3. Insect Control

3.1 Soil Pests - Detection and Control

Cutworms

A number of cutworm species can damage vegetables. Cutworm larvae (caterpillars) chew leaves, sever stalks and stems, and also may chew tubers, roots, spears or fruit, rendering them unmarketable. Most cutworm larvae are night feeders and hide during the day, *e.g.*, under sod clumps, stones, or decaying vegetation. During periods of drought, low-lying areas in fields are more subject to cutworm damage than other areas, presumably because of more desirable conditions.

For cutworm adults (moths), Weedy or minimum-tillage fields are especially attractive overwintering and egg-laying sites for cutworm adults. Cutworm adults can also lay eggs on transplants in greenhouses that are lighted at night, as the moths are attracted to light. Eggs and larvae may be transferred with transplants to the field.

Control. Where cutworms are suspected, a broadcast spray of a pyrethroid insecticide on no-till crop residue or broadcast incorporation of an insecticide treatment into the soil may be necessary just before planting (see individual crops for labeled insecticides). For organic producers, Seduce bait (OMRI listed) is labeled for cutworm control. **Always consult the label for rates and restrictions.**

Even if a broadcast treatment is used, fields should be scouted for cutworm damage within a week of planting or plant emergence. If cutworms are actively cutting plants, a post planting contact treatment may be necessary. The following procedures may help improve control when a contact insecticide treatment is used:

1. Direct sprays at the base of the plants where cutworms are actively feeding.
2. Increase the amount of water used to at least 30 gal/A, especially in dry weather.
3. Spray between midnight and 5 a.m. when cutworms are most active.
4. Cultivate after insecticide application to improve contact with cutworms, especially in dry weather.

Garden Centipedes (Symphylans)

Garden centipedes are arthropods that are related to insects. They feed on germinating seed and fibrous roots of many crop and noncrop plants, including practically all vegetable species, and on decaying plant material. They are often associated with moist, fine textured heavier soils and typically establish in spots or field edges. Crops planted into those areas are often damaged, because the symphylans are continuously grazing on the fibrous roots. Spinach acts as very good host for this pest. Rotation does not appear to be an effective control.

Detection. The first symptom is an area or patch of poorly developing plants, similar to other root problems. Check the soil in these areas so that treatment can be made before planting the next crop, as there is no practical postplanting control. A common practice is to flag off the spot and treat that area with soil insecticides in the following fall or spring. Soil solarization has not been an effective control. Symphylans can probably be transported in soil on field equipment. Dig up the soil and look for small, slender (smaller than 0.25 inch) white centipede-like animals that move quickly and try to avoid light. Another sampling method is to drop soil into a bucket of water. Symphylans will float to the top. Symphylans have beaded antennae and 12 pairs of legs on 14 body segments. Do not confuse symphylans with true centipedes (that eat other arthropods and are considered beneficial). Centipedes are not white and have large mandibles. Note: Dry or cold (under 45°F/7°C) soil will reveal few, if any, symphylans.

When to treat. For spring soil samples, control is generally warranted if there are more than 2 symphylans per shovelful on average. For September or October soil samples, on average 4 or 5 per shovelful warrants treatment before the next crop. Insecticides are generally applied before spring planting, and fumigant treatments are usually made in the fall. Effectiveness of soil-applied insecticides decreases if soil temperatures are below 55°F (13°C).

Grubs

Grubs are the larvae of various beetles and can be soil pests in most vegetable crops. Serious problems have occurred in potatoes, sweet potatoes, beans, corn, spinach, and strawberries. Grubs feed on the roots and underground parts of the plant from one to several inches below the soil surface. The plants may yellow and wilt, which causes a patchy growth in fields where plants are dead or dying. If injured plants are pulled up, the roots will show feeding damage, and usually the curve-bodied grub can be found in the soil. Adult beetles lay eggs in the soil during the summer. As the soil cools in the fall, grubs move deeper into the soil and return to the surface the following spring. Depending on the insect, grubs may take 1-3 years to become adults and may cause problems year after year.

