Insect Management for Organic Vegetable Gardens

There is a growing interest in organic vegetable production among home gardeners. Organic gardeners produce food without synthetic fertilizers and pesticides. This publication describes tactics and organic control recommendations for managing vegetable insect pests in Kansas.

Successful organic gardeners understand the following:

- Insect pests are a fact of life. Some insect damage may result in lower quality produce.
- They may experience lower yields because of insect damage.
- It is important to be able to identify which insects are pests and which are beneficial and to recognize developmental stages and understand the seasonal life of each pest.
- It takes time and effort to protect produce from pests without synthetic insecticides.

Integrated Pest Management (IPM) is an important component of organic vegetable production. IPM incorporates a number of strategies, including preplanting practices, to reduce pest populations and ensure a successful harvest.

Things to Consider

Insect Identification

When people find insects in their gardens, their automatic reaction is to kill them. Most insects are not pests, and some can be beneficial. It is important to distinguish between harmful and beneficial insects.

Gardeners should become familiar with pests associated with the vegetables they produce. This includes learning to recognize pest developmental stages and seasonal life cycles. It is equally as important to recognize common beneficial species that prey on pests. Gardening publications and Web sites provide photos and information for identification.

Scouting and Monitoring Activities

Gardeners often become aware of insect pests after they have caused noticeable, and sometimes irreversible, damage. Monitoring programs can detect insect pests early. Such a program might reveal foliar feeding or severed plants lying on the ground, which might indicate cutworms. Adult squash bugs would be a sign to look for eggs and monitor them for hatching. Delicate melon and cucumber seedlings should be inspected for striped cucumber beetles. Early insect pest detection allows gardeners to implement control measures before insect pests reach damaging levels.

Knowledge of when specific pests are active and good observation skills are important. For example, imported cabbageworm butterflies mean that cabbage and broccoli plants may soon be threatened by caterpillars. Squash vine borer moths are easily observed because of their buzzing, brilliant colors and wasp-like appearance.

Tools to help gardeners monitor insect populations include:

- Pheromone lures placed in sticky traps to detect moth species including true armyworm, black cutworm, cabbage looper, corn earworm, diamondback moth, squash vine borer and variegated cutworm.
- Yellow sticky cards to attract winged aphids, leafhoppers, thrips and whiteflies.
- Blacklight traps to collect a wide range of nighttime flying insects including garden pests.

Monitoring insects can be time consuming depending on inspection frequency, the number and types of vegetable crops and garden size. Several inspections per

Sticky card

week may be required to stay ahead of highly mobile pests that can move in overnight and cause extensive feeding damage. Small garden plots are easier to manage than large gardens. The number, size and variety of plants affect how long plant inspections will take.

Record keeping is important in a monitoring program. Records allow producers to understand insect population trends. Has the pest population increased, decreased or remained stable? Are beneficial insects present? If so, how many? Do they appear to be keeping pest populations under control? During winter, organic gardeners can study the previous season's insect activities and plan for the upcoming season.

Control Tactics

Many tactics can be used to control vegetable pests, but not all will be practical for every pest. To choose the best method, it is important to recognize insect pests and understand their life cycles.

Cultural controls

Cultural controls include preventative practices to minimize vegetable insect pests or make the environment less favorable for their survival, growth and reproduction. Cultural practices may only partially control insect pests. To be effective, they must be tailored to specific pests and performed before pests appear.

Site selection is an example of a cultural control. Establishing a garden where turf has been freshly broken increases risk of white grub and wireworm damage, especially to root crops. If possible, avoid planting gardens near field crops, uncultivated areas of native grass or naturally occurring vegetation. Pests that thrive in those areas, such as flea beetles, aphids and grasshoppers, can enter garden plots easily.

Changing garden sites can help deter certain pests. Some pests, such as spider mites, are incapable of traveling long distances and overwinter where they lived last growing season. Switching a garden site from one side of a property to the other protects plants from concentrated populations.

A similar separation might not protect against pests that can travel a short distance, such as squash bugs. In this instance, a new garden site that is miles from any squash bug overwintering site is more likely to protect growing pumpkins and squash. Squash bugs will eventually move to the new site and multiply until the garden must be relocated again.

Regardless of garden location, certain insect pests are constant threats. Highly mobile and strong-flying insects such as butterflies, moths, blister beetles and spotted cucumber beetles are unavoidable. Weak-flying insects, especially aphids, leafhoppers and thrips, are passively carried long distances by the wind.

Crop rotation is useful against some soil pests, especially fungal and bacterial plant pathogens and plant-parasitic nematodes. While crop rotation may be feasible against a few major insect pests on larger farms, this cultural control is less useful for home gardeners.

Proper sanitation can help control vegetable pests. Remove, discard or destroy unused squash and pumpkins, which are the sole food source for squash bug nymphs. This stops nymphs from becoming adults, and prevents adults from accumulating adequate food reserves for overwintering. Squash vine borer larvae can be killed by destroying crop residues where they overwinter. Eliminate soil surface debris, which provides hibernation sites for mites, flea beetles, cutworms, sowbugs and millipedes. Controlling weeds is important because pests feed on them before vegetable plants develop.

Tillage can reduce insect pest populations by crushing and destroying white grubs and cutworms, as well as overwintering pupae of squash vine borers, tomato hornworms and tobacco hornworms. Unearthed white grubs, cutworms and wireworms become more available to birds and vulnerable to harsh weather.

Crop selection is sometimes suggested as a cultural control. Gardeners should select crops that have minimal pest concerns. The drawback is that most vegetables favored by gardeners are preferred hosts of a variety of pests.

