IPM Plan

For

Chippewa Valley Produce LLC

Eau Claire, WI

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Introduction

The Fitzgerald Family Farm consists of 320 acres, 60 are tillable and the remaining 260 acres are woods. The soil is a sandy soil with most of the fields less than 5% slope. The fields are broken up into four fields two 20 acre fields, one five acre field, and a 15 acre field.

The best IPM plan starts with prevention. At the Chippewa Valley Produce LLC we use ground covers, host plants, deterrent plants such as garlic and onions, intense soil management, cover crops, and constant monitoring to prevent outbreak. The use of gloss ground cover can confuse insects with the redirection of light which confuses the insects and causes them to go to a less confusing plant. Ground cover also helps with the suppression of weeds. Host plants attract insects away from the agriculture crops, they allows us to identify the insects on the host plants before they spread to the agriculture crops. Deterrent plants such as garlic and onions aroma helps keep the insects away as the insects do not like the smell of garlic and onions. Intense soil management allows the plants to thrive as healthy plants building a natural defense system against insects. Healthy soil also allows beneficial nematodes the ability to thrive and minimize bad nematodes. Cover crops such as winter rye provide a natural herbicide that suppresses the ability for weeds to thrive, it also puts organic matter back into the soil and a ground cover in the late fall and early spring helping to prevent soil erosion. Monitoring for pests is one of the most preventable measures we practice; monitoring allows us to know which pests we have, the level of infestation, and what beneficial insects we should bring to suppress the pests identified.

On the Chippewa Valley Produce LLC our first approach is prevention and cultural control, followed by organic pesticide and herbicide use. As a last measure, to prevent total loss a nonorganic pesticide or herbicide may be used. In the result of a nonorganic pesticide and herbicide use the Chippewa Valley Produce LLC uses the least harsh chemicals with the lowest application rates available in order to help preserve the soil and environment for future generations.

Salad Mix

Insects

Aphids

Description

Aphids have an incomplete life cycle, meaning they start as eggs then turn to nymphs, which look like miniature adults, and finally grow large into adults. The female aphids are the only aphids that may grow wings. They only grow wings in two different circumstances. The first being the feeding area becomes over crowded the female aphids will grow wings and fly to a new feeding area. The second is if the feeding area becomes overcrowded, then the female aphids will grow wings to find a new place to feed and continue the life cycle. Aphids may over winter in the northern areas as eggs, but in a greenhouse setting they will continue to thrive as long as the temperatures are warm enough inside the greenhouse.

Monitoring Techniques

Aphids prefer the underside of lettuce leaves and also prefer certain types over others. You need to look at as many undersides of leaves as you can on a daily basis to keep the aphid levels to a minimum. Infestations are often localized because aphids don't fly until the feed source is limited or the leaves become over populated. Yellow stick traps DO NOT provide sufficient monitoring techniques because if aphids are found on them that generally means you have a large infestation somewhere that you have not checked yet.

Growing degree days for aphids are very broad because aphids overwinter as eggs. As soon as we hit 7 growing degree days aphids may start thawing the eggs to start hatching. Aphids can be present up to 2800 growing degree days as reproducing adults. Meaning that aphids can create a problem from the time the ground starts to fall until the ground starts to freeze outdoors. In a greenhouse setting growing degree days do not play any importance on aphids they will continue to thrive as long as they stay above freezing and then the eggs will over winter the frozen period hatching as soon as it gets warm.

Cultural Control of aphids

Sanitation is a major factor in a proper cultural control of aphids. The cleaner and free of weeds and area is the less likely aphids are to be present. Ground cover is a great way to keep weeds away from the growing areas or greenhouses. In greenhouses the ground cover should be put at least five feet out from all sides of the greenhouse to prevent weeds from growing next to them. Feeder crops such as cilantro and parsley are great ways to assist in the monitoring of aphids because aphids prefer the juice of cilantro and parsley over many other crops. The aphid infestations will generally start with them and move onto other crops.

Biological control of aphids

Biological control of aphids works great in small settings (less than 2400 sq. feet) such as single greenhouses and small fields. In large settings the cost of beneficial predators gets too high to be financially benefiting. Parasitic wasps such as *Aphelinus abdominails, Aphidius colemani,* and *Aphidius matricariae* are known to work against aphids in all stage of life (eggs, nymphs, and adults), which is important for complete control. Predators must be released into the fields or greenhouses over multiple weeks to be effective.

Chemical control of aphids

Insecticidal soap is the first method of chemical control that should be tried. Reasons are that insecticidal soaps are the most natural and environmentally friendly way to battle the aphids. Insecticidal soap must be reapplied to the infestations more than once repeating the spray every 5-7 days for a 2-3 week period depending on how bad the infestation is. Insecticidal soap must be applied directly to the aphids because it suffocates the aphids. Aphids breathe through their skin and insecticidal soap clogs the pores not allowing the aphids to breathe. Insecticidal soap is very cost effective compared to harsh chemicals that have may have longer reentry times. Insecticidal soaps have no reentry time allowing works to get back to work fast or not even miss a step.

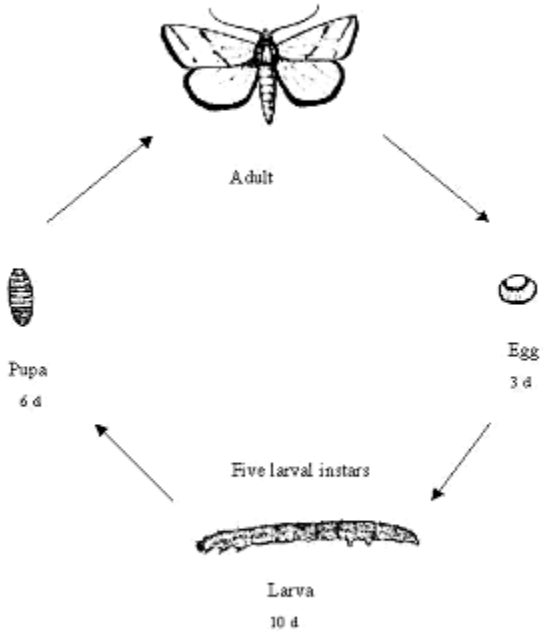
Pyrethrums are also a good method of chemical control because they are also environmentally friendly control methods. Pyrethrums are derived from chrysanthemum leaves and available in a aerosol can allowing for the workers to not have to spray just place the can in the infested area and walk away quickly. Pyrethrums generally have a 12 hour reentry period. Because pyrethrums are in an aerosol can they do not always get the undersides of the leaves. You want to apply the pyrethrum on several occasions over a 2-3 week period until the infestation is minimized

Cutworms

Description

Cutworms have a complete life cycle. There are many types of caterpillars that invade produce crops. Cutworms have a complete life cycle. Female nocturnal moths lay eggs on plants or surfaces, and then caterpillars hatch and feed on the underside of leaves for several days, often leaving the upper leaf surface intact. As the cutworms grow large they may start to feed on the tops of the leaves also. Cutworms generally feed at night or on cloudy days when the sun is not beating down on them. All caterpillars pupate on or

around the surface of the soil. Once the caterpillar is an adult they grow wings and turn into moths that usually fly at night and can lay several hundred eggs on plants and surfaces. Cutworms eggs will over winter outside and continue to thrive in greenhouse conditions.



Economic importance of cutworms on salad mix

The cutworm larvae feed on the leaves of lettuce and can destroy a crop in a relatively short period of time due to the number of eggs that are laid by the adult moths. The cutworms leave their droppings behind on the plants which are not acceptable to bring to market. Cutworms also once several weeks old will chew holes in the leaves which are also not acceptable to bring to market. Even a few small holes in a leaf make it not saleable and can create a huge problem very fast.

Monitoring

Moths are attracted to black lights and pheromone traps. Cutworms can be detected when fecal pellets are left behind near chewed produce plants are found. You can also check the undersides of leaves on plants you are transporting into the greenhouse or growing areas for clusters of eggs and if the eggs. Scouting should start in fields before 300 GDD with a base temp of 50 degrees.

Cultural Control

Screens on greenhouse will keep most moths out and removing the eggs from the undersides of leaves on plants you are introducing to the greenhouse or growing areas. Moths are also attracted to bug zappers that have black lights that will electrocute the moths before the infestation becomes a problem. You can also hand pick the cutworms off the plants in small settings; in large areas this is not economically feasible.

Biological Control

There are a lot of predators and parasites and only one bacterium that are useful on cutworms. *Trichogrammaia* a parasitic wasp that attacks the eggs of moths that hatches to cutworms. Green lacewings are voracious predators that will feed on moth eggs and small cutworms. Biological control works well in small growing areas or greenhouse under 2500 sq. ft. BT can provide good control of cutworms in greenhouse cutworm pests, but not persistent control under greenhouse conditions. BT does not does not disperse well enough and breaks down quickly in ultraviolet light. It must be applied when cutworm problems are present and in a manner similar to conventional pesticides. Sanitizing soil before using it can kill the cutworm eggs reducing the chance of an infestation.

Chemical Control

Spinosad is an insecticide derived from natural metabolites produced under fermentation conditions by *Saccharopolyspora spinosa.* It has a high level of contact and oral activity and a rapid speed of action. It also has a low to moderate impact on beneficial insects.

Slugs

Description

Slugs are not insects they are mollusks but can still be a very big pest to salad mix. Slugs range in size from ½ an inch to 4 inches in length and usually are grey or brown. The slugs leave a trail of mucous behind them as they travel. Slugs go through incomplete metamorphous. The adults have both male and female organs allowing them to reproduce asexually. First male then once older they obtain female organs. The adults can lay between 20-100 eggs and they can hatch in 10 days. Slugs mature in 3 months to a year. The eggs can stay in the soil for long periods of time and over winter in the soil.

Monitoring

Slime trails silvery in color are left behind from slugs and if seen. Shallow pans of beer can attract slugs and are also a good way to determine the size of infestation that one has. Also if there are holes in the salad mix but you do not see and fecal pellets from caterpillars there is a good chance you have slugs eating your plants. Using a flash light at night is a good way to see if slugs are active and moving around. Looking under bricks, wood, leaf piles, and other similar objects are good places to look for slugs during the day.

Slug eggs can hatch with as low as 40 degree temperatures much earlier than most growing degree day calculators have begun calculating the days. Once the night temps are 50 degrees the slugs will begin to reproduce and hatch in mass amounts.

Cultural control

Slugs want a moist, cool, and dark area to live so if you can alter one of these areas your slug problem will be minimized a very short period of time. By not letting the soil get to moist is the easiest way to scare slugs away, besides most plants do not like saturated soil. In the winter this is harder because the soil stays moist for a longer period of time in the greenhouse setting. Removing bricks, leaf piles, and wood are good ways to keep the slugs from having good places to hide during the day. If you do have bricks, leaf piles, and wood around and can't clean it up looking under them during the day is a good way to find quantities of slugs at one time. Once you see them you can simply just squash them to kill them.

Biological control of slugs

Beer is a great way to attract slugs and drown them to death. Garden slugs have lungs not gills like snails do so if they get smothered in water they cannot breathe and will suffocate to death. *Rumina decollate* are predators of slugs. They are predatory snails that live in the top inch of the soil. They predators will eat vegetation if slugs are not present so it is

important not to get too many otherwise you will have to battle those as well. *Euthycera cribata a*re the larvae of flies that feed in the insides of the slugs. The larvae will lie in wait for the slugs and once it sees one it will fly to the slug and burrow its way into the slug feeding on it until it is dead.

Chemical control of slugs

Metaldehyde and methiocarb are two pelleted brain baits available to combat against slugs. These baits must be replaced very frequently because they mold rapidly. Slugs have been known to build a resistance to metaldehyde so that should be used in alternation with methiocarb. If using metaldehyde or methiocarb chemicals and want to try a predatory slug you must use the biological control first because the predatory slugs will also fall for the pellets and die.

Diseases

Bottom rot

Description

Bottom rot is a fungus known as *Rhizoctonia solani* that affects many crops including salad mix. Bottom rot was first discovered in a Massachusetts greenhouse in 1900. It is prefers warm and wet environment and it is found in fields or greenhouses. Bottom rot starts as small spots on the outer leaves of the leaf that can grow and spread very fast.

Bottom rot starts as rust like color that may turn chocolate brown. They also may ooze a light brown or amber colored substance. Bottom rot will spread from the bottom leaves to the top leaves, turning the older leaves a slimy brown dead leaf. The stem will be the last part of the plant affected. Once bottom rot has been confirmed the problem will stay in the soil living of organic matter. Anywhere the soil or infested leaves are moved the disease will be present.

Monitoring

Bottom rot is very easy to see with the naked eye by looking at the older leaves and the soil under the leaves. Bottom rot is a rust or chocolate brown color that starts out small and can spread in a short period of time. Bottom rot also has an amber colored ooze that may leak from the infected leaves that can be noticed on the earliest infected leaves.

Cultural control of bottom rot

Not allowing water to build up and sanitation is a great way to keep bottom rot at bay. Good plant rotation is also a helpful way to reduce the likely hood of bottom rot by avoiding other susceptible crops in the areas that bottom rot was noticed last year. Or by using bottom rot resistant plants the following year where the disease was noticed the previous year.

Biological control

Mycostop is the only pathogen that has been able to reduce/minimize the bottom rot. Applying Mycostop will prevent the disease from spreading allow for the farmer to get a harvest from the crop.

Cultural control

Do not plant salad mix in fields that have had bottom rot confirmed in previous years is a great way to avoid the problem in the future. Another method is to use bottom rot resistant plant varieties where the bottom rot was noticed. Large amounts of organic matter will increase the chances of getting bottom rot, because bottom rot can thrive on organic matter if a better host is not available.

Chemical control

Quadris is a fungicide that has been proven to be effective in the control of bottom rot on salad mix. Quadris is a very expensive product to purchase it cost around $400/gallon. Once you spray the soil with Quadris you have to wait at least 36 days before planting an agricultural crop in that area. Quadris cannot be applied to harvestable crops. Quadris is a harsh chemical and should only be used if no other options are available.

Powdery Mildew

Description

Powdery mildew is a fungus that requires living plant tissue to survive. Powdery mildew can grow special resting spores to overwinter. Powdery mildew grows as thin layers of mycelium on the surface of the plant. Powdery mildew grows in chains with the spores on the infected plants. Wind, cutting tools, and physical contact can spread powdery mildew from one plant to the next. Powdery mildew starts as white powdery spots on the leaves of salad mix and can also be found on the stems. The spots will spread over a large area of the leaves and stems. The leaves will eventually turn yellow, die, and fall off the plant. Powdery mildew can shorten production time, reduce yields, and reduce the flavor of the crop.

Monitoring techniques

Powdery mildew can be noticed on plant leaves with the naked eye. Powdery mildew starts as small white spots and gradually increase in size until the whole plant is infested with powdery mildew. With a magnifying glass powdery mildew will be many spores connected in a chain unlike downy mildew that appears in clumps. Check the leaves of salad mix every few days during low light periods as that is when powdery mildew is most likely to break out.

Cultural control

Plant salad mix in sunny areas as often as you can. Provide good air circulation and avoid excess fertilizer. Overhead sprinkler system can help reduce the likelihood of an outbreak, because the spores are washed of the plants leaves as they begin to form.

Biological control

Serenade Wettable Powder Biofungicide is a biological control of powdery mildew, fire blight, sour rot, bacterial spot, and white mold on vegetable crops including salad mix. The active organism is *Bacillus subtills strain* QST 713. Serenade is listed on the OMRI list as an

organically approved Biofungicide for use in agricultural practices. You must apply the fungicide every 7-10 days until infestation is gone.

Chemical control

Milstop is very effective in the control of powdery mildew. Milstop is approved on the OMRI list for organic production and has no reentry time allowing for workers to continue working as the fungicide is being applied. Milstop is applied through a spray mixed with water and available at most agricultural supply stores. Milstop will need to be applied several times with 5-7 days between sprays. Milstop will also dry the leaves up on an infested plant if the infestations left to grow for too long of a period of time so timely spraying is a must.