Grubs - continued on next page

Grubs - continued

Control. Grub damage is usually associated with grassy or weedy fields. Clean fields may help prevent serious grub damage. Problems may occur in crops planted to fields that were previously sod.

Maggots

Three species of maggots (seedcorn maggot, cabbage maggot, and onion maggot) attack either the seed or roots of vegetables during the growing season. The biology is similar for these species, although the crops they feed on are often different. The adult of the maggot (a fly) fluctuates in abundance in different areas in different years. Since it is impossible to determine when and where maggots will attack and since nothing can be done once the injury is noted, preventive controls are good insurance before planting if you have previously had maggot problems.

Seed Maggots: A seed attacked by seed maggots usually fails to sprout or, if it does, it is weak or sickly. Newly transplanted plants are also susceptible to maggots that tunnel up through the stem causing the plant to wilt. Injury is most severe in wet, cold springs and on land rich in organic matter.

Control. Control may be achieved using commercially applied seed treatments containing either chlorpyrifos (Lorsban 50W), clothianidin (Poncho 600), imidacloprid (Gaucho 600), or thiamethoxam (Cruiser 5FS, or Farmore DI-400). The level of control will depend on soil type, soil moisture, crop, weather conditions, and other factors. Refer to each specific crop section of this manual for listing of labeled seed treatments. **Do NOT use treated seed for food or feed**

Root Maggots: Plant roots become riddled with maggot tunnels, and underground fleshy parts soon become rotten. Above ground, plants appear off-color, wilt, and seldom reach full growth. Transplant water treatments, in-furrow treatments, preplant broadcast, and postplant treatments may be recommended depending on the crop. Refer to insecticide labels for labeled materials.

Nematodes

See section E 1.6.Nematode Control.

Slugs

Slugs are closely related to snails. All slugs require damp or humid surroundings for development and will avoid the drying effects of sun and wind. During the day, slugs seek shelter under protective debris. This is why weed control is a useful deterrent to any slug problem. Slugs are particularly problematic in no-till or minimal till farming systems.

Control. Metaldehyde (*e.g.*, Deadline M-Ps Mini-Pellets) is an effective slug-control chemical, and numerous commercial preparations are available at farm supply centers. Sluggo or similar slug bait products such as Iron Fist (containing iron phosphate - OMRI listed) are also labeled for slug control on a number of crops.

Read the label for crops and use rates, as not all products are labeled for all crops!

Wireworms

Wireworms are the larval stage of click beetles. Some species can remain in the soil as a larvae for multiple years. They injure vegetable crops by killing seeds or seedlings and tunneling and scarring tubers, roots, bulbs and low-growing vegetable fruit in contact with soil.

Detection. Injury to young plants or tubers frequently is sufficient evidence to warrant future control measures. Since there is no effective post-planting rescue treatment, the following methods are useful to detect the presence of wireworms before planting:

Method 1: A technique using baits has been developed for evaluating wireworm potential before planting. The bait stations should be established 2-3 weeks before the anticipated planting date. Fields where small grain or grasses have been grown the preceding 2 or 3 years are the best candidates for bait stations. Since wireworm infestations are often localized within a field, it will be necessary to place the bait stations randomly throughout the field. One bait station per acre is desirable. Place 2 bait stations at the highest elevation in a field, 2 on a slope, and 2 in the lowest area. Follow this procedure for baiting:

1. Mix 1 cup of untreated wheat or rolled oats and 1 cup of untreated shelled corn at each station
2. Bury the bait about 2" deep (if buried too deeply the grain will rot). Cover the ground over each bait station with an 18" square of black plastic. The plastic collects solar heat and speeds germination of the corn and wheat, enticing overwintering wireworms to respond.
3. Mark each station with a flag or stake.

4. Dig up the bait stations after 10-14 days and count the number of wireworms. For best results wait until the germinating grain has emerged before digging. Look for slender, reddish-brown insects that are ¼-1" long.

Method 2: Be sure the soil temperature at the 6-inch depth ranges between 45-85°F (7-29°C) and that soil moisture is equivalent to that desired for planting.