Planting date is a useful cultural control depending on the insect and the crop. Seeds sown into cool soils may be slow to germinate, which makes them susceptible to white grubs and wireworm damage. By delaying planting, soils will have the chance to warm, which promotes rapid seed germination and plant establishment.

Early planting may be effective if an insect pest has a predictable seasonal appearance. For instance, because corn earworms do not overwinter in Kansas, current-year infestations rely upon influxes of corn earworm moths from southern overwintering areas such as Texas and southern Oklahoma. Female corn earworm moths prefer fresh green silks for egg laying. Early planted sweet corn is more likely to escape corn earworm damage because that corn has completed silking before corn earworm moths arrive. On the other hand, corn sown earlier in the season is more susceptible to black cutworm damage because black cutworm moths migrate into Kansas as early as late March.

Resistant vegetable varieties sound appealing, but these resistances are not to insect pests. In fact, there are no vegetable cultivars with insect pest resistance for home gardens. An example of a vegetable that might be considered resistant is sweet corn. Reduced corn earworm infestations are associated with tight-husked sweet corn varieties with ear tips that do not protrude beyond the husks. This is more of a physical barrier than a true biological resistance mechanism. There are no squash or pumpkin varieties known to be immune to squash bug damage. Some varieties tolerate low squash bug populations but suffer severe damage when greater numbers of squash bugs are present.

Planting techniques are discussed in gardening books and magazines. While the theory behind these techniques may be presented, explanations are often-general, with few examples of successful implementation. For instance, intercopping is often suggested for confining an insect that prefers a specific host. In reality, this practice would do little to contain populations of general feeders with a wide host range.

Trapcropping is a similar technique that uses a pest's host preference to trap that pest so it can be destroyed. While it has proven successful in field crops, trapcropping is not feasible in smaller plots with a variety of vegetable crops.

Companion planting uses certain plant species to repel insects from neighboring plants. Various herbs and flowers are used as companion plants, but research on companion planting under controlled conditions is limited. Results have been inconsistent, and companion planting has not proven beneficial. In fact, crop yields have been reduced because of competition for water and nutrients between companion and vegetable plants.

Mechanical and physical controls

Mechanical and physical controls are direct or indirect measures that kill insect pests or disrupt their activities. Handpicking is a classic example of physical control. Feasibility depends on the number of plants. In small gardens, white grubs and wireworm larvae can be eliminated while preparing the ground in the spring. Cutworm larvae can be exposed by disturbing debris and soil next to freshly cut plants or by using a water drench containing a lemon-scented detergent to force larvae to the soil surface where they can be disposed of or crushed.

Colorado potato beetle adults can be collected as they appear and before they deposit eggs. After that gardeners should crush eggs or remove egg-laden leaves. If larvae have already emerged, handpick the pink larvae. Imported cabbageworms can be controlled by crushing eggs, handpicking larvae and crushing the chrysalis. Cabbage looper eggs can be crushed, the larvae picked and the pupae crushed in their silky cocoons. Handpick adult squash bugs as they appear and before they deposit eggs, or remove leaves with eggs once they have been deposited. Tomato and tobacco hornworm eggs can be eliminated by removing egg-laden leaves and handpicking larvae.

Traps are another option. Millipedes, sowbugs, slugs and squash bugs prefer dark, moist habitats. Try placing shingles, wooden boards and cardboard on the ground and destroying the pests that accumulate. Some people douse pests with scalding water. Slugs can be eliminated by spraying them with a vinegar solution or by luring and drowning them in beer-filled pans lowered to the soil line.

Barriers can deter or exclude certain pests. When transplanting broccoli, cabbages and tomatoes, wrap aluminum foil collars around individual stems to deter cutworms. Build barriers or cages to exclude flying insect pests. Place mesh netting over individual plants. More extensive cages can be constructed to protect and cover several plants. Floating row covers can be deployed over greater areas. It is essential that netting, cages and row covers be anchored to prevent insects from crawling underneath them. Exclusionary tactics do not keep out soil-inhabiting pests.

Some vegetable plants require bees for pollination, so barriers must be removed to allow access to flowers at the right time. While insect pests will also be able to enter, plants will be stronger and more tolerant because they were allowed to develop and establish without pests.

Soil solarization uses the sun's radiant energy to elevate soil temperature. By covering the soil with dark plastic, gardeners can control certain weeds and diseases, and nematodes to a lesser extent. Soil solarization is not practical against insect pests.

Water can reduce pest populations. A strong stream of water can flush aphids and mites off plants. Many aphids and mites will drown, and others will be covered with mud and driven away. Some survivors might move back onto plants. Because aphids and mites can multiply rapidly, additional water treatments may be required. The water stream must be forceful enough to dislodge aphids and mites, but not forceful enough to damage plants.

Biological controls

Biological control is the use of beneficial organisms to control arthropod pests. Naturally occurring beneficials can keep pests at tolerable levels. This delicate balance may not be appreciated until the indiscriminate use of a broad-spectrum insecticide has suppressed predators and parasites and allowed pest populations to reach outbreak proportions.

Three approaches to biological control are establishing new natural enemies, releasing predators and parasites to add to an existing population, and adopting practices that conserve and support existing populations of beneficial organisms. Importation and release of new natural enemies are under federal control. Home gardeners have more control over conservation and augmentation techniques.