Fusarium wilt

Description

Fusarium wilt of lettuce is caused by the fungus *Fusarium oxysporum.* Fusarium wilt is a rather new disease to lettuce. It was first identified in central California in 1990. The first year there were only 6 fields infected the second year there were 11 and the third year there were 17 fields infected with it. The disease spread very fast from field to field and will take out an entire crop because it is a soil born pathogen. Seedlings will either die right away or have red streaks though the cortex of the crown and upper root. Older plants will have brown streaks in the vascular system of the crown. Fusarium wilt grows between 46 and 89 f, and the optimum temperature being 82 f. Other Fusarium wilts from other crops are not susceptible to lettuce, only Fusarium wilt of lettuce. Romaine lettuces have the most tolerance built up for Fusarium wilt while iceberg is the most susceptible.

Cultural control

The only two methods of cultural control is to avoid planting in fields with a history of Fusarium wilt or fields adjacent to infected fields. The second was to solarize the soil for

15 days during the highest heat of the summer. This did not get rid of the disease but it reduced the rate to very low numbers.

Biological control

I have not found any resource for biological control. Fusarium wilt is a fairly new disease to lettuce and there has not been extensive research done yet.

Chemical control

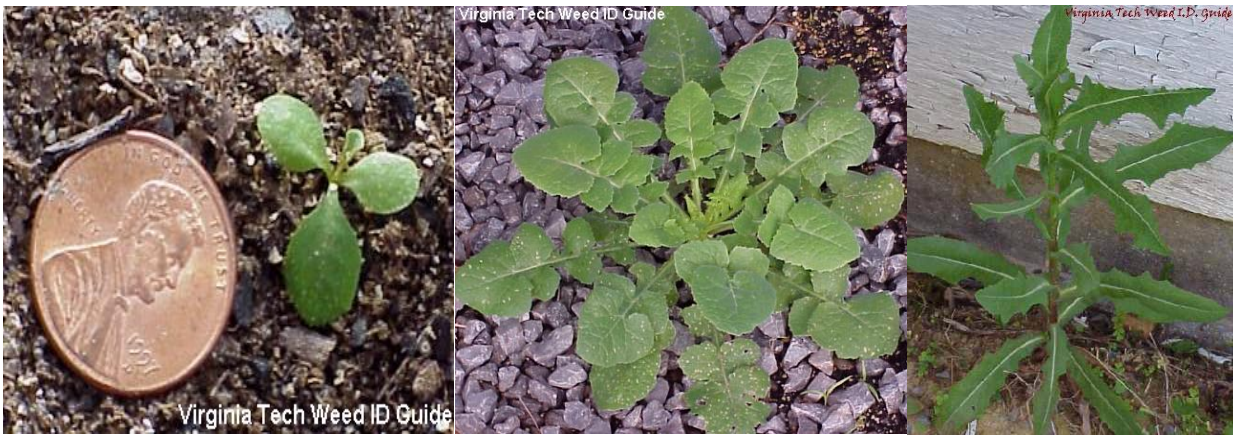
No chemicals have been found to control Fusarium wilt on lettuce yet. Some chemicals have been attempted but have had no success. Solarization of the soil is the only thing that has been found to reduce the Fusarium wilt break outs in lettuce.

Weeds

Prickly Lettuce

Description

Prickly lettuce is an annual or a biennial weed that has prickly leaves and emits a milky sap when cut. Prickly lettuce is found throughout the United States and is a common problem in nurseries, orchards, roadsides, and agricultural crops. Cotyledons are oval along with the young leaves. The young leaves have spines along the midvein of the lower leaf structure.



The leaves are arranged alternatively along the stem ranging from 2 to 14 inches long. All the leaves have prickles that occur along the leaf margins and along the midvein of the larger older leaves. The stems are hollow, light green to white and can reach 5 feet in height. The roots are a taproot and the fruit contain a single seed. Many flowers are produced on the upper part of the plant that are coned shaped and composed of 5 to 12

yellow toothed petals. Prickly lettuce was originally found in Eurasia and immigrated to North America around 1860.

Monitoring

You should begin monitoring for prickly lettuce early in the season as the plant begins to emerge. Prickly lettuce may be confused with dandelions at a young stage and will start emerging as soon as the ground has thawed and the nights are above 45 f. I could not find good information about growing degree days.

Cultural control

Seedlings and rosettes of prickly lettuce are easily controlled by cultivation. Mowing is ineffective. Rosette leaves lay close to the soil surface and mowing after stem elongation causes the plant to produce new flowering stems. Ground cover is also an effective way to keep the weed to a minimum.

Biological control

There has not been any proven biological control that is effective in the reduction or elimination of prickly lettuce.

Chemical control

Any broadleaf herbicide is effective against prickly lettuce for as many as five consecutive years. After that prickly lettuce will grow a tolerance to the herbicide. 2,4-d is an effective herbicide against prickly lettuce.

Burning nettles

Description

Burning nettles are also known as dwarf nettle or small nettle. They are native to Europe, are common in the United States in most of the states except the deserts. Burning nettles are a very problem weed in gardens, vegetable crops, sugar beets, citrus, and deciduous orchards. Burning nettles are a medium sized summer annual broadleaf common in gardens. The first cotyledons are bright green and notched at the tips. The first true leaves have serrated margins and are alternating on the stem. Mature plants can be from 5 inches to 2 feet tall. Burning nettle seeds germinate from late fall through early spring. Plants may produce seed within 5 weeks of germination.

Cultural control

Burning nettles can be controlled by removing the plants by hand. It is important to wear gloves while pulling out the burning nettles because they can create a burning sensation if touched for up to 12 hours. Mowing the burning nettles will cause the plant to not be able to develop fruit. Row covers can also help by not allowing the seeds to germinate in the low light conditions.

Biological control

Clove oil is an essential oil that functions as a contact herbicide and may provide an additional weed management tool for use on organic farms. Burning nettle, purslane, and rye responses to 5, 10, 20, 40, and 80% of reduced seed germination from clove oil.

Chemical control

Glyphosate is a systemic herbicide that will go into the vascular system of the weed and kill it from the inside. This is particularly effective on nettle due to its spreading roots. The poison will travel even out to the wide spread rooting system and kill those parts as well. Spray in June or just before the nettles flower. Clove oil is the preferred method over chemicals.

Crabgrass

Description

Crabgrass is a weed that almost everyone is familiar with. Crabgrass came from Eurasia and now widespread throughout the United States. Crabgrass is an annual so they

germinate, set seed, and then die. You can find crabgrass in lawns, ornamental landscapes, vineyards, gardens, and pretty much anywhere there is vegetation. Crabgrass is often confused with osegrass and the perennials dallisgrass, and bermudagrass.

Crabgrass is a low growing summer annual that can spread by seed or from rootings of the joints that lie on the soil. Seedling leaves are light green and the true leaves are dark green. Crabgrass will often grow in patches and the plants can grow together forming a clump. Crabgrass will begin to sprout when soil temperatures reach 50 to 55 f for at least 3 consecutive days.

Cultural control

Because crabgrass mainly reproduces by seed any attempt to remove crabgrass by hand will reduce the amount of seeds that will be allowed to germinate the following year. Ground covers are also a good cultural practice because the ground cover will not allow the crabgrass to germinate in the low light conditions.

Biological control

Crabgrass Killer available at planet natural is a new method of controlling crabgrass. Crabgrass Killer is made from cinnamon bark and should only is applied directly to the crabgrass. It will take 3-5 days to see the effects of Crabgrass Killer on the crabgrass. Crabgrass Killer works best when applied to wet crabgrass.

Chemical control

Avoid using chemical herbicides in vegetable gardens because of the variety of crops grown and planted there. But if it is an absolutely needed you can use a pre-emergent before the seeds germinate and before the salad mix seeds are planted. If the herbicide is a must you can use Simazine 4L Pre-Emergent Herbicide for Broadleaf and Grass Suppression in agricultural crops.

High Tunnel Tomatoes

Economic importance

High tunnel tomato production and local fresh tomato demand has been increasing for the past several years due to the demand for sustainable, tasteful, healthy, and extended shelf life tomatoes. High tunnel tomatoes extend the growing season 3-4 weeks early and late without the use of heat and 4-6 weeks with minimal heat. 1,896,490 metric tons of tomatoes were produced in 2003. The average American eats 22 pounds, about 11 pounds per year is consumed as tomato paste and ketchup.

Insects

Tomato Fruit Worm

Description

The tomato fruit worm (originally named *Heliotis armiger*) is also known as corn earworm, tobacco budworm, etc., depending on the kind of plane on which it is feeding.

Adults vary in colour, but are typically brown to greyish brown with a series of dark, irregular, transverse lines across the front wing. There is a darker area towards the tip with a paler band near the margin and dark spot almost at the centre. Hind wings are pale at the bases with the outer half of each much darker. Adult moths have a wingspan of about 35 mm. They are nocturnal in habit, flying, mating, and laying eggs at dusk.

The eggs are laid singly, under leaves, on buds, or on maize silks, etc. They are small, hemispherical, and creamy white.

The colour of larvae [caterpillars] can vary on a single food host from differing shades of green to pink, brown, or almost black. There is a double dark line down the middle of the back, and a broad pale stripe runs along each side of the body. There are five instars [larval stages], and fully grown larvae are about 35-40 mm long.

The pupae are dark brown. Pupation [change from a larva to a pupa] occurs in smooth-walled cells 70 mm or more underground.

Host Plants

The host range is very wide. Larvae feed mainly on flower buds, flowers, developing seed, and fruits; and sometimes on foliage. They are a major pest on maize, tomato, lucerne, lupins, and conifer (pine) seedlings. They also attack other cultivated plants including peas and beans, pumpkins and marrows, tobacco, clover, and linen flax, and a great number of ornamental herbaceous plants and shrubs.

Damage

Newly hatched larvae feed on surface tissues of the plant, but cause most damage by feeding on the buds and fruiting parts of the plants, and eating their way into flower buds, seed pods, and young fruits. On tomatoes, beans, etc., larvae bore completely into the fruit. on maize, after eating the silks, they feed on the soft seeds at the top of the cob. Foliage can be completely stripped from pine seedlings.

Monitoring

Monitor the pest by selecting a leaf from 30 random tomato plants. Choose leaves located below the highest open flower. Healthy eggs are white with a reddish ring. If more than five healthy eggs appear, begin treatments.

Control

Cultural Control

Discing after harvest destroys pupae in the soil. Rotations with crops that are not attacked

by hornworms will also help to keep population levels low in individual fields. Avoid planting tomato near corn or cotton to prevent heavy pest infestations.

Biological control

There are several important naturally occurring parasites that help control hornworms in tomatoes. Hornworm eggs are attacked by*Trichogramma* parasites and the larvae by*Hyposoter exiguae*. *Trichogramma* released for control of tomato fruitworm will also attack hornworm eggs.

Chemical control

This pest has developed resistance to many insecticides. Select an effective chemical. The following insecticides are often used for control: esfenvalerate (Asana), methomyl (Lannate), *Bacillus thuringiensis*, azinphosmethyl (Guthion), carbaryl (Sevin), and Pyrethrin/Rotenone.

White flies

DESCRIPTION

Several species of whiteflies may infest tomato. Proper identification of silver leaf whiteflies and greenhouse whiteflies is important because other whitefly species do not cause economic damage in tomato. Use a hand lens to examine both immature and adults. Whitefly adults are tiny (0.06 inch, 1.5 mm long), yellowish insects with white wings. Silver leaf whiteflies hold their wings somewhat vertically tilted or roof like, over the body; the wings do not meet over the back but have a small space separating them. Greenhouse whitefly adults are very similar in appearance to the silver leaf whitefly but hold their wings flatter over the back and there is no space between the wings where they meet in the center of the back. Banded winged whiteflies, *Trialeurodes abutilonia,* have brownish bands across their wings.

Whiteflies are found mostly on the undersides of leaves. They fly readily when plants are disturbed. The tiny, elongated eggs hatch into a first larval stage that has legs and antennae and is mobile. Both legs and antennae are lost after the first molt and subsequent stages

remain fixed to the leaf surface. The last nymphal stage, often called the pupa or the red-eye nymph, is the stage that is easiest to identify. Silver leaf whitefly pupae are oval, whitish, and soft. The edge of the pupa tapers down to the leaf surface and has few to no long waxy filaments around the edge. In contrast, greenhouse whitefly pupae have many long waxy filament around the edge and the edge is somewhat vertical where it contacts the leaf surface.

Currently silver leaf whitefly is only a problem of tomatoes grown in southern California and areas of the southern and central San Joaquin Valley. Greenhouse whiteflies are found in all but the lower desert growing areas.

DAMAGE

Both species of whitefly cause damage to leaves by feeding, which causes leaves to yellow and curl, and by the production of honeydew, which causes leaves to appear shiny or blackened (from sooty mold growing on the honeydew). Feeding by silver leaf whitefly is especially damaging because it also causes fruit to ripen unevenly.

In recent years, the greenhouse whitefly has been found to be the vector of tomato infectious chlorosis virus, a virus capable of causing heavy losses in the production of fresh-market and greenhouse tomatoes.

Bemisia species of whiteflies transmit Gemini viruses such as Tomato yellow leaf curl, which has recently been found in the Imperial Valley. The spread of this virus in the state is a major threat to tomato production. To prevent the spread of *Tomato yellow leaf curl virus* into other areas of California, do not bring transplants into California from out-of-state or move transplants or other *Bemisia*-infested hosts from an area that is known to be infested with the disease to uninfested areas.

MANAGEMENT

An integrated pest management program for whiteflies includes following good cultural practices, such as host-free periods, conserving natural enemies, routinely monitoring fields for trouble spots, and using pesticides only when necessary.

Biological Control

Several wasps, including species in the *Encarsia* and *Eretmocerus* genera, parasitize whiteflies. Whitefly nymphs are also preyed upon by big eyed bugs, lacewing larvae, and lady beetle larvae. Silver leaf whitefly is an introduced pest that has escaped its natural

enemies. Some indigenous native parasites and predators do attack it, but do not keep it below damaging numbers. The parasitic wasp, *Encarsia formosa,* has been used successfully to control greenhouse whitefly in greenhouses or protected crop situations elsewhere in the world where tomatoes are more commonly grown in this manner.

Cultural Control

The best control for whiteflies is to maximize the distance and time interval between host crops. When possible, plant tomatoes at least one-half mile upwind from key silver leaf whitefly hosts such as melons, cole crops, and cotton. Maintain good sanitation in areas of winter/spring host crops and weeds by destroying and removing all crop residues as soon as possible. Control weeds in non-crop areas including head rows and fallow fields and harvest alfalfa on as short a schedule as possible. In addition, allow the maximum time between silver leaf whitefly host crops and produce vegetables and melons in the shortest season possible.

Adult silver leaf whiteflies are repelled by silver- or aluminum-colored mulches. Place reflective polyethylene mulches on planting beds before seeding or transplanting to significantly reduce rate of colonization by whiteflies and delay the buildup of damaging numbers of whiteflies by 4 to 6 weeks. This delay in infestation can be especially important if virus transmission is a major concern. The mulches lose their effectiveness when more than 60% of the surface is covered by foliage. Therefore, they are effective only for the first few weeks after seedling emergence or transplanting of either spring or fall tomatoes.

Greenhouse whiteflies are often induced by applications of broad-spectrum pesticides. Avoid such materials early in the season.

Organically Acceptable Methods

Cultural and biological control as well as sprays of insecticidal soaps and oil plus azadirachtin are acceptable for use on organically certified produce.

Monitoring and Treatment Decisions

Routinely check field margins for whiteflies; these areas are usually infested first. Be especially alert for rapid population buildup when nearby host crops are in decline. During these critical periods, check fields twice weekly. Yellow sticky traps may be useful in detecting initial whitefly migrations into fields.

Allow beneficials an opportunity to control light whitefly infestations. If higher populations are present at the field margins than the field centers, then treat only the field margins. This approach will reduce treatment costs and help preserve beneficials in the field. The treatment threshold for silver leaf whitefly is about 4 adults per leaf in a random 30-leaf sample of healthy leaves. Thresholds have not yet been established for greenhouse whitefly.