1. Collect soil samples from 20 scattered sites per acre. Each sample should be about 12" deep and 6" in diameter. Sample sites should be near plant crowns.
2. Sift soil and count wireworms.

Control. If you find an average of 1 wireworm per bait station (Method 1) or if you find 5 or more wireworms in 20 soil samples (Method 2), a labeled soil insecticide should be used. Wireworm infestations tend to concentrate in some locations. Hence several wireworms may be found in one bait station and none in others. It may be possible to limit treatment to areas of the field with the largest concentration. **See individual crops for labeled insecticides.**

When to apply. Insecticides can be applied either in the spring or fall when the soil temperature at the 6-inch depth is at least 50°F (10°C) and soil moisture is equivalent to that desired for planting. Frequently, the insecticide is applied immediately before planting. Consider fall treatment if an early spring planting is planned.

3.2. Insecticide Mode of Action: Reducing the Risk of Insecticide Resistance

Resistance to insecticides develops because intensive pesticide use kills the susceptible individuals in a population, leaving only the surviving resistant ones to reproduce. Adopting the practices outlined below will help reduce the development of pest resistance.

a. Crop rotation to a nonhost crop reduces the need for pesticide treatment and, thus, reduces the ratio of resistant to susceptible individuals in the breeding population.
b. Spot treatment is an important practice. Early season insects are often concentrated in areas near their overwintering sites. Spot treating these areas, rather than the entire field, will reduce the resistance problem at a reduced cost.
c. Control efforts should be concentrated on the early stages of development, which are often easier to kill.
d. Do not overspray. Attempts to destroy every pest in the field by multiple applications or by using rates higher than labeled rates often eliminate the susceptible but not the resistant pests. **The way pesticides are used affects the development of resistance.** Insecticides within a specific chemical group usually share a common target site within the pest, and thus share a common Mode of Action (MoA). Resistance often develops based on a genetic modification of this target site. When this happens, the compound usually loses its pesticidal activity. Because all insecticides within the chemical grouping share a common MoA, there is a high risk that this resistance will automatically confer cross-resistance to all the compounds in that group. The MoA classification provides a guide to the selection of insecticides for an insecticide resistance management strategy. The MoA classification was developed and is endorsed by the Insecticide Resistance Action Committee (IRAC) to insure growers can effectively alternate insecticides with different modes of action. More information can be found at: *http://www.irac-online.org/documents/moa-classification/?ext=pdf*. In Table E-6 below, insecticides are listed with their MoA classification (IRAC Group).

3.3 Insect Pest and Mite Control for Greenhouse Production

Adequate ventilation is critical for greenhouse pesticide use. Follow the re-entry intervals (REI) listed on the labels for worker safety. Always read and fully understand the label before applying any pesticide.

Applications of insecticides in **high tunnels** may be considered equivalent to a greenhouse, depending on the state's definition of "high tunnel". Check with your state's pesticide regulatory agency for an interpretation concerning use of pesticides in high tunnels.

Yellow and blue sticky traps are very effective in catching winged aphids, leafminers, thrips, whiteflies, fungus gnats and shore flies. Traps can be hung vertically just above the plant canopy as well as the growing medium surface or near doors and side vents, or other areas where insects may enter or exit the greenhouse. It is suggested that at least 1 trap be used per 1,000 sq ft.

See Table E-6. Insecticides and Miticides Labeled for Use on Greenhouse Vegetables on the following pages

Table E-6. Insecticides and Miticides Labeled for Use on Greenhouse Vegetables

Pesticides are listed in alphabetical order by Active Ingredient. The IRAC number refers to the Mode of Action, see section E 3.2. "Insecticide Mode of Action: Reducing the Risk of Insecticide Resistance"