Gardeners can preserve natural populations of predators and parasites by eliminating insecticides or using them carefully. While synthetic insecticides are not used in organic gardening, acceptable botanical insecticides (also broad spectrum) should be used sparingly to preserve beneficial organisms. Horticultural oils and horticultural soaps are less disruptive because, unlike botanicals, there are no residual effects after treatments have dried. Oils and soaps are only effective against soft-bodied insects or the soft-bodied stages of insects that become hard-bodied adults.

Supplementing natural populations of beneficials with insects from a commercial insectry may be useful. When properly timed, such inoculatative releases can be effective. If beneficials are released before hosts are present, however, they will leave to search for hosts.

Periodic releases of beneficial insects may be required to prevent pest populations from reaching damaging thresholds. So-called augmentative releases are intended to rapidly control pest populations that are near or at damaging levels. If releases occur after pest populations have exceeded economic thresholds, crop damage is likely.

Predators include a wide variety of arthropods such as insects, predatory mites and spiders, as well as more obscure organisms, including centipedes, scorpions and pseudoscorpions. For example, more than 600 predatory species were recorded in a cotton field and represented 45 families of insects and 23 families of spiders and mites. Eighteen species of insects (not including spiders and predatory mites) were found in potato plantings. Although some predator species have only a minor effect on pest populations, the cumulative effect of all species is considerable. This emphasizes the importance of conserving naturally occurring populations of beneficials.

Predator insects

Ladybird beetle adults (lady bugs) and larvae search for prey. Eggs and pupae are often seen but not recognized as ladybird beetles. (Figures 1-4)

Syrphid flies, commonly called flower or hover flies, resemble wasps because of their color and ability to hover. The larvae-like maggots search for prey (Figures 5-6).

A variety of ground beetles and their larvae are predators (Figures 7-8).

Green lacewings and brown lacewings are delicate insects. Their larvae use prominent mandibles to feed on prey (Figures 9-11).

Praying mantids are widely recognized predators. The mantid's passive nature, however, does not make it effective against most garden pests (Figure 12).

Damsel bugs (Figure 13), assassin bugs (Figure 14), minute pirate bugs (Figure 15) and some stink bugs (Figure 16) use their piercing-sucking mouthparts to kill prey.

Parasitic insects (sometimes referred to as parasitoids) live in or on a host for at least part of their lives, deriving nourishment from host tissues and eventually causing its death. Some parasites are capable of attacking more than one species, while others attack a single pest. Parasite and host interactions are complex because only a certain stage of the pest is parasitized.

Most parasites are small wasps. Despite the number of wasp species, they often go unnoticed because of their small size. Some wasps attack the caterpillar stage. The cocoons may be carried by the parasitized host (Figure 17) or may be found in clusters on the ground (Figure 18). If isolated, the small wasps will eventually emerge from the cocoons (Figure 19).

Some parasitic wasps attack aphids by stinging them when they insert an egg. As larvae develop, the hosts become mummified, losing their natural color and developing a paper-like texture (Figure 20). If closely observed, a small wasp will emerge from a circular opening (Figure 21).

Another group of wasps are egg parasites (Figure 22). Because these parasites attack an extremely small developmental stage, the parasite and eggs go unnoticed. Despite their small size, egg parasites can aid biological control.

Some flies are important parasites, especially tachinid flies. While these flies vary in appearance, many are red-headed and bristly with a black-and grey-striped thorax. Caterpillars are often seen with white eggs on their sides. After hatching, maggots bore into caterpillars to feed and develop. Some

Figures 1-12

Figure 1. Ladybird beetle

Figure 2. Ladybird beetle larvae

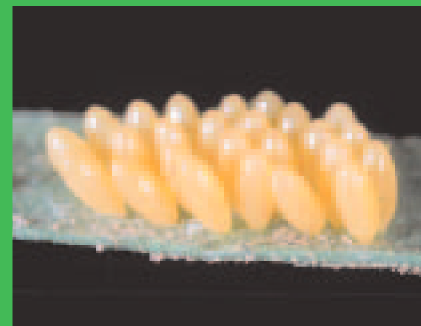

Figure 3. Ladybird beetle eggs

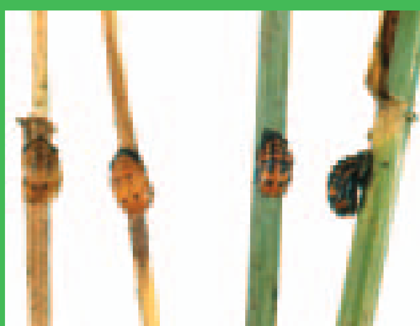

Figure 4. Ladybird beetle pupae

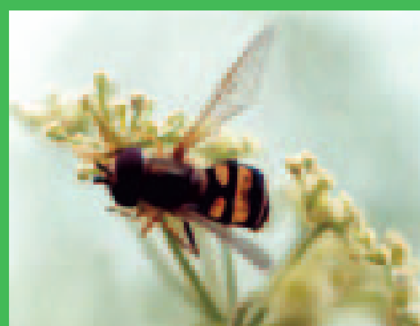

Figure 5. Syrphid fly

Figure 6. Syrphid fly larva

Figure 7. Ground beetle

Figure 8. Ground beetle larva

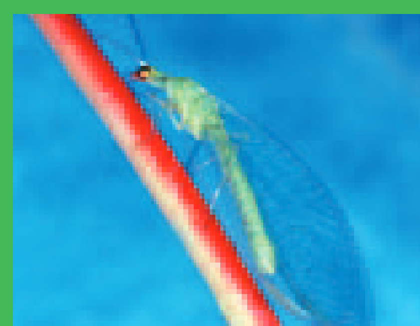

Figure 9. Green lacewing

Figure 10. Brown lacewing

Figure 11. Lacewing

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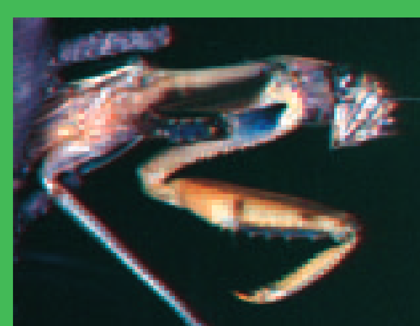