Cutworms

Description

Cutworm larvae come in various colors and patterns, but always appear smooth skinned to the naked eye. Most species of cutworms reach 1 to 2 inches when fully grown. They usually curl up when disturbed. Cutworms are mainly active at night. During the day, cutworms hide in soil, under clods, or in debris at the base of plants.

Damage

Early in the season cutworms may cause stand loss by cutting off seedling or recently transplanted tomato plants at the soil line. Later in the season these pests can also injure tomatoes by eating irregular holes in the surface of fruits, and tomatoes on the ground are generally the most seriously injured.

Management

Destroy plant residues before planting, especially when tomatoes follow a good host crop (e.g., alfalfa or beans and cover crops that include legumes) for the cutworms. Host plant material may also be controlled with herbicides, but if pupae are overwintering, just getting rid of host plants may not help much. Monitor fruit in combination with the beet armyworms damage sample or take a separate sample of the fruit touching the ground to detect damage are important strategies in managing these pests.

Cultural Control
Cutworm incidence is often associated with residue of host plants remaining in the field before planting. As most cutworm species have a wide host range, tillage at least 2 weeks before planting will help destroy plant residue that could harbor larvae. Because cutworm damage is often localized within a field, reseeding affected areas of a field rather than treating the whole field might be more economical.

Organically Acceptable Methods
Cultural control is an organically acceptable management tool.

Monitoring and Treatment Decisions
Treat only when the presence of cutworms is detected. Cutworms are usually localized within a field, so consider marking the areas where damage is observed and treating only those areas.

Aphids

Description

The green peach aphid and several other species are most commonly found on tomatoes early in the season. The green peach aphid is slender, dark green to yellow, with indefinite darker stripes on the abdomen, and no waxy bloom. This aphid is primarily an early-season pest and may transmit virus diseases to tomatoes.

Damage

Green peach aphid infestations may result in wilting, but this damage is usually not of great concern unless the crop is water-stressed or temperatures are extremely high. Research indicates that early-season infestations may delay maturity but usually do not result in yield loss unless other factors are also present that enhance the injury. More importantly,

these aphids vector diseases such as alfalfa mosaicand tomato yellow top. Treatment may be warranted when nearby alfalfa fields are not certified as virus-free. Virus transmission has been observed when alfalfa is part of interplants of floral mixtures used to attract beneficials.

Management

Conserve natural enemies by avoiding early-season use of disruptive insecticides. If virus transmission is a major concern, it may be economical to reduce or delay the early-season influx and buildup of aphid populations with the use of reflective mulches in fresh market tomatoes. These aphids do not usually require treatment.

Biological Control

Many parasites and predators attack aphids. Among the more common predators are lady beetles and their larvae, lacewing larvae, and syrphid fly larvae. Populations of green peach aphids are reduced in winter by a parasitic fungus, *Entomophthora aphidis.* Many materials available for aphid control are highly disruptive of natural enemy populations. Make sure that insectary mixes that might be used do not contain alfalfa seed unless it is certified virus-free.

Cultural Control

Winged aphids are repelled by silver- or aluminum-colored mulches. If there is a probability of severe virus pressure, place reflective polyethylene mulches on planting beds before seeding or transplanting to significantly reduce rate of colonization by winged aphids and delay the buildup of damaging numbers of aphids by 4 to 6 weeks. While this approach is mainly effective in delaying or reducing the incidence of virus diseases transmitted by winged aphids and whiteflies, reflective mulches can also delay the buildup of wingless aphids that arise as a result of colonization by winged individuals. The mulches lose their effectiveness when more than 60% of the surface is covered by foliage. Therefore, they are effective only for the first few weeks after seedling emergence or transplanting of either spring or fall tomatoes.

Organically Acceptable Methods

Cultural and biological controls and sprays of insecticidal soap, pyrethrin, or thyme oil are acceptable for use on organically certified produce.

Monitoring and Treatment Decisions

Green peach aphids may move into early-season tomato seedlings but rarely require treatment. Early-season aphids have many natural enemies, including lady beetles, lacewings, syrphids, and parasites that frequently bring them under control later in the season. Sulfur materials do not control aphids and can cause phytotoxicity when applied to

tender plants or under hot temperatures.

The chemicals listed are in order of least impact on natural enemies and honey bess and usefulness in an IPM plan. Insecticidal soap is the first action but must contact for it to be effective. Can be used to reduce populations and applied frequently every 7-10 days. Pymetrozine is a spray but do not exceed 5.5 oz per acre and allow 7 days between applications. Acetamiprid is third and must allow 7 days between applications with a maximum of 4 applications per season. Fourth is Oxamyl but should not be applied when psyllids are present as Oxamyl tends to promote development of their populations. Fifth is Lambda-Cyhalothrin works as suppression only. Do not use if leaf miners are present because it is destructive to leaf miner parasites.

Tomato bug

Description

The tomato bug is a slender plant bug, about 0.25 inch long, with long legs and a light green body. Eggs are inserted into stems. Nymphs resemble adults but are smaller and lack wings.

Damage

The tomato bug is also known as the tomato suck bug because both nymphs and adults will insert their long mouthparts into the stem to feed. Rings develop around stems at these feeding sites. The rings are thickened corky areas that become yellow to reddish. The stem

is weakened and brittle at these rings and can easily break when touched, causing blossom drop, dropping of young fruit, and breakage of vine stems.

Tomato bugs are common in tomato fields throughout the Central Valley and in southern California, but they do not typically cause economic damage to bush-type processing or fresh market tomato plants where fruit are picked only once. They have been observed on occasion in great abundance on commercially grown pole tomatoes, in greenhouse culture, and in back yard gardens. Economic damage has been observed in pole and greenhouse plantings when blossoms drop and vines break at feeding sites when they are contacted by workers moving past the plants.

Management

Tomato bugs are usually first noticed in mid-summer, and their populations continue to grow into fall, when treatments may become necessary. In general, treatments are not recommended except when high densities occur in pole or greenhouse tomato plantings which are picked multiple times. Although no research has been conducted on control it is believed that most insecticides used to control lygus bugs or stink bugs will also control the tomato bug.

Tomato russet mites

Description

Russet mites are so small that a 14X hand lens is needed to see them. Because of their size, these mites are rarely noticed until plants are damaged. By this time, there may be hundreds of yellowish, conical-shaped mites on the green leaves immediately above the damaged bronzed leaves.

Damage

Russet mites remove cell contents from leaves, stems, and fruit cells. Usually starting near the ground, infestations of this mite progress up the plant and lower leaves dry out, giving the plant an unhealthy appearance. The color of the stems and leaves frequently becomes greasy bronze or russet colored. If not controlled, this pest can kill plants.

Management

Monitor and treat for these mites if damage is occurring.

Organically Acceptable Methods
Mined sulfur dust or sprays are acceptable on organically certified produce.

Monitoring and Treatment Decisions
Look for bronzing on lower leaves and stems, then check damaged leaves and the green leaves immediately above them for mites. Damage is typically first observed when green fruit reaches 1 inch (5 cm); rarely is it first observed after more than 25% of the fruit are ripe. Determine the extent of each infested area in the field by examining leaves and stems for bronzing, and mark the boundaries of the infested areas. Check these areas again in 2 or 3 days to see if they are increasing in size. Immediate treatment is necessary when damage symptoms begin to spread.

Chemical Control

The chemicals listed are in order of least impact on natural enemies and honey bees and usefulness in an IPM plan. Sulfur Dust is the first mode of action. Sulfur dust is listed as an organic use. Thorough coverage is required and ground application is preferred. Do not apply when temperatures are in excess of 90 F, a heavy fog is present, or dew. Also you should avoid drifting as much as possible. Abamectin is the second chemical which is also effective against leaf miners and tomato pinworm. Abamectin does not harm beneficial insects. Do not exceed 48 fl oz per acre per season.

Wireworms

Description

Wireworms are shiny, slender, cylindrical, hard-bodied, wirelike, yellow-to-brown larvae found at all times of the year and in almost any kind of soil; the larval (or wireworm) stage of this beetle may last several years. Adults of these larvae are known as click beetles.

Damage

Wireworm larvae injure crops by devouring seeds in the soil, thus preventing seedlings from emerging; by cutting off small, underground stems and roots; and by boring in larger stems and roots.

Management

The presence of wireworm larvae can be monitored by burying carrot pieces partially into the soil at seeding to attract the wireworms

Chemical Control

The only useful chemical control for wireworms is Imidacloprid which is a neonicotinoid insecticide. Imidacloprid is a spray but may also be used as a soil application through irrigation. Apply immediately after transplanting for soil application. Repeat of any neonicotinoid insecticide can create a resistant to all neonicotinoid insecticides.

Diseases

Alternaria stem cancer

Symptons

Symptoms of Alternaria stem canker appear on stems, leaves, and fruit. Dark brown to black cankers with concentric zonation occur on stems near the soil line or aboveground. Cankers enlarge, girdle the stem before harvest, and kill the plants. Vascular tissue about 2 inches above and below the cankers exhibit brown streaks. Dark brown to black areas of dead tissue between leaf veins are caused by a toxin produced by the fungus. Dark brown sunken lesions with characteristicconcentric rings develop on green fruit either on plants or during transit.

Comments on the Disease

Alternaria stem canker is primarily a problem of coastal-grown tomatoes in California although the disease occurs occasionally in other areas of the state in fields planted with infested transplants. The fungus survives on infected tomato debris. Infection occurs when airborne spores land on tomato plants or when plants come in contact with infested soil. Free water is necessary for spore germination and infection. Disease spread is favored by rains, dew, and overhead irrigation. Symptoms develop 7 to 10 days after inoculation and develop most rapidly at temperatures of around 77°F (25°C).

Management

Many tomato cultivars with high levels of resistance to Alternaria stem canker are available.

Bacterial Cancer

Symptons

There are usually no symptoms of bacterial canker on seedlings; however, on young plants symptoms consist of poor growth and temporary wilting of branches. Lower leaves yellow and shrivel, but symptoms may not show until flowering. On mature plants there are two kinds of symptoms, those resulting from systemic infections (i.e., the bacteria enter the vasculature and invade much of the plant) and those resulting from secondary infections (i.e., the bacteria cause local infections of leaves, stem, and fruit).

In systemic infections of mature plants, leaflets of the oldest leaves curl, yellow, wilt, and finally turn brown and collapse (known as firing). Sometimes, one side of a leaf is affected. Plants grow poorly and wilt. Pith of stems becomes yellow and later reddish brown, especially at the nodes, and has a mealy appearance. The pith may later become somewhat hollow. In advanced infections, cankers may or may not form at the nodes. Light and later dark streaks may develop on stems. Branches break off easily. Plants may die.

In secondary infections, infection of the margins of leaves is common. Lesions are dark brown to almost black. Round to irregular spotting of leaves also occurs. Fruit may be spotted, especially near calyx.

On fruit bacterial canker symptoms appear as yellow to brown spots, slightly raised, surrounded by a persistent white halo ("bird's eye spot"). Spots are usually about 0.125 inch (3 mm) in diameter. Vascular tissue under the calyx scar and leading to seeds that may be brown.

Comments on the Disease

In California, the source of the pathogen is probably seed and transplants, although local contamination within greenhouses is a potential source. In California, the pathogen only overwinters in the soil when the previous crop residue is not thoroughly incorporated and does not decompose. In colder climates, the bacterium may overwinter on undecomposed plant residue.

Tomato is the most important host of the pathogen. Several nightshades, including perennial nightshade *(Solanum douglasii)*, black nightshade *(S. nigrum)*, and *S. triflorum,* are naturally infected. Pepper and eggplant can be successfully artificially inoculated, but they are probably not important in the epidemiology of the disease on tomato. It is not known how long the bacterium can persist on nightshade.

In California, economic losses in direct-seeded fields are probably very uncommon. During unusually wet weather, however, secondary spread from frequent vine-training, cultivation, or other operations may cause extensive leaf loss. Canker probably occurs at a low incidence in many direct-seeded fields but almost always goes unnoticed.

Seed contamination with only a few bacterial cells, apparently below the level of detection, can result in relatively high numbers of infected transplants. For that reason, certified seed reduces the chances of infections, but is no guarantee of contaminated-free seed. A seedlot contaminated with very few infested seeds can cause serious problems in a greenhouse.

When the seed germinates, the bacteria enter the seedling through small wounds in the cotyledon, probably through broken trichomes. The bacteria move systemically through the xylem from which it invades the phloem, pith, and cortex. In a highly conducive environment, like a greenhouse, bacteria on the surface of infected plants are then splashed to surrounding plants during overhead irrigation. This kind of spread accounts for the occurrence of groups of plants or trays in the greenhouse and subsequent rows of infected transplants in the field. During planting, which invariably causes wounds, transplants may also be infected after an infected plant is handled, especially if the plants are wet.

Secondary spread occurs in splashing water, on contaminated equipment, during clipping, cultivation, or vine training operations, and other activities. In the field, such spread usually only results in local infections, i.e., leaf, stem, and fruit spots. In the greenhouse, these sources can lead to local and systemic infections.

Management

In the field, the pathogen will survive indefinitely in tomato tissue. Once that tissue has decomposed in the ground, however, the bacteria will die because they are not soil inhibitors. Thus, it is very important to turn under infected plant residue at the end of the season. Once that residue decomposes, the bacteria will die and the field does not pose a problem for subsequently plantings. It is prudent, however, to rotate to another crop for at least one season to assure that the tomato residue is completely gone.

In research trials, bacteria have survived as long as 10 months on contaminated wooden stakes. Hence, in the greenhouse it may be extremely important to disinfest the surface of benches and equipment to prevent spread to subsequent trays of transplants. In fields of more mature plants, disinfesting equipment is not as critical because any spread to other plants would probably result in local, and not systemic, infections. It is cautious, however, to wash equipment that has been through a heavily infested field. Surface disinfectants include bleach solutions (0.5 to 1% calcium hypochlorite) and Physan, among other products.

Planting clean transplants is the most important control measure. Vigilantly monitor seed fields and implement strict quality control measures. Assay seed should for detectable levels of contamination and discard lots if the bacterium is found. It may be prudent to soak all seed for 30 minutes in a dilute solution of hydrochloric acid (the final concentration of hydrochloric acid should be 1.1% with a pH of 0.9). Alternatively, seed could be soaked in 130°F water for 25 minutes. In the greenhouse, potting mix and flats should be steamed or washed with a 1% solution of calcium hypochlorite. Empty greenhouses between crops of transplants to allow time to disinfest benches, irrigation hoses, etc. Overhead water pressure should be low to prevent wounding. Copper applications may be necessary to reduce the efficient, yet unnoticeable spread between plants.

In the field, special measures may have to be taken once canker has been identified. Do not work fields when the foliage is wet. Frequent field operations at the wrong time can result in spread of the disease throughout the entire field. Unless the number of infected plants is small, it may do more harm than good to try to remove the symptomatic plants. Copper applications offer limited benefits because systemic infections cannot be affected and localized infections (the most probable scenario if other precautions are taken) pose a small economic threat. During wet weather, however, bactericides may be justified. At the season's end, incorporate all plant tissue. Tissue that remains on the surface and doesn't decompose is a real risk to subsequent tomato crops. Once the tomato residue decomposes, however, canker is no longer a threat. To be absolutely certain that the bacterium has been eliminated from the field, rotate out of tomatoes for at least one year.

Bacterial spec

Symptons

Bacterial speck appears as dark brown to black lesions of various sizes and shapes on leaves, fruit, and stems. Tissue adjacent to the lesions is initially yellow. Leaf lesions are frequently concentrated near margins, causing extensive marginal necrosis (tissue death). Lesions on immature fruit are slightly raised and small, varying in size from tiny flecks to 0.125 inch (3 mm) in diameter and cause raised black spots on mature fruit. Fruit lesions are superficial, seldom penetrating more than a few cells deep.

Comments on the Disease

The bacteria survive in soil, in debris from diseased plants, and on seeds. Infection is favored by cool, moist weather. The pathogen is spread by splashing rain or sprinkler irrigation. Disease progress is stopped during hot weather. In severe cases, infected plants are stunted, which may result in a delay in fruit maturity and yield reduction.

Management

Cultural controls and copper spray generally provide adequate control of bacterial speck in early planting.