IRAC Group	Active Ingredient Product Name(s)	Target Pests	Labeled Crops	PHI (d)	REI (h)	Comments
20B	**acequinocyl** Kanemite 15SC, Shuttle O	Two spotted spider mites	Fruiting vegetables, **except** cucurbits	1	12	Use at least 100-gal water/A 2 applications per year No surfactant or adjuvant use
4A	**acetamiprid** TriStar 30SG	Aphids, leafhoppers, mealybugs, caterpillars, plant bugs, whiteflies, fungus gnat larvae, thrips, beetles, leafminers	Leafy vegetables, fruiting vegetables, cole crops, cucurbits, onions and bulb vegetables	7	12	**For vegetables grown as transplants only.** Treat small area to test for phytotoxicity first.
18b	**azadirachtin** Azatin XL, Azatrol EC, Neemix, Ornazin, Azahar, Aza-Direct	Immature stages of whiteflies, aphids and other listed insects; fungus gnat larvae (as soil drench)	Most vegetables including fruiting vegetables and cucurbits, herbs, spices and others	0	4 or 12 Check label	Botanical insect growth regulator (some products OMRI listed). Can be applied via chemigation. Spray water pH should be between 5.5 and 6.5. REI 12 for Neemix and Ornazin
11	***Bacillus thuringiensis*** var ***aizawai*** XenTari, Agree	Armyworms, beet armyworm, cabbage looper, tomato fruitworm	Most vegetables including fruiting vegetables and cucurbits, herbs, spices and others	0	4	Lepidopteran larvae only - most effective against early instars.
11	***Bacillus thuringiensis*** var ***israelensis*** Gnatrol	Fungus gnats (larvae only)	All vegetables	0	4	Drench. Repeat applications may be needed.
11A	***Bacillus thuringiensis*** var ***kurstaki*** Dipel, Javelin, Deliver, Biobit	Armyworms, beet armyworm, cabbage looper, tomato fruitworm,	Most vegetables including fruiting vegetables and cucurbits, herbs, spices and others	0	4	Lepidopteran larvae only - most effective against early instars.
n/a	***Beauveria bassiana*** strain GHA Mycotrol O (OMRI listed) BotaniGard ES, BotaniGard WP	Aphids, thrips, whiteflies, certain other pests	All vegetables, herbs, spices and others	0	4	Slow acting, fungus infects insects. Repeat applications at 5-10-day intervals may be needed. Note storage and other restrictions. **Do not use BotaniGard ES on tomatoes**.
25	**bifenazate** Floramite SC	Spider mites, clover mites	Tomatoes	3	12	No more than 2 applications per crop per season for tomatoes that are greater than 1" in diameter at maturity. Maintain spray water pH 5.5-6.5. **Do not use an adjuvant**.
16	**buprofezin** Talus 40SC	Leafhoppers, mealybugs, whiteflies	Tomatoes	1	12	Insect growth regulator for immature stages only. Maximum 2 applications per season at least 5 d apart. Will reduce egg viability.
13	**chlorfenapyr** Pylon	Caterpillars, spider mites (*Tetranychus* spp.), broad mites, western flower and melon thrips	Tomato, tomatillo, ground cherry, peppers, eggplant, pepinos	0	12	**Do not** use on tomato varieties with mature fruit less than 1 inch in diameter. No more than 3 applications per crop.
28	**cyantraniliprole** Exirel	Thrips, Whitefly	Tomato, eggplant, peppers	1	12	For whitefly add effective adjuvant. Only suppresses thrips

Table E-6. - continued on next page

Table E-6. Insecticides and Miticides Labeled for Use on Greenhouse Vegetables - continued