Figure 12. Mantid

Figures 13-24

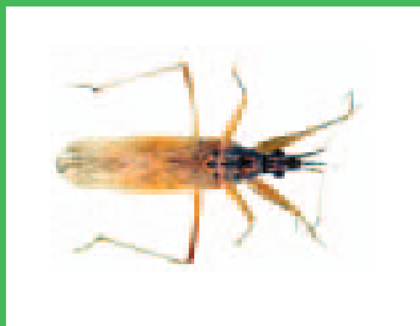

Figure 13. Damsel bug

Figure 14. Assassin bug

Figure 15. Minute pirate bug

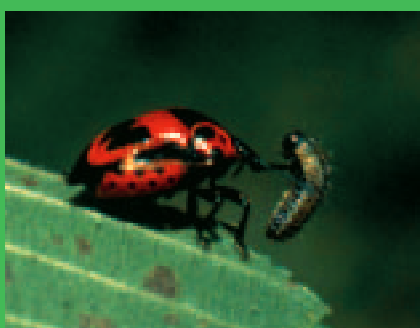

Figure 16. Stink bug

Figure 17. Cocoons attached to insect

Figure 18. Parasite cocoons

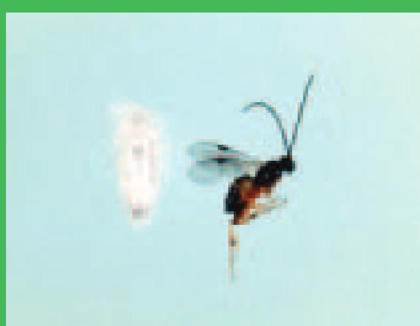

Figure 19. Parasitic wasp

Figure 20. Parasitized aphids

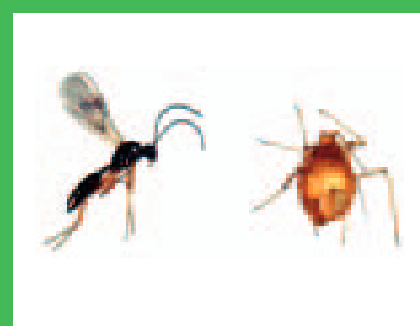

Figure 21. Aphid wasp

Figure 22. Egg parasites

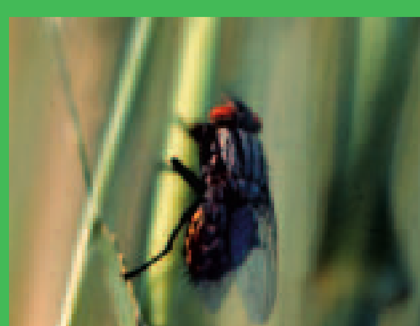

Figure 23. Tachinid fly

Figure 24. Tachinid eggs

species pupate inside the bodies of their host, while others pupate outside. After emergence the adults begin the process again (Figures 23-25).

Insecticidal controls

Despite various control methods, occasionally insecticides are needed to prevent an outbreak. Insecticides from natural sources may be used in organic gardening.

Microbial insecticides contain living organisms or the toxic substances they produce. A limitation of microbials is that they are specific to certain pests. They are also sensitive to the environment and break down quickly. This is an advantage because microbials are less hazardous to humans and the environment.

Bacillus thuringiensis (Bt) produce toxic protein crystals that cause the gut walls of susceptible insects to burst when ingested. Stomach contents spill into the insect's body cavity, resulting in death by septicemia (blood poisoning). Various Bt strains and substrains produce endotoxins specific to particular insect pests.

Spores of the fungus *Beauvaria bassiana* germinate and invade cuticular cells, resulting in rapid water and nutrient loss, which kills the insect.

Actinomycetes include *Saccharopolyspora spinosa,* which produce substances known as spinosyns. The active ingredient, spinosad, is a naturally occurring mixture of spinosyn A and spinosyn D. When insects ingest these substances, spinosads prevent acetylcholine from binding to appropriate receptor sites, causing paralysis and death.

The protozoa *Nosema locustae* can be useful against some grasshopper species. The inactive spore is incorporated into a bait. Once inside the grasshopper, activated protozoa consume fat reserves. The remaining reserves are insufficient to nourish grasshopper nymphs during molting periods, which prevents them from maturing and reproducing. Although *Nosema locustae* has been used successfully in rangeland grasshopper control programs, results might be disappointing in home gardens.

Although not unicellular organisms, nematodes are included with microbials because of their microscopic size. Infective-stage nematodes enter pests through natural body openings. Bacterial symbionts within nematodes are released into the infected pests, and they eventually die from septicemia.

Botanical insecticides are natural toxicants from plants. Pyrethrum is a mixture of four compounds from flowers of tropical chrysanthemum species. Pyrethrum kills on contact. It is commonly marketed as pyrethrin and may be combined with rotenone.

Rotenone is derived from root extracts of tropical plants. Working as a contact and stomach poison, rotenone kills sucking and chewing insects. Control may not be achieved with a single rotenone application because of its sensitivity to photodecomposition.