Cultural Control

Delay planting in spring to avoid exposing tomatoes to cool, wet conditions that favor disease development. When the disease appears, change from overhead to furrow irrigation. Do not plant tomatoes in a field previously planted to tomatoes that developed the disease; instead rotate with a non-host crop such as small grains or corn.

There are two races in California: Race 0 and Race 1. Many varieties are resistant against Race 0 but none currently possess resistance against Race 1 and the occurrence of this race is increasing throughout the state.

Organically Acceptable Methods

Cultural control is acceptable for use on organically certified produce.

Monitoring and Treatment Decisions
Copper-containing bactericides provide partial disease control. Timing is critical. Apply before rainfall and repeat at 10- to 14-day intervals when cool and moist conditions prevail. Copper is strictly a protectant and must be applied before an infection period occurs. One or two treatments are usually enough to protect tomatoes during the most susceptible stages of growth. Spraying can stop when temperatures move into the 90° F range.

Chemical Control

Copper hydroxide is the first chemical that should be used the addition of mancozeb increases the efficacy of copper. Check with your processor concerning allowed materials and rates. Be sure to follow label directions on all products when making a tank mix; the most restrictive label precautions and limitations must be followed.

Bacterial Spot

Symptons

Bacterial spot develops on seedlings and mature plants. On seedlings, infections may cause severe defoliation. On older plants, infections occur primarily on older leaves and appear as water-soaked areas. Leaf spots turn from yellow or light green to black or dark brown. Older spots are black, slightly raised, superficial and measure up to 0.3 inch (7.5 mm) in diameter. Larger leaf blotches may also occur, especially on the margins of leaves. Symptoms on immature fruit are at first slightly sunken and surrounded by a water-soaked halo, which soon disappears. Fruit spots enlarge, turn brown, and become scabby.

Ccommetns on the Disease

The bacterial spot bacterium persists from one season to the next in crop debris, on volunteer tomatoes, and on weed hosts such as nightshade and ground cherry. The bacterium is seed borne and can occur within the seed and on the seed surface. The pathogen is spread with the seed or on transplants. Secondary spread within a field occurs by splashing water from sprinkler irrigation or rain. Infection is favored by high relative humidity and free moisture on the plant. Symptoms develop rapidly at temperatures of

68°F (20°C) and above. Night temperatures of 61°F (16°C) or below suppress disease development regardless of day temperatures. Some pathogen strains are virulent on either tomato or pepper and some may be virulent on both.

Management

Cultural practices and preventive sprays of copper help to manage bacterial spot.

Cultural Control

Bacterial spot occurs commonly in tomatoes throughout California. Using pathogen-free seed and disease-free transplants, when possible, is the best way to avoid bacterial spot on tomato. Avoiding sprinkler irrigation and cull piles near greenhouse or field operations, and rotating with a non-host crop also helps control the disease.

Organically Acceptable Methods

Cultural controls are acceptable for use on organically certified produce.

Monitoring and Treatment Decisions

Copper-containing bactericides provide partial disease control. Apply at first sign of disease and repeat at 10- to 14-day intervals when warm, moist conditions prevail. Copper is strictly a protectant and must be applied before an infection period occurs.

Chemical Control

Copper hydroxide is the first chemical that should be used the addition of mancozeb increases the efficacy of copper. Check with your processor concerning allowed materials and rates. Be sure to follow label directions on all products when making a tank mix; the most restrictive label precautions and limitations must be followed.

Corcky Root Rot

Symptons

Infected roots of plants with corky root rot are distinctly corky. Extensive brown lesions, often arranged in bands with lengthwise cracking of the cortex, develop on the larger roots. The tips of infected older roots are pinched off. Small feeder roots may be completely decayed. Infected plants are stunted and slow growing. Branches on mature plants may die back from the tips.

Comments on the Disease

The fungus survives for long periods as microsclerotia. Potential alternate hosts include cucurbits, peppers, safflower, and solanaceous weeds such as on nightshades. Corky root is generally a problem in early plantings under cool conditions. Disease development is optimal at 60° to 68°F (15.5° to 20°C). Corky root usually does not kill plants, but may reduce yields.

Management

Cultural practices, or soil fumigation on fields with a history of corky root rot, will help to minimize problems from this disease.

Cultural Control

Plant when soils are warm in spring. Avoid consecutive crops of tomatoes. Although not extensively tested in California, soil solarization has been used to control corky root rot in other areas of the world. Rotate with nonhost crops.

Organically Acceptable Methods

Cultural control is acceptable in an organically certified crop.

Treatment Decisions

In fields with a history of corky root rot, a pre-plant treatment with metam sodium may reduce disease in a subsequent tomato crop.

Chemical Control

Metam Sodium is a source of volatile organic compounds (VOCs) but are minimally reactive with other air contaminants that form ozone. Fumigate only as a last resort when other management strategies have not been successful or are not available.

Early Blight


Symptoms

Plants infected with early blight develop small black or brown spots, usually about 0.25 to 0.5 inch (6–12 mm) in diameter, on leaves, stems, and fruit. Leaf spots are leathery and often have a concentric ring pattern. They usually appear on older leaves first. Spots on fruit are sunken, dry, and may also have a concentric pattern; frequently they occur near the calyx end of the fruit.

Comments on the Disease

Early blight is not common in California; it occurs in coastal areas and mainly affects tomatoes exposed to rain. Damage can occur if conditions remain cool and humid for several days after a rain. The early blight fungus survives in the soil on residue of infected tomatoes, potatoes, and nightshade weeds. The fungus is spread by spores that are carried by the wind or splashed in water. Germination of spores and infection require free moisture. Disease development stops in dry, hot weather.

Management

Most California varieties are susceptible to early blight, but treatment is rarely needed because its occurrence is uncommon. Destroy volunteer tomato and potato plants and nightshades. Proper crop rotation is important to ensure infected plant debris decomposes. Treat when environmental conditions are favorable and the first sign of disease becomes apparent.

Chemical Control

Chlorothalonil, mancozeb, Maneb 75 DF, Fixed Copper not all copper compounds are approved for use in organic production; be sure to check individual products. Bacillus

substilis for suppression begin applications when plants are 4-6 inches tall. Repeat on a 5-to-7-day interval or as needed.

Gray Mold

Symptoms

Gray mold appears on young plants as gray-brown velvety mold covering stems or leaves. Infections that girdle the stem cause wilting above the infected area. In the field gray spores cover dying flowers and the calyx of fruit. Under a hand lens, the spore-bearing structures resemble bunches of grapes. Infections spread from flowers or fruit back toward the stem, which turns white and develops a canker that may girdle it.

Green fruit decays and turns light brown or gray, starting at the point where it touches other infected plant parts. Small green fruit infected directly by airborne spores instead of by contact with other infections usually does not decay, but develops white, circular rings called "ghost spots." Infected fruit held in storage at high humidity often decays and shows the typical gray coating of spores; it may also have a white mycelium on the surface.

Comments on the disease

Gray mold is one of the main causes of postharvest rot of fresh market tomatoes, and it occasionally affects processing tomatoes when there is a rain, heavy dew, or fog before harvest. Careful management of irrigation water keeps the disease to a minimum.

Gray mold can be a problem in greenhouse-grown tomatoes. It can develop where supporting wires and strings rub against stems, causing a wound.

Botrytis spores originate in the residue of tomatoes, peppers, and weeds and are spread by wind. Spores landing on tomato plants germinate and produce an infection when there is free water on the plant surface from rain, dew, fog, or irrigation. Infection is fastest when the temperature is about 65° to 75° F. Dying flowers are the most favorable sites for

infection. Infection may also result from direct contact with moist, infested soil or plant debris.

Management

Cultural Control

Inspect transplants before planting them into the field. Remove and destroy plants found with severe *Botrytis* symptoms such as obvious active lesions or dead leaves or petioles. Also, avoid unnecessary late irrigations and keep the tops of beds dry when fruit is present to help reduce the chance of infection.

Organically Acceptable Methods

Cultural control is acceptable in an organically certified crop.

Treatment Decisions

Treatments may be required in fresh market and greenhouse-grown tomatoes if gray mold infections are occurring. Fungicides will not suppress an established infection and are applied to protect against infection.

Fungicides cannot prevent disease development in fruit touching infested soil or plant debris, so treatments are not recommended for processing tomatoes. Infection of bush tomatoes is more likely when vines grow into furrows, allowing fruit to contact irrigation water.

Late Blight

Symptoms

Leaf symptoms of late blight first appear as small, water-soaked areas that rapidly enlarge to form purple-brown, oily-appearing blotches. On the lower side of leaves, rings of grayish white mycelium and spore-forming structures may appear around the blotches. Entire leaves die and infections quickly spread to petioles and young stems. Infected fruit turn brown but remain firm unless infected by secondary decay organisms; symptoms usually begin on the shoulders of the fruit because spores land on fruit from above.

Comments on the disease

Late blight is found when humid conditions coincide with mild temperatures for prolonged periods. When humidity is above 90% and the average temperature is in the range of 60° to 78°F, infection occurs in about 10 hours. If conditions are ideal for disease development, disease development is rapid and losses can be severe. The fungus overwinters in potatoes, tomatoes, hairy nightshade, and possibly in the soil. Spores of the fungus are easily spread by wind to other plants.

Management

Tomato varieties resistant to certain races of the late blight fungus are grown where the disease occurs regularly. Remove any nearby volunteer tomato and potato plants and nightshades. Check transplants to ensure they are free of late blight before planting. Fungicides are generally needed only if the disease appears during a time of year when rain is likely or overhead irrigation is practiced. Disc tomato fields in fall to eliminate a winter reservoir for the fungus. Avoid sprinkler irrigation, if possible, because it favors the development of late blight. Mefenoxam-resistant strains of the pathogen are widespread in California, and this fungicide is no longer effective.

Monitoring and Treatment Decisions

Apply a protectant fungicide before disease development begins; once an outbreak occurs in a field, it is important to apply additional applications at regular intervals. Coverage must be thorough for applications to be effective.

Chemical Control

There are many different chemicals that can help control blight, but cultural and choosing a resistant cultivar are by far the best ways to avoid the disease. Chemicals such as, listed in order of least impact on natural beneficials and bees, Famoxadone, Dimethomorph, Azoxystrobin, Chlorothalonil, Mancozeb, Maneb 75 DF, and Pyraclostrobin are all chemicals listed for blight control. These chemicals are strong and most should not be applied with a total of a few ounces each year.

Powdery Mildew

Symptoms

Symptoms of powdery mildew are limited to leaves. Symptoms initially appear as light green to yellow blotches or spots that range from 0.125 to 0.5 inch (3–12 mm) in diameter on the upper surface of the leaf. A white, powdery growth of the fungal mycelia and spores is obvious on the top of leaves. As spots coalesce, the leaf tissue dies. The entire leaf eventually turns brown and shrivels but remains attached to the stem.

Comments on the disease

In California, powdery mildew caused by *O. neolycopersici* is limited to greenhouses and fields close to the coast. Conidia are easily windborne and are carried long distances. The conidia land on leaves where they germinate and enter the leaf stomata. The fungus grows at moderate to cool temperatures. Little moisture is required for the fungus to establish itself on a plant. There is experimental evidence that the pathogen has a wide host range and probably survives on other hosts or volunteer tomato plants from season to season.

Management

This powdery mildew is generally not severe in coastal fields and control measures are usually not warranted. Greenhouse-grown tomatoes, however, can suffer to the point of severe economical damage. Registered fungicides, such as sulfur, may be required to control the disease in the greenhouse. Begin applications when the disease first appears.

Chemical Control

The only listed chemical control found as of 3/2012 is sulfur. The best control method besides cultural is Milstop, Milstop is an organic approved method.

Organically Acceptable Methods

Sulfur and Milstop sprays are acceptable for use on organically certified produce.

Strawberry field preparation

Careful preparation of your fields for pre-plant treatments and planting can make pest management easier. Important considerations include soil type, crop residue, bed design, proper drainage, and whether you plan to fumigate the soil before or after beds are formed.

- Do not work the field when the soil is wet or when it is very dry because the soil structure will be damaged. Prepare beds with proper slope (at least 0.75%) so that water does not stand in the field and drains off during rainy weather without causing soil erosion. Shape beds properly so that water drains away from the tops of the beds. On hillsides, form beds on a contour to minimize soil erosion.
- Prepare fields far enough in advance of fumigation that residue from the previous crop will be decomposed. Pathogens present in crop residue may not be killed by fumigation. Work reasonably dry soil until it is free of clods; fumigants do not penetrate clods, and working wet soil causes compaction that interferes with successful fumigation. It may be necessary to sprinkle-irrigate dry soil before fumigating because fumigation is less effective in dry soils. These guidelines also apply if you are planning to use soil solarization or drip fumigation.
- If sulfur or gypsum is needed, apply the material several months before planting and thoroughly mix it with the soil. Rain or irrigations will then leach excess salts from the root zone. If gypsum is being used to improve water infiltration, apply it to the soil surface without mixing it into the soil.

Drainage

Good drainage is essential to keep salts from building up in the root zone and reduce root disease problems. Always rip the subsoil several times to provide adequate drainage. Perched water tables, compacted soil layers, and stratified or layered soils must be corrected during field preparation. Deep subsoiling or chiseling to a depth of 30 inches may remove these obstructions and should be repeated every year.

In some cases organic amendments can improve drainage. Be careful to choose amendments that do not contribute to salt problems. If using manures or composts, mix them into the soil far enough in advance that rains or irrigations will ensure that excess salts are rinsed from the root zone before planting.

High beds improve drainage, so increasing bed height may help alleviate drainage problems. Be sure to provide for adequate drainage from the field during rainy weather; standing water favors the development of root and crown diseases. Drip-irrigated fields

should have a uniform slope of 0.75 to 1%. Ideally, water from rains should not be allowed to stand in strawberry fields for more than about 6 hours.

Forming beds

Planting beds may be formed before or after soil fumigation. If you are planning to use solarization for weed control, you must form the beds first. Two–row or four–row beds may be used. Four-row beds are most common in the Santa Maria Valley and southern California areas, while two-row beds are most common in the Watsonville/Salinas area. Salinity management, pest control, and harvest may be more difficult with four–row beds.

When setting up planting beds in hilly areas, plan to leave natural draws free of plants—for example, by making them roadways between planting blocks. This will allow cold air drainage and help reduce the risk of low temperature injury.

Polyethylene Mulch

Covering the planting bed with polyethylene mulch helps regulate soil temperature, which in turn helps regulate plant growth and fruit production. Mulching also conserves soil moisture and reduces salinity build up on the soil surface and is very important in reducing decay problems by limiting fruit contact with soil and irrigation water.

Preplant weed control is critical, unless opaque mulch is used, because clear and translucent mulches do not control weed growth. The type of mulch used and the timing of application depend on cultivar, planting and harvest seasons, and other management practices.

Polyethylene mulch may be applied by machine before planting or by hand or machine after plants are in place. When applied after planting, the plastic is unrolled lengthwise over the bed and secured to the bed shoulders with metal pins placed every 6 to 8 feet or with a layer of soil turned over the edge of the mulch. Either rotating drums with knives that slice the plastic are used to create a hole for the plant or a special burner is used to heat a metal cylinder that punches a hole in the plastic over each plant and the plants are pulled through the holes. (Advantages of the knives is that they create a smaller hole and there is less weed growth, but the larger holes created by the burners allow more water to get to the plant if overhead irrigation is used.) If bed fumigation is used, mulch is applied before planting. Plastic bags filled with soil are placed as needed to keep wind from damaging the mulch.

Clear Polyethylene

Clear mulch allows sunlight to heat the soil during short winter days, stimulating crown development and thereby enhancing early and total yield.

- In the Santa Maria Valley and southern California, apply clear polyethylene to fall-planted strawberries before or as soon as possible after planting.
- In the Watsonville/Salinas area, short-day cultivars may be planted through clear mulch or clear mulch applied soon after planting to encourage winter growth. For day-neutral cultivars, clear mulch is usually applied in mid- or late December.
- Clear polyethylene may also be used in Central Valley areas when summer plantings are planted later than recommended; it is important to apply the clear mulch in early November to stimulate crown growth during late fall and winter. Applying clear mulch in late December or January when day length is increasing stimulates runner growth and shortens the fruit production season.