IRAC Group	Active Ingredient Product Name(s)	Target Pests	Labeled Crops	PHI (d)	REI (h)	Comments
28 + 6	**cyantraniliprole + abamectin** Minecto Pro	Leafminer, Spider mites, Tomato russet mite, Tomato psyllid, Whitefly	Tomatoes	1	12	Tomatoes only. Foliar feeding thrips suppression only. Thorough coverage is essential to obtain best results.
17	**cyromazine** Citation	Leafminers, fungus gnats, shore flies	Only for vegetable transplant production grown for consumers	7	12	**Do not** apply within 7 d of shipping to market. No more than 6 applications per crop
4A	**dinotefuran** Safari 20 SG	Aphids, leafminers, mealybugs, whiteflies	Cucurbits, fruiting vegetables, head and stem brassicas, leafy vegetables	1 or 7	12	One application/crop. For vegetable transplants only. May be applied via a chemigation system. PHI 7 for leafy vegetables, PHI 1 for all other.
10B	**etoxazole** TetraSan 5WDG	Spider Mites	Tomatoes only	1	12	**Do not** make more than 2 applications per season. **Do not** use with an adjuvant.
21A	**fenpyroximate** Akari	Two spotted spider mites (suppresses whiteflies)	Cucumbers	7	12	One application per growing season. **Do not** use adjuvants.
29	**flonicamid** Beleaf 50 SG	aphids, plant bugs, GH whitefly	Cucumbers	0	12	Allow a minimum of 7-days between applications. Whitefly suppression only
4D	**flupyradifurone** Altus 1.67 SL	Aphids, whiteflies, chili thrips, squash bug, psyllids, leaf hoppers	Cucumbers, Lettuce, Tomatoes, Peppers, Many vegetable transplants	1-all but Pepper-3	4	**Do not make more than 1 (one) application to transplants per season**
10A	**hexythiazox** Onager miticide 1EC	Two spotted spider mites, European red mites	Tomatoes	1	12	**Do not** make more than 1 (one) application per year
4A	**imidacloprid** Marathon	Aphids, fungus gnat larvae, leafhoppers, whiteflies	Cole crops, collards, kale, kohlrabi, lettuce, mustard greens, pepper, tomato, eggplant.	-	12	**Use on vegetable plants intended for resale only**. May be applied via a chemigation system.
4A	**imidacloprid** Admire PRO	Aphids, whiteflies	Tomato and cucumber only in production greenhouses.	0	12	**Only** for plants growing in field soil, potting media or mixes. **Do not** apply to plants growing hydroponically or in rock wool, perlite or other soil-less mix. May be applied as drench or chemigation system. Label notes possible repellent effect on bumblebees and some beneficials (*Orius* sp.)
n/a	**iron phosphate** Sluggo-AG, Escar-Go	Slugs and snails	All vegetables	0	0	OMRI listed. Bait; scatter around plants or perimeter of plantings.
1B	**malathion** Gowan Malathion 8F	Japanese beetles, thrips, onion maggots	Succulent beans, cucumbers, eggplant, lettuce, green and bulb onions, sweet corn, tomatoes (crops vary depending on label)	1 to 7	12	See label for specific crops. May be applied through a chemigation system.
n/a	**paraffinic oils** Sunspray Ultra-fine SuffOil-X	Aphids, two spotted spider mites, leafminers, thrips, whitefly	Tomato, pepper, lettuce, cucurbits, radish, squash, herbs, spices	1	4	**Do not** exceed 4 applications a growing season. Allow 2 w between applications.

Table E-6. - continued on next page

Table E-6. Insecticides and Miticides Labeled for Use on Greenhouse Vegetables - continued