NEEM is a complex of oil extracts from seeds of the neem tree. One of the extracts, azadirachtin, acts as an insect growth regulator by inhibiting the metabolism of the ecdysome molting hormone. Some extracts such as lemonoid oils, which do not contain azadirachtin, act as repellents and antifeedants.

Horticultural oils are petroleum or plant-based hydrocarbon chains with insecticidal and miticidal properties. These oils cause suffocation or penetrate egg membranes and soft cuticular tissues coagulating the cytoplasm and resulting in water imbalances or enzymatic and hormonal irregularities. Horticultural oils are highly refined and can be used as dormant and in-season foliar treatments.

Insecticidal soaps are derived from the salts of fatty acids, which are the principal components of fats and oils in plants and animals. Soaps are strictly contact materials for use on soft-bodied insects and soft-bodied stages of insects that are hard-bodied as adults. Insecticidal soaps break down soft cuticular tissues. Soaps also destroy cell membranes and disrupt cellular metabolism.

Inorganic insecticides are elemental or carbon-free compounds. Sulfur dusts are effective against adult mites and also act as an ovicide. Silicon-based materials act as abrasives and desiccants. Water loss occurs through abraded cuticular coverings. Dusts also have adsorptive properties to hasten the drying and killing process. Products are marketed as diatomaceous earth. Iron phosphate is incorporated into a bait that is consumed by slugs and snails. Once ingested, the compound disrupts feeding and kills slugs in about a week.

Common Insect Pests in Kansas

Aphids

While several aphid species are associated with vegetables, green peach aphids are the most common (Figure 26). Aphids reproduce parthenogenically during the gardening season. An adult aphid may produce more than 100 offspring. Because newborn nymphs become reproducing adults in as little as a week, aphid populations rapidly escalate to overwhelming levels. Aphid infestations are caused by winged individuals entering gardens. Most people are familiar with their wingless progeny.

Mechanical and physical control

Keep winged aphids away by caging individual plants or covering and draping several plants with protective screening or cloth. A stream of water can be used to flush aphids off plants.

Insecticidal control

Microbial – *Beuvaria bassiana*
Botanical – rotenone, NEEM
Horticultural oil
Horticultural soap

Cabbageworms

Imported cabbageworm butterflies and cabbage looper moths are drawn to cole crops for laying eggs (Figures 27-28). As they grow, larvae consume greater amounts of foliage, depositing waste on the plant. Larvae-covered, contaminated produce is of inferior quality and difficult to sell (Figure 29).

Mechanical and physical control

Cage individual plants to prevent butterflies and moths from laying eggs. On uncaged plants, inspect undersides of leaves and destroy elongated yellow imported cabbageworm eggs and globular white cabbage looper eggs. Squash or handpick green fuzzy imported cabbageworm larvae and looper larvae. Destroy imported cabbageworm chrysali and cabbage looper cocoons (Figures 30-35).

Insecticidal control

Microbial – *Bacillus thuringiensis*, spinosid
Botanical – NEEM, pyrethrin, rotenone
Horticultural oil
Horticultural soap

Colorado potato beetle

Colorado potato beetles and their larvae cause extensive foliar feeding damage to potatoes. Although Colorado potato beetles produce two generations per year, only the first generation coincides with the main potato production period in Kansas.

Cultural control

Colorado potato beetles overwinter as adults under a protective cover. Take old potato vines and make piles in gardens. In the middle of the winter, remove plant material. The inactive beetles will be exposed to harsh winter conditions and die. Similar clean-up around garden sites will expose beetles beneath other debris.

Mechanical and physical control

Monitor plants and handpick beetles and larvae. Inspect undersides for eggs, and destroy eggs or remove egg-covered leaves (Figures 36-38).

Insecticidal control

Microbial – *Bacillus thuringiensis* (strains designated for beetle larvae), spinosid
Botanical – pyrethrin, rotenone
Horticultural oil (against larvae)
Horticultural soap (against larvae)

Corn earworm

Corn earworm moths migrate yearly into Kansas from overwintering sites in southern states. Moths are attracted to green corn silks where they deposit eggs. Two to three days later larvae emerge and move to the ear. Larvae grow into large worms (Figures 39-44).

Cultural control

Select tight-husked sweet corn varieties to deter corn earworm larvae or plant sweet corn as early as possible because corn earworm moths do not deposit eggs on browned silks. In early planted corn, the green silk stage is completed by the time the moths arrive.

Cucumber beetles

The spotted cucumber beetle and the striped cucumber beetle are foliar feeders. Spotted cucumber beetles have a wider host range than striped cucumber beetles, which are restricted to cucurbits and melons. Striped cucumber beetles are especially attracted to new plants, which they overwhelm and destroy. Overwintered, striped cucumber beetles transmit bacterial wilt disease, which can kill plants (Figures 45-46).

Cultural control

Increase seeding rates to allow for some plant mortality while maintaining sufficient numbers for an acceptable plant stand. Plantings can always be hand-thinned if cucumber beetles do not thin stands.

Mechanical and physical control

Use row covers to keep beetles away from susceptible seedlings. After plants are well established, remove row covers to allow pollinating insects access to flowers and blossoms.

Insecticidal control

Botanical – pyrethrin, rotenone

Cutworms

Various cutworm species are occasional garden pests (Figures 47 - 49). Cutworms develop on various plants or weeds in and around gardens. Large cutworms often wander and randomly attack plants and sever them at ground level (Figure 50).