White Polyethylene

White or white-on-black mulch cools the soil significantly, slowing early growth, and favoring production of larger fruit and prolonging the fruit production season of some cultivars. In the Central Valley, apply white polyethylene to summer plantings immediately after pruning. White mulch is least likely to burn fruit during hot weather. Most white mulch is translucent and does not inhibit weed growth. White mulch with black backing does control weed growth. Reflection from white and silver-colored mulches helps repel some insect pests such as greenhouse whitefly.

Opaque Polyethylene

Opaque polyethylene, such as those colored black, brown, or green, provides considerable soil warming (but less than clear) and controls weed growth on the planting bed. However, shoots of yellow nutsedge can puncture holes and grow through opaque mulch. With black mulch fruit burn can be a problem when temperatures are high (above 90° F).

Insect Problems

Aphids

Description of the pests

Strawberry aphid is pale green to yellowish in color. Both adults and nymphs appear to have transverse striations across the abdomen and are covered with knobbed hairs that are readily seen with a hand lens. These striations and hairs are not found on any of the other aphid species infesting strawberry.

Melon aphid is small, globular, and varies in color from yellowish green to greenish black. This species is often the first to migrate into the strawberry fields each season and is the most difficult to control with insecticides.

Green peach aphid and potato aphid are less common in strawberries than the other species. The green peach aphid is green to greenish yellow in color and is more streamlined than the rounded melon aphid. Winged adults typically have a black spot on the top of the abdomen that is easy to observe with a hand lens.

The potato aphid is much larger than the other species and has both a pink form and a green form in California. The long legs on this species gives it a characteristic spiderlike appearance.

Damage

Populations of aphids usually peak during late March in central and southern California and undergo a natural decline to noneconomic levels during May and June. (In high elevation nurseries, populations peak in mid- to late-summer.) Populations may continue to increase to damaging levels when spring temperatures are moderate and humidity is high. In California strawberry production fields, aphids rarely reach damaging levels but occasionally cause yield losses because of honeydew production. Honeydew deposits on fruit cause sooty molds to develop and the white skins shed by aphid nymphs to stick to the fruit. This contamination renders the fruit unmarketable as fresh fruit.

Aphids transmit several viruses that can cause significant economic losses in strawberries if the planting remains in the field for several years. While not a serious problem in annual production plantings, aphid transmission of viruses is a major concern for nursery production.

Management

While biological control can help to keep aphid populations low, treatments may be necessary in southern California, and occasionally in Central Coast fields, if spring weather

is conducive to their development. Treatments are also applied in strawberry nurseries to prevent aphid buildup and virus spread. In other strawberry fruit production areas, aphids rarely reach damaging levels and are not treated.

Biological Control

A complex of at least seven species of primary parasites have been reared from aphids infesting strawberry plants. Unfortunately, the parasites themselves are attacked by a large group of hyperparasites (parasites of the parasites) that limits the buildup of primary parasites.

Predators such as syrphid fly or green lacewing larvae often provide a greater level of control. Lacewings can be purchased and released to help control aphids but research is lacking on the efficacy of augmentative releases against aphids. Naturally occurring biological controls can keep aphid densities below economically damaging levels, such as with the case of the melon aphid in southern California strawberry-growing regions, so consider parasite and predator densities before any treatment decision is made.

Cultural Control

Some row covers (plastic tunnels or Remay-type enclosures) have reduced aphid populations to below economic levels, but the costs are substantial and the economic viability for large- or even small-scale plantings has not been established. Controlling dust is important to facilitate parasite and predator activity. Aphid populations tend to be especially large in plants that receive an excess of nitrogen fertilizer.

Organically Acceptable Methods

Cultural and biological controls and sprays of insecticidal soap, azadirachtin (Neemix), neem oil (Trilogy), and pyrethrin (PyGanic) are acceptable for use on organically certified strawberries.

Monitoring and Treatment Decisions

- *In Southern California,* start taking weekly samples when the first leaf is fully expanded. Remove the oldest trifoliate leaf and record if any aphids are present. Randomly sample 40 trifoliate leaves per acre and calculate the percent of leaves that have aphids. Treat if the infestation level reaches 30%.
- *In strawberry nurseries,* consider controlling aphids as soon as they appear to reduce the spread of virus, especially for the earliest generations.
- *In Central Coast fields,* aphids rarely reach damaging levels. If aphid numbers appear to be increasing, an insecticidal soap spray will help reduce the aphid populations with minimal damage to beneficials. Take a newly unfolded leaf from each plant

sampled for mites and count the number of aphids. If populations reach an average of 10 per leaf, treat with insecticidal soap.

Chemical Control

Organic approved methods are the first action. Insecticidal soap is the first choice. Insecticidal soap do not apply more than 2 applications per season. A single application should reduce aphid population about 50%. Second organic method is Azadirachtin, third Neem oil which we have not had many good results from, and fourth is Pyrethrin which has shown little or no effect unless used in maximum amounts and used as aerosol can. Nonorganic chemicals include Imidacloprid which you should apply to root zone through drip, trickle, or microsprinkler irrigation after plants are established or on perennial crops in early spring before bud opening. Or, just before or during transplanting, treat plant or plant hole. Thiamethoxam for resistance management an application of Admire, Provado, or Actara to the same crop is not recommended. Do not make foliar treatments when bees are actively foraging or up to 10 days before bloom. Diazinon may injure mite predators resulting in increase of twospotted spider mites. Provides longer residual activity than soap does. Apply in 100 gal water/acre. Diazinon has been found in surface waters at levels that violate federal and state water quality standards. Avoid runoff into surface waters or choose alternative materials.

Cyclamen Mites

Description of the pest

At low population densities, cyclamen mites(Family Tarsonemidae) are usually found along the midvein of young, unfolded leaves and under the calyx of newly emerged flower buds; when populations increase, these mites can be found anywhere on non-expanded plant tissue. They are not visible to the naked eye, and when mature, they measure only about 0.01 inch (2.5 mm) long. Mature mites are pinkish orange and shiny. The hind legs are

thread- or whip like in the female and grasping or pincer like in the male. Eggs are translucent and comparatively large.

Adult females lay about 90 eggs, 80% of which develop into females. During summer, newly hatched mites develop into mature adults within 2 weeks. Populations build rapidly soon after a field becomes infested. Cyclamen mites overwinter as adult females in the strawberry crown and can be present on transplants if the nursery field was infested.

Cyclamen mite can be distinguished under magnification from non-damaging tarsonimid mites in the genus *Tarsonemus* by examining the 4th femur of male mites. The cyclamen mite has a "flange" or distinct bulge present while the males of both *Tarsonemus* species do not.

Damage

Cyclamen mites are primarily pests in fall-planted and second-year plantings, but they can be transplanted into first-year fields and the damage symptoms become apparent on leaves as the season progresses. Leaves heavily infested with cyclamen mites become severely stunted and crinkled, resulting in a compact leaf mass in the center of the plant. Feeding on flowers can cause them to wither and die. Fruit on infested plants is dwarfed, and the seeds stand out on the flesh of the berry. When uncontrolled, this mite can prevent plants from producing fruit.

Management

Management of cyclamen mite requires carefully timed sprays of miticides that do not harm natural enemy populations. Prevent its introduction into strawberry fields by following good cultural practices. Propagating nursery stock free of cyclamen mites is essential to prevent introducing populations to fruit-producing fields. This mite may survive in furrows of fields that have been bed fumigated. Because other nondamaging tarsonemid mite species, including *Tarsonemus setifer* and *Tarsonemus confusus,* occur in strawberry fields and it is very difficult to distinguish one species from another, focus control efforts in those fields where damage symptoms occur.

Biological Control

Two naturally occurring predatory mites of cyclamen mite are *Typhlodromus bellinus* and *T. reticulatus,* but their populations build up too slowly to provide economic control. Early season releases of the commercially available predatory mite, *Amblyseius californicus,* may be able to control this pest mite. *Amblyseius cucumeris* releases have not proven to be effective.

When pest populations become large, the six's potted thrips, minute pirate bugs, and western predatory mite *(Galendromus occidentalis)* all feed on cyclamen mites.

Cultural Control

Cyclamen mites can easily be transferred from one location to another by pickers, bees, birds, and equipment, including strawberry freezer trays. It may be worthwhile to dip trays of long-term cold storage (28°F) transplants into a hot water bath for 7 minutes right before planting to prevent infestation. (Infested nursery plants are the major source of this pest in annual plantings; be sure to use uninfested nursery stock.) Prepare plants for this treatment by thoroughly washing them to remove all dirt; then place them in a circulating water bath that is held at a constant temperature of 120°F. Afterwards, submerge them in very cold water and then plant them as soon as possible. (This treatment is not recommended for fresh-dug transplants that have only been stored at 33°F.) Avoid second-year plantings in problem areas. To slow the spread of infestations, rogue infested plants as soon as symptoms appear.

Organically Acceptable Methods

Biological and cultural control methods are acceptable for use on organically certified strawberries.

Monitoring and Treatment Decisions

If any damage symptoms are observed, be sure to monitor the rest of the field carefully to determine the extent of the infestation. Monitor newly unfolding leaves and treat the area of the field believed to be infested when densities of one cyclamen mite in 10 leaves are found. To control cyclamen mites, a high rate of water per acre (300–500 gal) is necessary to soak the folded leaves and immature flower buds located in the crowns. Effective control requires a high rate of kill because populations of this mite can increase rapidly. Roguing and treating infested hot spots with a hand-sprayer can be useful in suppressing infestations without having to treat the entire field. In nurseries, early season control before plant canopy closes over is critical.

Chemical Control

Abamectin is toxic to predatory mites and relatively toxic to parasites, but fairly safe for general predators. Apply in up to 600 gal water/acre to soak the material into the crown of the plant. Works poorly under cold weather conditions. Make 2 applications 7–10 days apart when mites reach detectable levels under warmer temperatures in late winter/spring. Repeat this sequence of applications if necessary to maintain cyclamen mite control. Do not exceed 16 fluid oz/acre/application or 64 fl oz (4 applications)/acre in a growing season. Do not repeat treatment within 21 days of 2nd application. Not registered for strawberry nurseries. Dicofol 4E should be applied with a wetting agent. Toxic to predaceous mites and relatively toxic to general predators and parasites. Do not apply after fruit formation or when temperatures exceed 90°F. Do not make more than 2 applications/season, Endosulfan is another chemical but do not reapply within 35 days.

Use of this product may not be allowed in some counties; cannot be applied in any situation where run-off may occur. Consult county agricultural commissioner for local restrictions. Do not make more than 2 applications/year or exceed 2 lb a.i./acre/year. Fenpropathrin is limited to 2 applications/year (totaling 2.66 pt/acre), but to reduce the pressure for resistance development, make no more than 2 applications of all pyrethroids to the crop each year. Acequinocyl does not become evident until 48 to 72 hours after application. Do not use less than 100 gal water/acre and do not apply more than twice/year. Allow a minimum of 21 days between treatments. Crops other than strawberries may not be rotated for at least 1 year following treatment.

Spotted wing Drosophilia

Description of the pests—Male/Female Identification Card

Spotted wing drosophila has recently been found in many California counties infesting ripening cherry, raspberry, blackberry, blueberry, and strawberry crops; it has also been observed attacking other soft-flesh fruit such as boysenberry, varieties of Japanese plums, plumcots, and nectarines. Adults and maggots closely resemble the common vinegar fly, *Drosophila melanogaster,* and other*Drosophila* species that primarily attack rotting or fermenting fruit. The spotted wing drosophila, however, readily attacks undamaged fruit.

Adults are small (2-3 mm) flies with red eyes and a pale brown thorax and abdomen with black stripes on the abdomen. The most distinguishable trait of the adult is that the males have a black spot towards the tip of each wing. The female does not have spots on its wings, but their ovipositor is very large and serrated, unlike other common *Drosophila*species. Larvae are tiny (up to 3.5 mm), white cylindrical maggots that are found feeding in fruit. One to many larvae may be found feeding within a single fruit. After maturing, the larvae partially or completely exit the fruit to pupate.

At this point not much is known about its life cycle in California; however, like other vinegar flies it appears to have a short life cycle (one to several weeks depending on temperature), and may have as many as ten generations per year. This rapid developmental rate allows it to quickly develop large populations and inflict severe damage to a crop.

In Japan and in coastal California the adult flies may be captured throughout much of the year. They are most active at 68°F; activity decreases at temperatures above 86°F, and egg laying stops at about 91°F.

Damage

Unlike other vinegar flies that occur in California, spotted wing drosophila attacks healthy ripening fruit as well as damaged or rotting fruit. The female's serrated ovipositor is very large and able to penetrate the skin of soft-skinned fruit and lay eggs just under the skin, creating a small depression ("sting") on the fruit surface. Each clutch of eggs is from one to three, and the female will oviposit on many fruit. Multiples of larvae within a single fruit are quite possible because many females may visit the same fruit to oviposit. As fruit integrity is compromised by spotted wing drosophila's activities, common vinegar flies (i.e., *Drosophila melanogaster)* may also oviposit in the damaged fruit.

Eggs hatch and the maggots develop and feed inside the fruit, causing the flesh of the fruit to turn brown and soft; sunken areas that exude fluid often appear on the fruit surface. Damage can provide an entry site for infection by secondary fungal and bacterial pathogens, but this is not always the case.

Management

Spotted wing drosophila may be monitored with a variety of traps. In the berry production districts of the Central Coast of California, one of the most successful trapping methods has been a yeast-sugar-water mix in a jar or bottle trap. Beyond the capability to consistently trap spotted wing drosophila, this mix is sufficiently clear to easily distinguish the flies, and it can be used for several weeks without changing the liquid.

To make the bait solution, mix 12 oz of water with 0.25 oz of baker's yeast (e.g., Fleischmann's) and 4 teaspoons of sugar. Allow the solution to ferment for a day or so (in an open or loose-lidded container–quite a bit of gas is formed during the fermentation process) then transfer 3 to 4 fl oz of the liquid to a 500-ml Nalgene bottle or other container of low height that has four or more 7/16-inch diameter holes drilled into the lid. (The idea is to use a container that is low enough that the opening is well below the plant canopy.) Flies enter the bottle through these holes and while there is the possibility of flies escaping back out through the holes, most eventually land in the liquid and drown.

While some jars or bottles can be hung with a wire in the shady, cooler areas of the field or farm, others should be placed directly in the strawberry field itself. It is important that the traps be placed in the shady canopies of the strawberry plants. Check traps at least weekly and count and remove the flies.

While no set management program has yet been determined for spotted wing drosophila, a successful one will need to focus on controlling flies before they lay eggs and reducing breeding sites. There are no effective tools for controlling maggots within fruit. Three essential parts of a management program will likely include:

1. *Attractant bait sprays and pesticides.* Pesticides such as malathion, pyrethroids, and spinosyns have been shown to be very effective in reducing numbers of spotted wing drosophila. Horticultural oils do not show much promise as a control agent. As always, applicators should be aware of restrictions in using pesticides, especially the effects that they may have on non-target organisms such as predators, parasites, and honeybees. Growers should consult with their processors concerning any export restrictions for specific products.

2. The fruit seems most susceptible to attack after it has colored and developed some sugar. If monitoring indicates pest presence, apply a spray to protect the fruit. If monitoring indicates a high population early in the season, an earlier spray to lower populations may be warranted in addition to harvest applications.

3. Attractant-based bait sprays targeting adult flies such as GF-120 (bait plus insecticide) can be applied and could prove effective, but data on this approach are lacking for strawberries. Because it is bait, coverage is not as important as keeping the bait attractive. Applications made at greater product concentration and with very large droplet size (4-5 mm diameter) across the field and border areas can be useful in reducing fly populations while minimizing effects on predators, parasites, and honeybees. However, because the efficacy of any bait and toxicant decreases over time, this material need to be re-applied, perhaps at weekly or bi-weekly intervals to be effective. Traps will need to be monitored to assure that adult fly suppression has been achieved.

