cost by using the very low rate of 0.25 units per square yard. *Encarsia Max* lives longer and flies farther than refrigerated *Encarsia*. *Encarsia Max* should not be refrigerated and should not be older than 48 hours from harvest. For heavy infestations, *Delphastus catalinae* should also be introduced at a minimum of 40 units per acre every two weeks until the whitefly population is significantly reduced or eliminated. Once plant leaves become sticky with honeydew, the parasitoid *Encarsia*’s movement becomes impaired. *Delphastus* releases should be increased to 2000 units per acre if control is at stake. *Delphastus catalinae* should also be released to feed on large numbers of whitefly eggs, thereby reducing severe outbreaks of the whitefly. If *Bemisia* are present, the *Delphastus* should be released every two weeks at a rate of 400 to 4000 units per acre, depending on the level of infestation.

The use of eggplant as a trap or bank can be very effective as whiteflies have a very advanced sense of smell and they will move onto the eggplant in a very profound manner. The eggplants should be strategically located along the greenhouse aisles or field rows at a rate of four to six plants per acre. These eggplants will draw the whiteflies out of the crop, wherein the high levels of whiteflies can be vacuumed off the eggplant. Freeze the vacuum bag.
over night to kill the whiteflies. A daily vacuuming can strip a significant number of adult whiteflies out of the crop. Orius, Delphastus and Encarsia should be introduced onto the eggplant, as it will become a nursery for the beneficial predators. The presence of thrip predators in a crop will also help with whitefly control, as they will feed on whitefly eggs and larvae. Aphidoletes also feed on whitefly larvae when they are starving for aphids.

If Bemisia have become established, parasitoids are at a disadvantage because they are all reared on greenhouse whiteflies and parasitoids always work best on their established host. All parasitoids will adapt to Bemisia and they will all host feed aggressively. The use of Delphastus will have a major impact on Bemisia, and if started early, will eliminate the Bemisia before they move on to the greenhouse whitefly. Bemisia are much harder to monitor because they do not evenly distribute themselves, as do the whiteflies.

If whiteflies are not kept under control during the spring and summer, they will become uncontrollable in the fall. Adding trap egg plants will help if the plants are vacuumed daily. Adding parasites beyond six units per square yard will have very little effect, as there are just too many whiteflies. The stickiness of the honeydew will begin to impair the movement of all parasitoids. Delphastus will continue to work at very high whitefly densities, but their impact will not be quickly apparent as they will graze on the whitefly eggs, but the adult whitefly will live for months.

Biological Control of Thrips
Total prevention of trips is impossible as they can penetrate any screen and will always get into any greenhouse. Monitoring is essential to determine their initial arrival. Yellow or blue sticky traps should be used rather than waiting to see damage to a crop. Once thrips arrive, corrective action must be immediate and overwhelming. Neoseiulus cucumeris should be applied at a rate of at least ten mites per plant. They can be shaken onto a crop from a bulk tube, scattered over a crop by using a hand spreader, puffed over a crop by pouring the bulk product into a rose duster wherein the bran will stay behind, or it can be blasted over a crop using a modified and governed Echo backpack leaf blower. The N. cucumeris, however, can only feed on the early instars of thrips. Eggs of thrips are injected into the plant tissue, making them unavailable to predators. For many thrips, pupation occurs away from the plant, further impairing the predators’ ability to gain control. Adult thrips are rapid movers and capable of flight. Therefore, also applying Hypoaspis at the pupating site will help prevent the thrp from successfully completing it life cycle. Orius is another aggressive predator that will feed on all mobile stages of thrips as well as loopers, aphids and whiteflies. However, they are expensive and will leave a greenhouse if conditions are not suitable to them.

Major inflows of thrips into a greenhouse occur when they are disturbed from their outside habitat. Communicate with local farmers to be aware of when they will harvest or mow alfalfa or other host plants. Unfortunately, this is usually done on a sunny day when the wind is blowing and the greenhouse vents are open. Reducing the vent opening gap and the duration of the time open, can significantly reduce the number of thrips that will move into a greenhouse.

The use of blue sticky cards will help track the arrival of thrips because only thrips prefer the color blue. The incorporation of vanilla to the traps will increase the trapping of the adults and this can serve as a limited control. Plants such a fennel will give the thrips a sweeter alternative than most greenhouse or landscape plants and will concentrate the beneficial Orius with the destructive trips. The fennel will also attract local Orius species to a specific site.