Cultural control

Figures 25-36

Figure 25. Tachinid pupae and flies

Figure 26. Green peach aphids

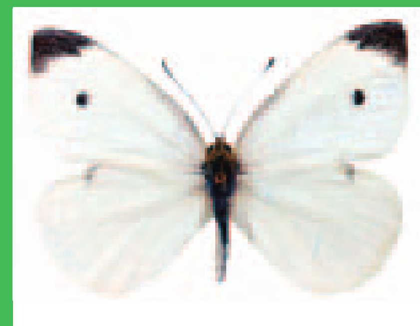

Figure 27. Imported cabbageworm moth

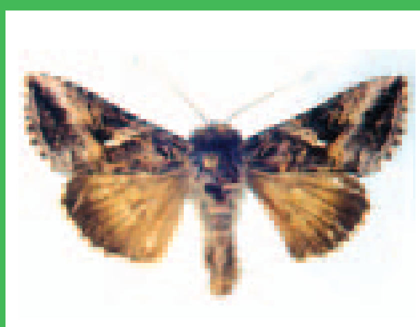

Figure 28. Cabbage looper moth

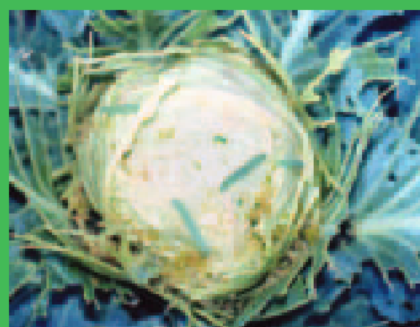

Figure 29. Contaminated cabbage

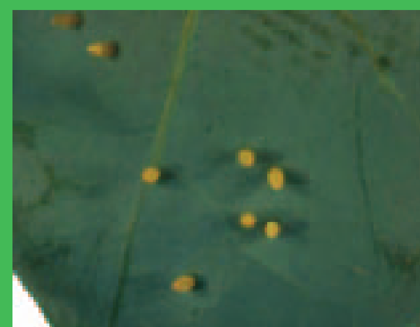

Figure 30. Cabbageworm eggs

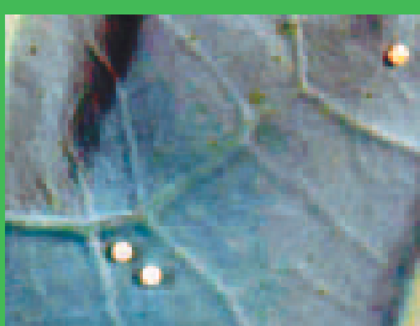

Figure 31. Cabbage looper eggs

Figure 32. Cabbageworm larvae

Figure 33. Cabbage looper larvae

Figure 34. Cabbageworm pupae

Figure 35. Cabbage looper pupae

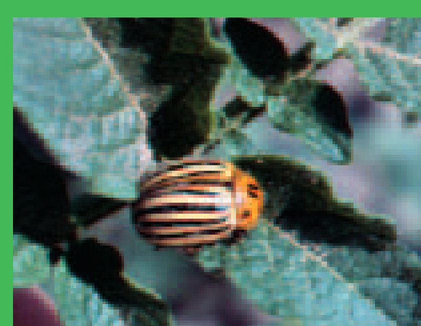

Figure 36. Colorado potato beetle

Figures 37-48


Figure 37. Colorado potato beetle eggs

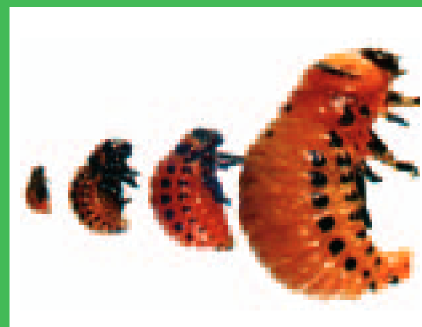
Figure 38. Colorado potato beetle larvae

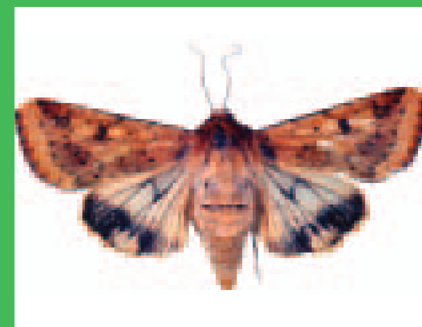
Figure 39. Corn earworm moth


Figure 40. Corn earwom silks


Figure 41. Corn earworm eggs


Figure 42. Corn earworm eggs

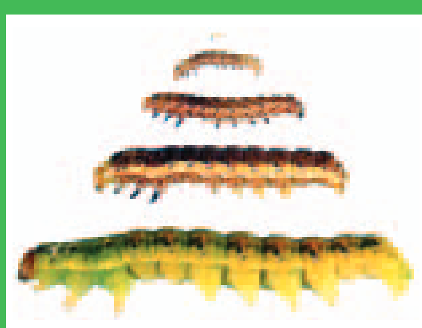
Figure 43. Corn earworm stages


Figure 44. Earworm infested corn


Figure 45. Spotted cucumber beetle


Figure 46. Striped cucumber beetle


Figure 47. Cutworms

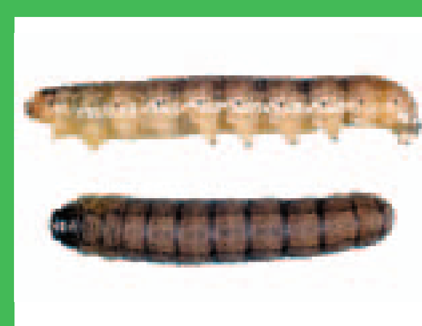
Figure 48. Cutworms

If possible, establish gardens away from areas with unmanaged plant growth. Cutworms developing in these areas can easily move into gardens. Garden sanitation is important, especially eliminating weeds that serve as an alternate food source.