4. *Sanitation.* Infested fruit that remains in the field or orchard serves as a food source and allows eggs and larvae to fully develop and serves as a source of more flies. When feasible, removing ripe, overripe, and rotten fruit from the crop site and destroying, either by burial or disposal in a closed container can help to reduce populations of this pest. This can be especially important if a nearby susceptible crop will soon be ripening.

5. *Harvest intervals.* Even though spotted wing drosophila oviposits in newly ripening fruit, they readily infest older, over ripe fruit as well. Extending harvest intervals, as may occur for the processing crop, will results in larger populations, more fruit damage, and a greater risk for future infestations of the new crop.

6. *Area-wide management.* In looking at other successful programs of fruit or vinegar fly management, it is clear that using the above practices over a wide area is essential. It is important for every grower within a fly-infested area to participate, because a single,

unmanaged field or orchard will serve as a source of infestation to nearby susceptible crops.

White Flies

Description of the pests

Populations of iris whiteflies and, to a lesser extent, strawberry whiteflies have always been present in low numbers in strawberry fields in California. These species are usually kept below damaging levels by naturally occurring beneficial insects. In recent years, however, a third species, the greenhouse whitefly, has become a major pest in certain areas on the Central Coast and in southern California. The greenhouse whitefly has a large host range including alfalfa, avocados, beans, blackberries and other berries, cucumbers, eggplants, grapes, lettuce, melons, peas, peppers, potatoes, tomatoes, and many ornamentals, and these alternate hosts serve as sources for whiteflies that enter strawberry fields.

Whiteflies go through six stages in their development: eggs; first, second, third, and fourth instar immature; and the adult. Eggs are microscopic and laid on the underside of leaves. Whiteflies do not have a true pupal stage, but the last part of the fourth instar, when the red eyes of the adult whitefly begin to appear, is often referred to as the "pupa." Only adults and the newly hatched nymphs (i.e., crawlers) are mobile. Greenhouse whiteflies tend to build up in fall, reaching peak densities in late fall through winter in central coast plantings. In warm weather, whiteflies can complete a generation in as little as 18 days.

Whiteflies are easy to distinguish from other insect pests: adults of all species are about 0.04 inch (1 mm) in size with four membranous wings that are coated with white powdery wax. Whitefly species are most reliably distinguished from each other by examining the late fourth instar or red-eyed "pupal" stage. The greenhouse whitefly has long, waxy filaments around the margins in this stage. When seen from the side, the greenhouse whitefly "pupae" are circular with flat tops, with the filaments emerging from the tops. Adult greenhouse whiteflies are solid white and hold their wings parallel (flat) to the top of the body. Both adults and nymphs look similar to the strawberry whitefly, but the

strawberry whitefly nymphs never have the long filaments often found on the greenhouse whitefly "pupae." Iris whitefly "pupae" also lack long filaments but have short waxy ones around their bodies. Iris whitefly adults hold their wings flat over their backs and have a dot on each wing.

Damage

Greenhouse whitefly can transmit viruses and is known to vector pallidosis-related decline of strawberry in California. Whiteflies may reduce crop yields directly through their feeding on leaf tissue, which removes plant sap, stunts plant growth, and decreases sugars in fruit. They also produce sticky honeydew that they excrete during feeding. The honeydew may cover plants and support the growth of black sooty mold fungus.

Management

Successful management of greenhouse whiteflies requires an integrated program that focuses on prevention and relies on cultural and biological control methods when possible. Treatments are often necessary if strawberries are grown so that continuous plantings are present in areas where greenhouse whiteflies have become established (summer plantings or second-year plantings adjacent to new plantings), if whitefly biological controls are disrupted by the use of a nonselective pesticide, or if adult whiteflies invade the strawberry plantations from adjacent crop hosts or from backyards. No precise treatment threshold has yet been developed for greenhouse whiteflies on strawberries, but even feeding at relatively low densities after transplanting can result in yield loss. Treatment may be necessary when honeydew or moderate to heavy whitefly populations are apparent during periods of warmer weather for summer- and fall-planted berries. Select treatments carefully and use them only when monitoring indicates a need.

Biological Control

In most crops, greenhouse whiteflies and iris whiteflies are generally kept under control by naturally occurring parasitic wasps and general predators. Their natural enemies include parasitic wasps of the genera *Encarsia, Eretmocerus,* and *Prospaltella,* big eyed bugs, pirate bugs, and lacewing larvae. In summer, in certain areas on the Central Coast and in Ventura County, 30 to 40% of greenhouse whiteflies are parasitized by native parasites.

Encarsia formosa is used worldwide for greenhouse whitefly suppression in greenhouses, but more research is necessary to determine if the release of this or other parasites can be helpful in preventing whiteflies from increasing in numbers in field situations.

Cultural Control

For summer-planted strawberries, the practice of topping in spring helps to reduce overwintering immature populations. Monitor whiteflies on adjacent hosts and initiate

control there, if possible, before these crops are harvested to prevent the whiteflies from moving to strawberries. Minimizing dust by keeping field roads watered or oiled allows biological control to work effectively.

The source of infestation for new plantings on the Central Coast appears to be adjacent strawberry fields that are being maintained for a second year of berry production and summer plantings that have become infested from the previous season's fall plantings. It is important that berries held for a second year be monitored beyond the last day of harvest. If whitefly populations are observed in the previous year's plantings once new fields are transplanted, the older plants need to be treated to protect new plantings in adjacent areas. Early pruning may be beneficial to reduce source populations. When berries are pruned it is important that the discarded material is removed from the field. It may not be economically feasible to maintain multiple-year plantings when severe infestations have been experienced the area.

Organically Acceptable Methods

Preserving naturally occurring biological control agents, cultural controls, sprays of narrow range oil, azadirachtin (Neemix), and insecticidal soaps, and releases of *Encarsia formosa* into hot spots against low-to-moderate populations of greenhouse whitefly are acceptable for use on organically certified strawberries.

Monitoring and Treatment Decisions

There are two monitoring methods for whiteflies: yellow sticky traps and leaf counts. Sticky cards are useful for detection of whitefly infestation and determining relative infestation levels, but the number of whiteflies may not correlate closely with the number of immature whiteflies on leaves. Back up sticky trap counts by inspecting strawberry foliage throughout the field on a weekly basis. Place one yellow sticky trap every ten acres and next to field edges to catch adult whiteflies as they move into the strawberry fields. Put the sticky cards vertically on stakes, just above the crop canopy. Count the number of adults trapped on each card weekly and record counts to track population numbers. Replace sticky cards as necessary.

Monitor plants by counting the number of adults on 20 midtier leaflets in each quarter of a field and determine the average number. Also examine nymphs to determine what proportion of the nymphs are black, indicating they are parasitized.

When monitoring indicates that adult populations are increasing rapidly and nymphs that are detected on leaves have no indication of parasitism (i.e., are not black in color), begin treatments with products that control adult whiteflies. Insecticides (except imidacloprid), oils, and soaps are most effective against adults and early instar whiteflies but not against eggs. Very few materials are effective against the fourth instar "pupal stage." Try to time

treatments when monitoring indicates that most of the population is in the adult and first-, second-, or third-instar stage.

If there is high risk of new plantings from nearby summer plantings or second-year fields that already have whiteflies, consider a preventive application of imidacloprid (Admire) at planting by injection into the planting hole or through the drip system. If application is through drip irrigation, it is best to preirrigate to make sure that the soil profile is well watered, then apply enough water to move the material into the root zone. Imidacloprid (Admire) must be taken up by the plant to be effective.

Good coverage of the underside of leaves is essential for effective use of insecticides against whiteflies, but dosage applied is also important. When treating whiteflies, use lower volumes of water than would normally be used against pests like spider mites and drive the sprayer more slowly over the field if possible. An air-assist sprayer might help. More than one application may be required for heavy populations or if monitoring indicates that populations are continuing to increase. Rotating between chemical classes when making multiple applications is recommended to reduce the development of resistance.

Chemical Control

Imidiaclorpid is a neonicotinoid insecticide. Best used as a preventive treatment. Can be applied through drip lines; see label for restrictions. When applying through drip, preirrigate so soil is moist. This material must move into the root zone and be taken up by the plants to be effective, so sufficient water must be applied to promote its movement through the soil. Only one application/year but has a long residual activity; more moves into plant with each irrigation. Pyriproxyfen is allowed under a Supplemental Label. Apply after an application of imidacloprid (Admire) and when whitefly populations just begin to increase. Control of adult whitefly populations will take about 2-3 weeks following application so apply before populations build. Narrow range oil is also available but the potential for phytotoxicity has not been fully evaluated. Growers are encouraged to test product or product mixes for phytotoxicity before field applications to determine safety margins. Apply in 60 gal water/acre with air-assist, low-volume ground equipment or 200 gal water/acre. Moderately effective against low to moderate populations when coverage is excellent. Make applications only during winter months when plants are semi-dormant to reduce the risk of phytotoxicity. Do not use oil from peak bloom through fruiting period or when air temperatures are expected to exceed 75°F within several days following application. Do not apply from Jan 16 to May 30 in Orange and San Diego counties or the Oxnard Plains; do not apply from Feb 1 to June 15 in the Santa Maria Valley, and do not apply from Mar 1 to Jun 30 in Monterey and Santa Cruz counties. Insecticidal soap is also available but must be applied directly to the pest,

Disease

Botrytis fruit mold

Symptoms

The fungus that causes Botrytis fruit rot, also known as gray mold, is widespread in the environment. It can infect strawberry flowers when spores landing on them are exposed to free water and cool temperatures. Infections can either cause flowers to rot or Botrytis can become dormant in floral tissues. Dormant infections resume activity on the berry later in the season any time before or after harvest when sugars increase and conditions become favorable to disease development.

Infections first appear as small brown lesions, often under the calyx. Lesions begin to sporulate within a day after resumption of activity, and spore structures appear under the calyx as tiny stalks with clusters of spores at their tips. Lesion size increases rapidly. Both green and red berries are susceptible. Infected berries maintain their original shape and take on a velvety, gray-brown coat of mycelium and spores. Initially, rotted areas are soft and mushy, becoming leathery and dry in the absence of high humidity. Millions of spores are produced on each berry and become airborne at the slightest touch or breeze.

Direct infection of the berries also occurs if berries are exposed to free water. These infections develop in the same manner as flower-infected berries, but differ in that multiple initial lesions may appear anywhere on the berry's surface.

Comments on the disease

During the growing season, the fungus is constantly present and is often found in new plantings. Nothing can be done to escape the presence of this fungus, but the level of inoculum in a particular field can be reduced by removing dead leaves and infected fruit. After harvest, the fungus survives in the soil as small, black, inactive sclerotia on tilled-in leaves and fruit. In addition, the fungus lives on decomposing, dead organic matter of many plant species in and around the growing area. Because wet, cool weather is necessary for development of this disease, it is mostly limited to the coastal growing regions and

northern nurseries and causes very little damage in inland growing regions except during periods of unusually wet weather during active growth.

Management

Presently, control of Botrytis fruit rot ranges from repetitive fungicide treatments with no cultural control to intensive cultural methods with no fungicide applications. Environmental conditions in various microclimates play an important role in determining control strategies. Planting in areas where wind can rapidly dry out the plants and interrupt disease progress helps to reduce disease incidence.

Cultural Control

Remove and destroy dead or infected plant material to help reduce the amount of inoculum capable of producing new infections. Also, remove all ripe fruit during harvest as well as any fruit with signs of decay or rain damage. Growing strawberries in plastic tunnels has proven to effectively reduce the incidence of *Botrytis* infections. Using plastic mulches to prevent berry-soil contact also reduces disease except where water puddles under the fruit on the plastic.

Some cultivars have flowers and fruit that develop with an upright stature, which allows fruit to be exposed to better air movement and sunlight, and this reduces the risk of infection, but fruit tend to be more exposed to rain and hail.

Organically Acceptable Methods

Select fields that are isolated from conventional growing areas and have environmental conditions that are not conducive to disease development (i.e., warm, dry spring weather or areas where wind is prevalent at some point during the day). Use varieties that are suited to the growing area. Sanitation is crucial for good control; therefore remove all fruit after spring and summer rains and all plant residue after harvest.

Monitoring and Treatment Decisions

In areas without heavy coastal summer fog, inoculum levels may be low enough in clean fields that early sprays in spring can be omitted. In dry areas, leaf wetness seldom is of long enough duration to cause epidemics, and some growers are finding it possible to grow berries without fungicides when strict sanitation practices are adhered to. In dense fog areas, inoculum density and environmental conditions conducive to disease development (i.e., wet weather and cool temperatures) should always determine when to apply fungicides. Because these conditions are usually seasonal, use a protective fungicide to prevent germination of spores when conditions ideal for disease development are anticipated. Thereafter, set spray schedules according to disease pressure and environmental conditions.

A Botrytis infection risk model has been developed that allows growers to define an infection period as light to severe based on field level temperature and wetness data. No fungicide is recommended when conditions are determined not suitable for infection.

Chemical Control

There are many chemical controls for Botrytis fruit mold on strawberries some include Pyraclostrobin/Boscalid which is a carboxyanilide fungicide where application should begin at bloom and alternate with cyprodinil/fludioxonil r fenhexamid. Fenhexamid is a fungicide. Begin applications at early bloom before disease development begins; continue applications at 7- to 10-day intervals when conditions favor disease development but do not make more than 2 consecutive applications before alternating with a fungicide of a different chemistry for at least 2 applications. May be applied alone, or under light to moderate disease pressure it can be tank mixed at a rate of 1–1.5 lb/acre with a fungicide of a different chemistry (e.g. captan). For tank mixes, observe all directions for use on all labels, and employ the most restrictive limits and precautions. Never exceed the maximum a.i. on any label when tank mixing products that contain the same a.i. Do not exceed 6 lb/acre/season. Cyprodinil/Fludioxonil is an anilinopyrimidine fungicide and fludioxonil is a phenylpyrrole fungicide. Begin applications at or before bloom and continue on a 7- to 10-day interval as long as conditions favor disease development. Do not plant rotational crops other than strawberries or onions for 12 months following last application and do not exceed 56 oz/acre/year. Thiophanate-methyl should be tank mixed with fungicide of different chemistry (e.g. captan) to reduce resistance problems. Do not apply more than 4 lb/acre/year. For tank mixes, observe all directions for use on all labels, and employ the most restrictive limits and precautions. Never exceed the maximum a.i. on any label when tank mixing products that contain the same a.i. Iprodione is a dicarboximide fungicide. Do not make more than 1 application/season to reduce the likelihood of resistance development. Do not apply after first fruiting flower. Captan 50WP is a phthalamide fungicide. Can be tank mixed with fenhexamid (Elevate), thiram, or thiophanate-methyl (Topsin-M) for more effective control. For tank mixes, observe all directions for use on all labels, and employ the most restrictive limits and precautions. Never exceed the maximum a.i. on any label when tank mixing products that contain the same a.i. Do not apply in combination with, immediately before, or closely following oil sprays. Do not apply more than 48 lb/year. Thiram is a carbamate (DMDC) fungicide. Good coverage of buds, blossoms, and fruits required for best results. Can be tank mixed with captan. For tank mixes, observe all directions for use on all labels, and employ the most restrictive limits and precautions. Never exceed the maximum a.i. on any label when tank mixing products that contain the same a.i.

Leather Rot

Symptoms

All stages of fruit are susceptible to leather rot. Infected fruit develop diseased areas that are brown to shades of purple in color. The decay often expands throughout the fruit, resulting in a brown, leathery berry. The external infected area becomes tough while the internal tissue is somewhat softer. The central hollow cavity of the fruit may contain the white mycelium of the pathogen, and the fruit tastes bitter.

Comments on the disease

The leather rot pathogen requires splashing rain to transport the zoospores (motile spores) to the fruit, or in very wet conditions (i.e., flooding, standing water or pools of water on beds) the zoospores can swim to the plant.

Management

Leather rot is not common on annual plantings of strawberries in California because it is usually controlled by preplant fumigation and plastic mulches. Cultural practices play an important role in disease prevention; soil solarization may also provide control. Plantings held for 2 or 3 years, however, could be infected by the leather rot pathogen.