IRAC Group	Active Ingredient Product Name(s)	Target Pests	Labeled Crops	PHI (d)	REI (h)	Comments
n/a	**potassium salts of fatty acids** insecticidal soap M-Pede	Aphids; leafminer; spider, broad and russet mites; thrips; whiteflies; plant bugs; leafhopper; powdery mildew (cucumber only)	Many vegetables (see label for specifics), herbs, spices	0	12	Works well on whiteflies, mites and aphids if coverage is good but has no residual control. Note label cautions about application frequency, water quality and tank mixing. OMRI listed
3a	**pyrethrins** Pyrenone Crop Spray, Pyronyl Crop Spray, PyGanic, Pyrethrum PT	All	All vegetables, herbs, spices	0	12	Pyrenone and Pyronyl include PBO synergist; PyGanic is OMRI listed.
21	**pyridaben** Sanmite	Two spotted spider mite, whiteflies, leafhoppers, European red mite, some aphid species, broad mite	Tomatoes (PHI 2) and Cucumbers (PHI 1)	1 or 2	12	Only 2 applications per crop per year. Allow 30 days between sequential applications.
7c	**pyriproxyfen** Distance	Whiteflies, aphids, fungus gnats, shoreflies	Fruiting vegetables (except non-bell peppers)	1	12	Insect growth regulator. **Do not** use on tomato varieties with mature fruit less than 1 inch in diameter. Spray, sprench or drench.
n/a	**rosemary oil + peppermint oil** Ecotec	Aphids, beetles, mites, thrips, plant bugs, others	Many vegetables, herbs, spices	0	0	OMRI listed. Can be applied in drip for soil pests.
23	**spirotetramat** Kontos	Aphids, leafhoppers, mealybugs, psyllids, spider mites, spittlebugs, whiteflies	Vegetable transplants only (see label for list)	-	24	Apply as drench or via an irrigation system to plants in containers. Not for use in vegetable production.
4a	**thiamethoxam** Flagship 25WG	Whiteflies, leafhoppers, Colorado potato beetle, stinkbugs	Fruiting vegetables and cucurbits	-	12	**ONLY** use for vegetable transplants intended for resale

3.4 Insect Pest and Mite Control for Chemigation

Table E-7. Insecticides with Labels for Chemigation
Note: Read and understand all chemigation instructions on the label before use on any crop!

Drip/trickle Systems	
azadirachtin (Aza-Direct or OLF)	imidacloprid (Admire PRO or OLF)
chlorantraniliprole (Coragen)	malathion (Malathion 8 Aquamul)
clothianidin (Belay)	oxamyl (Vydate)
dimethoate (Dimate)	rosemary oil + peppermint oil (Ecotec)
diazinon (Diazinon)	thiamethoxam (Platinum)
dinotefuran (Venom)	thiamethoxam + chlorantraniliprole (Durivo)
Overhead and Sprinkler Systems	
acetamiprid (Assail 30SG)	imidacloprid + beta-cyfluthrin (Leverage 2.7)
azadirachtin (Aza-Direct or OLF)	indoxacarb (Avaunt, Avaunt eVo)
bacillus thuringiemsis (DiPel, XenTari)	lambda-cyhalothrin (Warrior II)
beta-cyfluthrin (Baythroid XL)	lambda-cyhalothrin + chlorantraniliprole (**potato only**) (Voliam Xpress)
bifenthrin (Capture or OLF)	lambda-cyhalothrin + thiamethoxam (Endigo ZC)
bifenthrin + imidacloprid (Brigadier)	malathion (Malathion 8 Aquamul)
carbaryl (Sevin or OLF)	methomyl (**green/bulb onions, potatoes only**) (Lannate LV)
chlorantraniliprole (Coragen)	novaluron (**potatoes only**) (Rimon)
chlorpyrifos (Lorsban)	permethrin (Pounce or OLF)
chlorpyrifos + gamma-cyhalothrin (Cobalt)	propargite (**sweet corn, potatoes only**) (Comite)
clothianidin (Belay)	pymetrozine (**potato only**) (Fulfill)
cryolite (Kryocide)	pyrethrins (PyGanic)
cyfluthrin (Renounce, Tombstone or OLF)	spinetoram (Radiant)
deltamethrin (Battalion)	spinosad (Entrust, SpinTor)
diazinon (Diazinon)	spinosad + gamma-cyhalothrin (**corn only**) (Consero)
dimethoate (Dimate or OLF)	spiromesifen (Oberon)
dinotefuran (Venom)	spirotetramat (Movento)
esfenvalerate (Asana)	thiamethoxam (Platinum, **potato only**) (Actara 25WDG)
flonicamid (Beleaf)	thiamethoxam + chlorantraniliprole (**potato only**) (Voliam Flexi)
gamma-cyhalothrin (Proaxis)	zeta-cypermethrin (Mustang Maxx)
imidacloprid (Admire PRO or OLF)	zeta-cypermethrin + bifenthrin (Hero)