Mechanical and physical control

When transplanting, wrap aluminum foil collars around the stems of individual plants. Expose cutworms by digging around the base of damaged plants or by dousing the surrounding soil with a flushing agent (i.e. 1 tablespoon of a lemon-scented dish detergent in a gallon of water). Five to 10 minutes later, check for cutworms brought to the surface. Place shingles or similar materials between plant rows. Inspect daily and remove or destroy cutworms.

Grasshoppers

While there are many species of grasshoppers, two are the most familiar to gardeners: differential grasshoppers and two-striped grasshoppers, both of which originate outside of garden areas. Eggs are deposited in undisturbed areas (hatching beds). Nymphs are confined to these areas when they develop in the spring. Later in the season, as highly mobile winged adults, grasshoppers seek additional food sources and move into lush gardens (Figures 51-52).

Cultural control

Establish gardens far away from grasshopper hatching areas.

Mechanical and physical control

Exclude grasshoppers by placing protective cages around individual plants.

Hornworms

Gardeners encounter two types of “big green worms” on tomato plants. While the green color varies, tobacco hornworms have seven oblique white stripes and a red horn (Figure 53, bottom), while tomato hornworms have eight chevron-shaped markings and a black horn (Figure 53, top). The parent moths of both species look similar and are referred to as hummingbird moths because of their large size, ability to hover and the unfurling of their long proboscis when feeding on floral nectars (Figure 54).

Cultural control

Till garden to unearth cocoons and destroy overwintering pupae (Figures 55-56).

Mechanical and physical control

Be alert for moth activity. Inspect undersides of leaves for eggs and remove leaves with eggs. Inspect plants for larvae. Because larvae blend in with foliage, they often go unnoticed until plants are defoliated. By that time, larvae are quite large and near the end of their feeding cycle. Larvae can be handpicked and eliminated (Figures 57-60).

Insecticidal control

Microbial – *Bacillus thuringiensis*, spinosid
Botanical – NEEM, rotenone

Spider mites

Spider mites overwinter as adult females. Females reproduce and deposit eggs on the undersides of leaves. Spider mites are difficult to see because of their small size. An individual spider mite is relatively harmless, but spider mites can multiply quickly, and the total effect of their feeding becomes evident.

Cultural control

Proper sanitation can reduce spider mite infestations. Eliminating trash and plant debris in and around gardens removes cold weather protection.

Mechanical and physical control

Use a stream of water to wash spider mites off plants.

Miticidal control

Botanical – rotenone, pyrethrin
Horticultural soap
Horticultural oil
Dusting sulfur

Squash bugs

Overwintered adult squash bugs become active at the same time squash and pumpkin plants begin vining. Initial squash bug activities often go unnoticed in dense foliage. Gardeners may only become aware of squash bugs later in the season after extensive damage.

Mechanical and physical control

Begin regular plant inspections immediately after plants emerge and continue to remove adult squash bugs (Figure 61). Inspect leaves for egg masses (Figure 62). Destroy eggs or remove egg-covered leaves. Place shingles or flat boards between plants and remove or destroy squash bugs daily.

Cultural control

Sanitation practices include destroying or removing vegetation and unused fruit that squash bugs feed on (Figures 63-64). Squash bug nymphs will eventually starve. Adult squash bugs will perish because they lack food reserves for overwintering.

Squash vine borer

Squash vine borer moths are easy to spot because they fly during daylight, are brilliantly colored, and make an audible buzzing noise (Figure 65). Moths primarily deposit eggs at the base of the main stem. Usually, squash vine borer larvae are detected after they are established. Wilted plants signal the need for a close inspection. The base of the stem may be covered with a frassy discharge (Figure 66). Splitting the stem often reveals a nearly full-grown larvae (Figure 67).

Cultural control

Dispose of infested plants. Till garden in the fall to destroy overwintering pupae.

Mechanical and physical control

Split the stem and remove borer larva. Bind stem back together and cover with dirt to stimulate advantageous root production. Use a syringe to inject beneficial nematodes into stems where borers feed.

Insecticidal control

Microbial – beneficial nematodes
Botanical – NEEM, pyrethrin, rotenone

White grubs and wireworms

These two pests are the immature stages of May beetles/June beetles and click beetles, respectively. Immature stages of both beetles have an extended feeding period of two to three years. They feed on the roots of grasses that attracted the beetles for egg laying. When gardens are planted in sites broken out of sod, white grubs and wireworms accept underground portions of vegetable plants as their new food source.

Cultural control

Do not establish a garden in ground freshly broken out of grass. Till garden to expose grubs and wireworms to the weather and predation by birds.

Mechanical and physical control

Tilling can physically destroy grubs. Wireworms and surviving grubs can be handpicked and removed or destroyed (Figures 68-69).