Cultural Control

Ensure that fields are prepared so that they have adequate water drainage. Remove diseased fruit and use plastic mulches. Avoid overhead irrigation; use drip irrigation. Straw mulch has been effective in controlling this disease in the eastern United States.

Soil Solarization

In warmer areas of the state, solarization has been shown to be effective for the control of soilborne pathogens and weeds. Solarization is carried out after the beds are formed and can be effective if weather conditions are ideal (30-45 days of hot weather that promotes soil temperatures of at least 122°F). The effectiveness of solarization can be increased by solarizing after incorporating the residue of a cruciferous crop, in particular broccoli or mustards, into the soil or following an application of metam sodium (40 gal/acre). For

more details on how to effectively solarize soil, see *Soil Solarization: A Nonpesticidal Method for Controlling Diseases, Nematodes, and Weeds*, UC ANR Publication 21377.

Organically Acceptable Methods
Field sanitation, proper irrigation, soil solarization, and mulches are acceptable management tools in an organically certified crop.

Treatment Decisions
If drip fumigation is planned, good results have been obtained with a sequential application of chloropicrin (200 lb/acre) or 1,3-dichloropropene/chloropicrin (300 lb/acre) followed 7 days later with metam sodium (45 gal/acre) or metam potassium (37 gal/acre). During the growing season, research data from the eastern United States indicate that mefenoxam (Ridomil Gold), fosetyl-aluminum, and phosphorus acid (Fosphite) are effective in controlling this disease. Treat before the advent of splashing rains or very damp conditions.

Chemical control

Preplant Fumigation

Methyl bromide/chloropicrion the current Critical Use List only allows use where 1,3-dichloropropene can't be used because of local township limits. Fumigants such as methyl bromide are a source of volatile organic compounds (VOCs) but are not reactive with other air contaminants that form ozone: methyl bromide depletes ozone. Fumigate only as a last resort when other management strategies have not been successful or are not available. 1,23-Dichloropropene/chloropocrin (telone C35) is effective for control of nematodes, soilborne fungal pathogens, and insects. One gallon of product weighs 11.1 lb. 1,3-Dichloroproene/chloropicrin is effective for control of nematodes, soilborne fungal pathogens, and insects. Requires plastic mulch. Using higher rates or plastic mulch, especially virtually impermeable film (VIF), improves weed and nematode control. One gallon of product weighs 11.2 lb. Should be followed 5-7 days later with Metam Sodium. Metam Sodium is a water soluable liquid that decomposes to a gaseous fumigant (methyl isothiocyanate). Efficacy affected by soil texture, moisture, temperature, and percent organic matter. One gallon of product contains 4.26 lb of metam sodium.

Growing Season

During the growing season there are three chemical applications that can help Fostyl-Aluminum (aliette), Mefenoxam (ridomil gold), and Phosphorous acid (fosphite).

Carrots

Carrot pests

Bean Aphid

Description of the pest

Bean aphid is a dark, olive-green to black colored aphid. It is most easily confused with the cowpea aphid. Bean aphid has a dull, mattelike appearance while the cowpea aphid is shiny. The cauda (tail-like structure) of the bean aphid has more hairs than that of the cowpea aphid and thus appears bushy. Except for the presence of wings, the winged form of the bean aphid is similar in appearance to the wingless forms.

Damage

Bean aphid may transmit celery mosaic but little is known in this regard. Bean aphid only occasionally builds up on carrots and little is known regarding economic thresholds and damage.

Management

Biological Control
Bean aphids are attacked by a variety of common aphid predators and parasites. Lady beetles, green lacewing larvae, and syrphid fly larvae are frequently found associated with aphid colonies. Bean aphid is also attacked by a very prolific parasitic wasp, *Lysiphlebus testaceipes.*Parasitized aphids become bloated and their bodies turn tan in color. Bean aphid is also attacked by a fungus disease that leaves the aphid body flattened and with the appearance of being glued to the leaf.

Cultural Control
No cultural control strategies are presently available for managing bean aphids in carrots.

Organically Acceptable Methods
Biological and cultural controls are acceptable for use on organically grown produce.

Monitoring and Treatment Decisions
Monitor fields for aphids weekly during spring and summer by examining the upper and lower surfaces of leaves. Also, look for evidence of predators and parasites and their impact on aphid populations. Treatment is rarely required. No thresholds have been established for the treatment of bean aphid on carrots. Chemical treatments are not effective in preventing virus transmission and this aphid rarely causes economic damage.

Chemical Control

There are several Chemical control methods including Imidacloprid (provado) and Diazion 50WP. You should avoid drifting with both chemicals and runoff into water sources. Uniform coverage is very important and needed for good control.

Crown and Rot aphids

Description of the pests

These aphids form colonies near the top of the root and at the base of the stems. They occasionally form colonies on the root slightly below ground. All are similar in appearance with the wingless forms being pale yellow to gray green in color and covered with a powdery wax. The tulip bulb aphid is covered with a white waxy powder while the wax covering the hawthorn parsley aphid is grayish white. The hawthorn carrot aphid is yellowish gray to greenish gray with a very light dusting of wax. All three species, when present, are usually attended by ants. The presence of ants around the base of the plants is usually a good clue to the presence of these aphids.

Damage

These aphids occur infrequently and only occasionally cause injury. High populations may stunt growth, but more serious is that the tops may be weakened by their feeding and break off during harvest, leaving the carrot in the ground.

Management

Biological Control
Because of their location near and below the soil line, predators and parasites have a difficult time finding these aphids. Ants that tend aphids also discourage the activity of predators and parasites.

Cultural Control
Sanitation and crop rotation to nonhost crops is important in reducing the buildup of these aphids and their injury. You should avoid drifting with both chemicals and runoff into water sources. Uniform coverage is very important and needed for good control.

Organically Acceptable Methods
Cultural controls are acceptable for use on organically grown produce.

Monitoring and Treatment Decisions
No treatment thresholds have been established for these aphids.

Chemical Control

Imidacloprid (provado), Cyfluthrin (baythroid XL), and malathion (Malathion 8 Aquamul) are all acceptable chemical control methods. You should avoid drifting with both chemicals and runoff into water sources. Uniform coverage is very important and needed for good control.

Cotton/Melon Aphid

Description of the pest

Cotton/melon aphid is a small to medium-sized aphid. It is highly variable in color, ranging from lemon yellow to blackish green in different individuals, often within the same colony. The aphid is commonly lighter in color during the hotter times of the year and darker during cooler periods, but both color forms may be found throughout the year.

Damage

Cotton/melon aphid is known to transmit more than 50 viruses, some of which affect carrots. It does not generally build up large populations on carrots but may occasionally

cause some feeding injury. Injury is typical of aphid feeding with curled and distorted leaves. If populations are large enough, honeydew accompanied by sooty mold may be produced.

Management

Biological Control
Cotton aphid is attacked by the common aphid predators including green lacewing, lady beetles, and syrphid fly larvae. Several parasites of this aphid are present in California and can provide effective control. Parasitized aphids can be identified by their tan color and bloated appearance.

Cultural Control
Carrots planted adjacent to infested cotton or melons are at risk of becoming infested with this aphid particularly in fall following cotton defoliation or termination of the melon crop. Carrots should be planted a safe distance from both, if possible.

Organically Acceptable Methods
Biological and cultural controls are acceptable for use on organically grown produce.

Monitoring and Treatment Decisions
Monitor fields for aphids weekly during spring and summer by examining the upper and lower surfaces of leaves. Also, look for evidence of predators and parasites and their impact on aphid populations. Treatment not normally required. No thresholds for cotton/melon aphid on carrots have been established. Chemical treatments are not effective in preventing virus transmission and this aphid rarely causes economic damage.

Chemical Control

Both Imidacloprid (Provado) and Diazinon 50 WP are good chemical control methods. You should avoid drifting with both chemicals and runoff into water sources. Uniform coverage is very important and needed for good control.

Green Peach Aphid

Description of the pest

Green peach aphid is most common in spring and fall but may be found at any time throughout the year. It is a medium-sized aphid and the wingless forms are uniformly pale green in color. At times, a pinkish form may be present. During cool weather, individuals of both color forms may be slightly darker than those found during hotter times of the year. Both winged and wingless forms have prominent cornicles that are slightly swollen and clublike in appearance. The frontal tubercles at the base of the antennae are very prominent and are convergent. The winged forms have a distinct dark patch on the top of the abdomen; wingless forms lack this dark patch.

Damage

The green peach aphid vectors more plant viruses than any other aphid, transmitting over 100 different virus diseases. It does not, however, vector *Carrot motley dwarf virus* or *Carrot red leaf virus.* Aphid-infested leaves are distorted and curled. If populations are high enough, stunting may occur. Infestations on young plants are more serious than those on older plants.

Management

Biological Control
Green peach aphid is attacked by a number of common predators and parasites and is susceptible to the fungus disease that commonly attacks aphids. Common predators include green lacewing, lady beetles, and syrphid fly larvae.

Cultural Control
Field sanitation is important in reducing the number of aphids in and around carrots.

Organically Acceptable Methods
Biological and cultural controls are acceptable for use on organically grown produce.

Monitoring and Treatment Decisions
Monitor fields for aphids weekly during spring and summer by examining the upper and lower surfaces of leaves. Also, look for evidence of predators and parasites and their impact on aphid populations. Small colonies occasionally develop on carrot leaves and may reach treatable levels, but no treatment thresholds for green peach aphid on carrots have been established. Green peach aphid has developed a high level of resistance to many chemicals and may be hard to control.

Chemical Control

Imidacloprid (provado) is the only chemical control method, thorough and uniform coverage is important for good control.

Pale Stripped Flea Beetle

Description of the pest

Flea beetle adults are small (about 0.12 inch long), shiny, beetles with enlarged hind legs that allow them to jump like fleas. The palestriped flea beetle has a broad, white stripe down each brown wing.

Damage

Adult flea beetles do most of the damage by feeding on the undersides of leaves, leaving small pits or irregularly shaped holes on the leaves. Large populations can kill or stunt seedlings. Older plants rarely suffer economic damage although their older leaves may be damaged. In the Imperial Valley, larvae feeding on roots have caused serious damage on occasion. This damage is easily confused with cavity spot symptoms.

Management

Cultural Control
Remove weeds along field margins and deeply disk plant residue in infested fields after harvest.

Organically Acceptable Methods
Cultural controls are acceptable for use on organically grown produce.

Monitoring and Treatment Decisions
Check newly emerged seedlings twice weekly for flea beetle damage until plants are well established. Relatively low populations can cause economic damage when plants are in the cotyledon or first leaf stages. Treat if you find several damaged rows; spot treatment of outside rows or borders may be sufficient. Baits are not effective.

Once plants have several true leaves, they can tolerate several beetles per plant without damage. Older plants are even more tolerant. Insecticide treatment should rarely be required, but if it is, one application should suffice. However, chemical treatment may disrupt biological control of aphids and whiteflies.

Chemical Control

Esfenvalerate (Asana XL), Carbaryl (sevin), and Diazinon are all acceptable chemical control methods where drifting and runoff into water supplies should be avoided.

Salt Marsh Caterpillar

Description of the pest

Saltmarsh caterpillar larvae are hairy and gray when first hatched, then darken to yellow, brownish, or almost black with yellow lines. They are covered with reddish or black hairs, and can be up to 2 inches long when fully grown. Eggs are spherical, whitish, somewhat flattened, about 0.03 inch in diameter, and found in clusters on the undersurface of leaves.

Damage

In the southern San Joaquin Valley saltmarsh caterpillars are occasional pests that feed on foliage. They are primarily a problem in fall when neighboring cotton fields are defoliated.

Management

Cultural Control
Ditch or trench around the edges of fields that border cotton.

Organically Acceptable Methods
Cultural control and sprays of the Entrust formulation of spinosad are acceptable for use on organically grown produce.

Monitoring and Treatment Decisions
In fall, if saltmarsh caterpillars are migrating into carrots, a treatment may be necessary.

Chemical Control

Spinoad (entrust) and Carbaryl (sevin) are chemical control methods that are acceptable for control. Drifting and runoff should be avoided.

Whitflies

Description of the pests

Whiteflies are small insects that are about 0.04 inch (1 mm) long. The body and wings of adults are covered with a fine, whitish powdery wax that is opaque in appearance. Whiteflies colonize the underside of leaves; adults and eggs are commonly found on the lower surface of younger leaves and the scale like nymphal stages on somewhat older

leaves. Distinguishing whitefly species is difficult; use a hand lens to examine both immatures and adults. Adult silver leaf whiteflies hold their wings somewhat vertically tilted like the peaked roof of a house, instead of flat over their bodies like the greenhouse whitefly. During the last part of the fourth larval stage, often called the pupa, the whitefly develops red eyes and stops feeding. This is the stage that is easiest to identify silver leaf whitefly; pupae have no waxy filaments around their edges as do most other species of whiteflies.

Damage

Extremely dense populations of silver leaf whitefly may immigrate into late August or September plantings of carrots in the low deserts of southern California and damage seedlings. In light to moderate infestations, leaves show no distinctive symptoms as a result of whitefly feeding; however, copious quantities of honeydew are deposited on leaves, resulting in a shiny, sticky appearance.

Management

Whiteflies can be very difficult to control with insecticides. Natural or introduced biological methods provide the best long-term solution to keeping whitefly numbers at a minimum along with reducing host plants in areas of heavy infestation. If you treat for silverleaf whitefly, make applications before pests build up and contaminate carrot tops with honeydew.

Biological Control

Several parasitic wasps, including species in the *Encarsia* and *Eretmocerus* genera, control whiteflies. Whitefly nymphs are also preyed upon by bigeyed bugs, lacewing larvae, and lady beetles. The lady beetles, *Delphastus pusillus* and *Serangium parcesetosum,* were introduced into the lower desert region to assist in biological control, but their impact has yet to be determined. Encourage buildup of beneficial insects by avoiding the use of nonselective pesticides and by protecting their habitat.

Cultural Control

Remove field bindweed and other weeds in and adjacent to the crop field as well as crop residues. Host-free periods (168 KB, PDF) are valuable for controlling several of the whitefly species.

Organically Acceptable Methods

Biological and cultural controls, as well as soap sprays, are acceptable for use on organically grown produce.

Monitoring and Treatment Decisions

Carrots are not a preferred host of whiteflies and in some areas treatment with insecticides

is rarely justified. Where silverleaf whitefly is a chronic problem, a treatment with imidacloprid (Admire) at planting will effectively control whiteflies during the critical period of stand establishment. If treatment is not applied at planting, occasionally dense colonies of silverleaf whitefly nymphs can necessitate treatment of bunching carrots to prevent honeydew and sooty molds from severely contaminating the carrot tops.

For foliar treatment, combinations of a pyrethroid insecticide (esfenvalerate) with either methomyl or endosulfan provide superior control over applications of a single insecticide. Rotate pyrethroid treatments with a treatment of insecticidal soap to help slow development of insecticide resistance. There is some evidence of endosulfan resistance in populations of silverleaf whitefly in the Imperial Valley. Insecticidal soaps control all immature stages of whiteflies, including eggs, whereas the other materials control first instar nymphs and adults only; thus, treatment timing is critical.

Chemical Control

Imidacloprid (admire pro) is a chemical control that should be applied at planting to control migrating whitefly adults during stand establishment. Has minimal effect on beneficial insects. Do not exceed 10.5 fl oz/acre/season. Insecticidal soap must contact the insects to be effective but is safe for the environment and should be applied every 10-14 days. Mehomyl (lannate) should be applied as needed for control, but do not exceed 0.5 lb a.i. (3 qt esfenvalerate/acre/season). Use ground application only.

Alteraria Leaf Blight

Symptoms

Alternaria leaf blight symptoms appear as dark brown to black irregularly shaped lesions on leaf blades and petioles. Spots are initially surrounded by a yellow margin and often begin on the older leaves. Leaves can be killed when spots grow together. Lesions that develop on petioles may kill entire leaves. Leaves weakened by blight may break off when gripped by mechanical harvesters, resulting in the roots being left in the ground. The pathogen also causes damping-off of carrot seedlings.