Figures 49-60

Figure 49. Cutworms

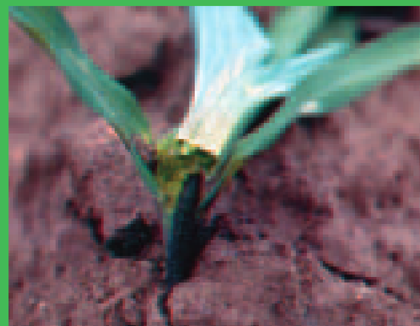

Figure 50. Severed plant with cutworm

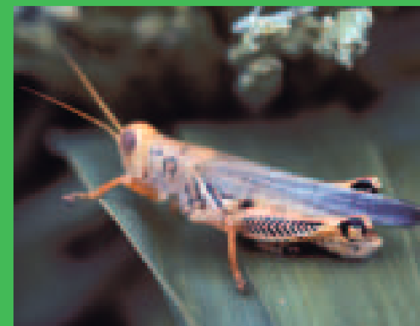

Figure 51. Differential grasshopper

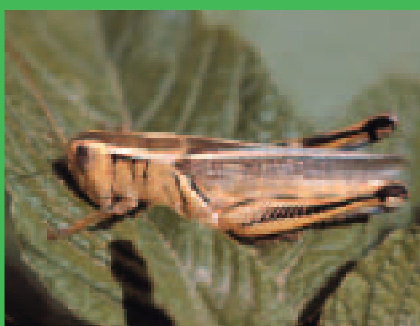

Figure 52. Two-striped grasshopper

Figure 53. Tobacco and tomato hornwoms

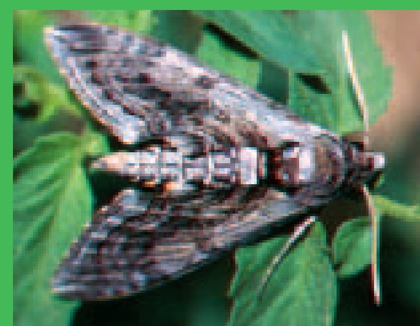

Figure 54. Hornworm moth

Figure 55. Hornworm cocoon

Figure 56. Hornworm pupa

Figure 57. Hornworm eggs

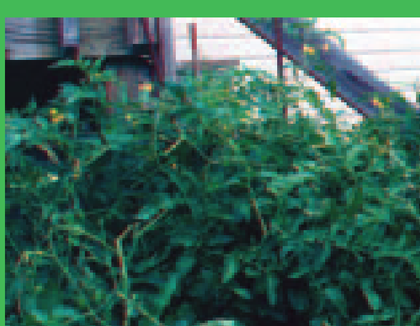

Figure 58. Hornworm infested plant

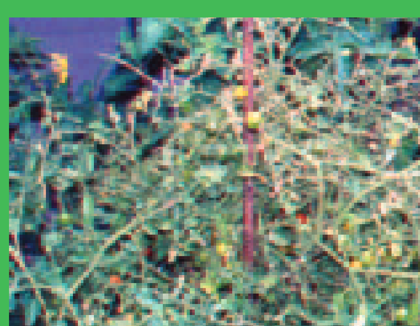

Figure 59. Hornworm infested plant

Figure 60. Hornworm larva

Figures 61-69

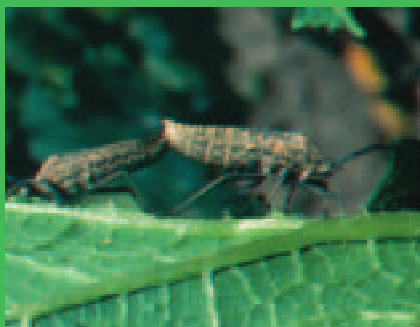
Figure 61. Squash bugs


Figure 62. Squash bug eggs

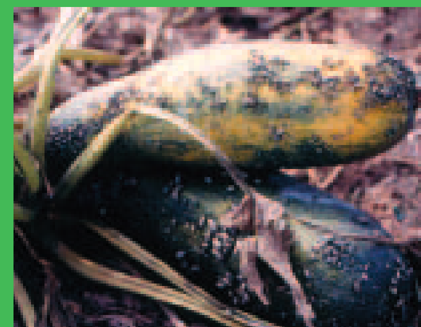
Figure 63. Squash bug infested zucchini

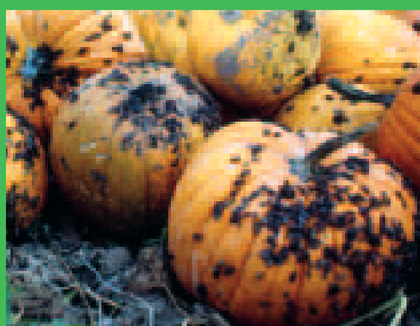
Figure 64. Squash bug infested pumpkins

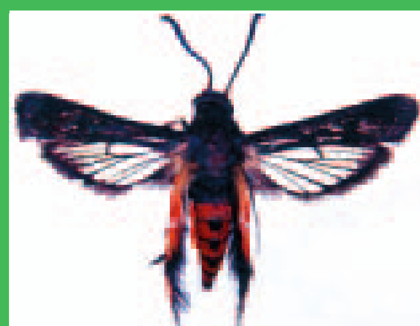
Figure 65. Squash vine borer

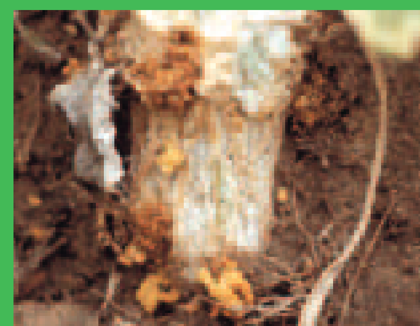
Figure 66. Squash vine borer discharge


Figure 67. Squash vine borer


Figure 68. Wireworms


Figure 69. Wireworm grubs

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