Comments on the disease

The disease is favored by rainy weather and/or overhead irrigation. The pathogen,*Alternaria dauci,* is seedborne and survives on and is spread on carrot seed. It can also survive in carrot debris and on volunteer carrots. Spores are dispersed in air and splashing water. The optimum temperature for growth and infection is 82°F with some infection occurring at temperatures as low as 57°F and as high as 95°F. Although the fungus survives on carrot debris left in the field after harvest, once the crop residue decomposes, the fungus dies.

Management

Cultural Control
Planting *Alternaria*-indexed seed or treating seed in a hot water bath is very important. Turn under carrot residue by tillage or plowing to hasten decomposition of debris. Practice 2-year rotations: avoid continuous carrot culture. Do not plant new fields near existing fields with blight symptoms.

Many growers use sprinkler irrigation throughout the growing season. In areas with rainy weather, furrow irrigation may aid in disease reduction. In the Coachella Valley, sprinklers are the preferred irrigation method used.

Organically Acceptable Methods
Cultural control, hot water dips, and foliar sprays of Serenade ASO and MAX are acceptable for use on organically grown produce.

Monitoring and Treatment Decisions
Seed treatments may reduce *Alternaria dauci.*Assay the seed and if pathogen is found, treat. If seed are not treated, apply fungicides when the first blight symptoms appear, at biweekly intervals, and/or when conditions are favorable for disease development.

Chemical Control

Seed Treatment

Iprodione (Rovral) Soak seeds for 24 hours at 86°F (30°C) in a solution of iprodione and water. Use 6 gal of solution for 3 lb of carrot seed. Use of this material allowed under a 24(c) registration.

Foliar Treatment

Azoxystrobin (Quadris) do not make more than one application before rotating to a fungicide with a different mode of action. Do not make more than four foliar applications of strobilurin fungicides per crop. Boscalid (Endura) is another foliar treatment that you

should limit potential for resistance development, do not make more than 5 applications per season or more than two sequential applications before alternating to a fungicide with a different mode of action. Chlorothalonil (Bravo Weatherstik) should be repeated every 7-10 day intervals if necessary to maintain control. Pyraclostrobin (Cabrio) can be used but do not make more than two sequential applications before rotating to a fungicide with a different mode of action. Do not make more than three applications of strobilurin fungicides per crop.

Bacterial Leaf Blight

Symptoms

Bacterial leaf blight is often first noticed in fields as brown areas about 3 to 4 feet in diameter. Leaf symptoms appear as irregular brown spots, often beginning on the leaf margins. Lesions initially have an irregular, yellow halo and may appear water soaked. Spots coalesce and cause a leaf blight and dark brown streaks develop on leaf petioles. Floral parts may also be blighted. A sticky amber-colored bacterial exudate, which is a diagnostic sign of the disease, may be present on leaves or observed flowing downward on petioles and flower stalks.

Comments on the disease

Xanthomonas campestris pv. *carotae* is seedborne and survives on and is spread with carrot seed. The bacteria also survive in carrot debris but cannot survive in the soil in the absence of debris. Rain or sprinkler irrigation is required for optimum disease development. Warm weather favors infection and disease development. Optimum temperatures are between 77° and 86°F; infection does not occur below 65°F. The pathogen is dispersed in splashing water. Plant-to-plant spread may occur under heavy dew conditions.

In most carrot-growing areas bacterial blight does not warrant control. In a few areas, such as the Antelope Valley, severe outbreaks may occur.

Management

Cultural Control

Plant *Xanthomonas*-indexed seed or treat seed in a hot water dip. Use furrow or drip irrigation rather than sprinklers. Turn under carrot residue to hasten decomposition. Avoid continuous carrot culture by using a 2- to 3-year crop rotation scheme.

Organically Acceptable Methods

Cultural controls, hot water dips, and sprays of certain copper sulfate formulations are acceptable for use on organically grown produce.

Monitoring and Treatment Decisions

Assay seed and treat if pathogen is found. Foliar treatments occasionally necessary if rainy weather persists.

Chemical Control

Seed Treatment

Seed can be soaked in hot water (above 126 degrees) for 25 minutes.

Foliar Treatment

Copper Sulfate can be applied must repeat applications at 7- to 14-day intervals, if necessary, to maintain control. Not all copper compounds are approved for use in organic production so be sure to check individual products. Copper Hydoxide (Champ, Kocide 2000) can also be applied to field.

Black Rot

Symptoms

Black rot starts in the carrot crown at the point of leaf attachment, beginning with the outermost petioles; eventually all the leaves can be killed. The upper part of the carrot root will show a dark rot, which occasionally may continue into the lower part of the carrot root. Leaves weakened or rotted by black rot may break off when gripped by mechanical harvesters, resulting in roots being left in the ground. Black rot can also be a problem in storage.

Under certain conditions, the fungus also can cause a leaf blight, which is characterized by dark brown lesions along the leaf margins. The fungus can also cause a pre- and postemergence damping-off of carrot seedlings.

Comments on the disease

The fungus is favored by sprinkler irrigation or rainy weather and high temperatures, which may predispose tissue to infection. *Alternaria radicina* is seedborne and may be spread on carrot seed. It also survives in carrot debris and in the soil for several years. Black rot is important only in certain areas or regions in California. It is common in coastal mountain valleys, e.g., the Cuyama Valley.

Management

Cultural Control

Plant *Alternaria*-indexed seed or treat seed in a hot water bath; this is especially important in fields where black rot has not been identified or carrots have not been grown.

Furrow rather than sprinkler irrigation may reduce disease development. Crop rotation is highly recommended to prevent buildup of the fungus in the soil. Deep tillage may provide some control by burying inoculum of the fungus away from the carrot crown.

Organically Acceptable Methods

Cultural controls are acceptable for use on organically grown produce.

Monitoring and Treatment Decisions

Assay seed; if pathogen is found treat seed. Foliar applications of fungicides to control black rot are marginally effective.

Chemical Control

Seed Treatment

Iprodine (rovral) can be used to treat seed, soak seeds for 24 hours at 86°F (30°C) in a solution of iprodione and water. Use 6 gal of solution for 3 lb of carrot seed. Use of this material allowed under a 24(c) registration. You can also use a hot water dip that is above 122 degress for 25 minutes, but do not soak seed longer or seed could be damaged.

Foliar Treatment

The only foliar treatment is Iprodine (rovral) that is available as of today.

Asparagus

Asparagus Beetle

Description of the pests

Asparagus beetle larvae are dark green-gray grubs about 1/3 inch (9 mm) long when fully grown. Adults are blue-black beetles with a red prothorax. Their elytra (wing covers) have yellow spots and red borders.

Spotted asparagus beetle larvae are orange colored and adults are reddish orange with six prominent black spots on each wing cover.

Damage

Asparagus beetles injure the plant by feeding on the tips of tender young shoots. After leaves come out, asparagus beetles and their larvae gnaw on the surface of the stems and devour the leaves. If injury to the fern is severe, the crown is weakened, particularly if the asparagus stand is young.

Management

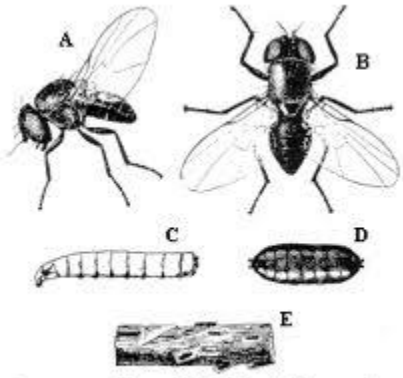
Although they are found wherever asparagus is grown, asparagus beetles are not normally serious pests in California. Some local infestations do occur, however, and control measures may be necessary to prevent serious injury to the asparagus stand, particularly when the stands are young. If beetles are feeding on spears early in the season, let some plants near the edge of the field produce fern growth to attract the beetles away from the spears. If necessary, treat these areas.

Chemical Control

Spinetoram (Radiant) apply only postharvest to ferns, do no tapply within 60 days of spear harvest. Chlorpyrifos (Lorsban Advanced) apply to the fern stage; limited to 2 postharvest applications/year; Avoid drift and tail water runoff into surface waters. Use allowed under a Supplemental Label. Methomyl (lannate) Apply at 5–7 day intervals as needed. Do not apply more than 4.5 lb a.i./acre/crop. Carbaryl (sevin XLR Plus) apply to ferns or brush

growth. Repeat applications as necessary but not closer than 7 days and not more than 5 applications/year. Permethrin (Ambush, Pounce) apply by ground equipment only. Do not apply more than 0.4 lb a.i./acre/season. Pyrethrin/rotenone (Pyrellin EC) apply at intervals of 7 days or less and repeat as necessary. Less effective than other materials.

Asparagus Miner



Asparagus miner. A-B, Adult. C, Maggot. D, Puparium. E, Damage.

Description of the pest

Adult asparagus miners are present in May and again in late summer. They are shiny black, slightly humpbacked flies that are about 0.1 inch (2.5 mm) long. Tiny, whitish eggs (0.001 inch) are laid at the base of the stem are seldom seen because they are deposited beneath the epidermis of an asparagus stalk. The white-colored larva is about 0.015 inch (0.4 mm) long when it hatches from the egg and grows to about 0.2 inches long. Dark brown, flattened, pupae can be seen beneath the epidermis at the end of mines and measure up to 0.17 inch (4 mm) long. Asparagus miner overwinters in the pupal stage either in the stalk or in the soil.

Damage

Asparagus miner larvae occasionally injure asparagus during the fern growth stage but in California are not usually found damaging spears. Larvae mine just beneath the surface of fern stalks. Often the miner feeds upward in a meandering pattern and then turns downward as it continues to feed and can occasionally girdle the stalk causing the fern to yellow. Under heavy infestation, multiple mines may be seen in a single fern stalk. A direct association of asparagus miner feeding during the fern stage of plant development and yield losses in asparagus spear yield has not been conclusively shown.

Management

Asparagus miner populations have been reported to be reduced by several parasitic wasps *(Dacnusa rondani, Dacnusa bathyzona, Pleurotropis epigonus,* and *Sphegigaster* spp.), all of which attack pupae.If a heavy infestation is found, burning to destroy the pupae may help reduce the overwintering population (where burning of shredded asparagus ferns is still allowed in California). Spraying insecticides to control asparagus miner is rarely if ever justified.

Organically Acceptable Methods
Encouraging natural enemies.

Cutworms

Description of the pests

Cutworm larvae feed at night and come in various colors and patterns but always appear as smooth-skinned caterpillars to the naked eye. They frequently roll into a C-shape when disturbed. The mature variegated cutworm larva is yellow to brown, a little over an inch long (3 cm), with a row of 4 to 6 yellow or pink diamond-shaped spots down the back. The mature dark-sided cutworm is somewhat larger than the variegated cutworm (1.5–2 inches, 4–5 cm) and gray to greenish gray in color with irregular, longitudinal stripes.

Adult cutworm moths are rather nondescript with dark gray or brown front wings that have irregular spots or bands and lighter hind wings.

Damage

Larvae feed at night on the tender tips of new asparagus spears where they eat small holes. One-sided feeding may also cause the spears to curl. The variegated cutworm also feeds underground and at the soil surface. Fern damage is generally rare.

Management

Carry out good weed control in and around the field and incorporate field trash and previous crop residues thoroughly to reduce egg and worm overwintering. Look for damage symptoms and confirm cutworm's presence by digging into the soil an inch or so

around a damaged spear. Begin applications when insects first appear. If infestations are localized, consider spot treatments.

Organically Acceptable Methods
Good weed management and field cultivation are acceptable to use in an organically certified crop.

Chemical Control

Carbaryls (sevin) apply when pests appear in damaging numbers and repeat 7–14 days later if necessary. Ground application; do not apply more than 20 lb/acre to spears. Methomyl (Lannate) use low rate for variegated cutworm. Apply at 5- to 7-day intervals as needed. Do not apply more than 4.5 lb a.i./acre/crop. Permethrin (Ambush,Pounce) apply by ground equipment only. Do not apply more than .4 lb per acre per season.

Diseases

Asparagus Viruses I And II

Symptoms

Asparagus viruses I and II produce no distinct symptoms unless both viruses infect the plant. Either virus by itself may only slightly reduce vigor. When both are present in the same plant, survival and vigor are severely reduced, especially in young plants. The combination of both viruses may be partly responsible for the reduction in the profitable life of asparagus plantings. Also, when plants are infected with both viruses, they become more susceptible to Fusarium wilt.

Comments on the diseases

Both viruses are transmitted by aphids.*Asparagus virus II* is also transmitted through seed and may be transmitted in pollen from male plants to seed produced by female plants. *Asparagus virus II* is more prevalent in older cultivars, such as Mary Washington.*Asparagus virus II* may be transmitted mechanically on harvest knife blades, mowers, cultivation equipment, or any other activity that moves plant sap from one plant to another.

Management

Plant virus-free seed grown from healthy plants or plant transplants grown from tissue culture to eliminate the viruses.

Organically Acceptable Methods
Purchase of virus-free seed or transplants is acceptable for use in an organically certified crop.

Crown and Spear Rot

Crown Rot

Symptoms

Phytophthora spear rot is characterized by soft, water-soaked lesions on shoots at, slightly above, or below the soil level. The lesions elongate rapidly and become light brown. As the lesion collapses and shrivels, the affected side of the spear becomes flattened, and the shoot becomes extremely curved and may even collapse. This symptom is not diagnostic, however, as insect and mechanical injury can result in crooked spears. Infected young storage roots appear water soaked but firm.

Crowns infected with *Phytophthora* spp. have yellow-orange colored tissue. In severe infections the tissue appears waterlogged and fibrous.

Comments on the disease

Phytophthora is a soilborne fungus; it infects the shoot near or just below the soil line during very wet periods. Heavy spring rains can induce severe disease losses. Although crown and spear rot is erratic in California, the fungus is present in all production areas of the state. Desert areas, however, usually escape the disease unless conditions are unusually wet. Infected spears, if hydrocooled during packing for market, may contaminate the water and spread the pathogen to other spears, causing extensive rot during transit.

Management

Whenever possible, plant in *Phytophthora*-free soil and use disease-free transplants. Provide good drainage and do not overwater. If symptoms occur, treatment may be necessary.

Organically Acceptable Methods

Avoid *Phytophthora*-infested soils and use disease free transplants when growing an organically certified crop.

Chemical Control

Mefenoxam (Ridomil Gold) cutting beds; apply 30–60 days before the first cutting. For additional control, make another application just before the beginning of harvest. New plantings: Apply after planting seedlings or after covering 1-year-old crowns. Fosetyl-al (Aliette) apply once over the top to fully expanded asparagus ferns. Control with fosetyl-al is erratic.

Rust

Symptoms

Rust is most common on fern growth after the harvest season is over. Infections begin in spring from spores that overwintered on crop debris. These infections produce the orange stage (pycnia and aecia) of the disease. Occasionally, this stage can be found in spring on emerging spears from new or established plantings. The orange stage is characterized by light green patches on new spears that mature into yellow or pale orange pustules in concentric ring patterns. Spores produced by these spring stages are airborne to new fern growth. Infection occurs and brick red pustules develop on stalks, branches, and leaves of the fern. These red pustules produce airborne, rust-colored spores (urediospores) in a powdery mass, which can reinfect the fern and increase disease incidence. Fern yellowing and browning, defoliation, and dieback may occur. As ferns mature and senesce, or autumn weather begins, the black spore stage may develop. The same pustules that produced the red spores begin producing black spores (teliospores). The pustule will slowly convert in

appearance to a powdery mass of jet-black spores. These black spores are the overwintering stage of the fungus.

The overall effect of rust on asparagus is reduced plant vigor the following year and reduced yields.

Comments on the disease

Rust diseases have several stages, some of which may occur on different hosts. In asparagus rust, however, all the life stages (orange spore in spring, red spore in summer, and black spore in fall and winter) occur on asparagus. Therefore, what may appear to be a different disease, could be a different stage of rust.

Rust is favored by temperatures between 55° and 90°F. Several hours of dew or rain (free water) are necessary for spores to germinate and infect the host.

Management

Good field sanitation and irrigation practices are important components of managing rust. Treatments are necessary when monitoring indicates rust is present.

Cultural Control

Provide adequate irrigation during the spring/summer fern period so that plants are neither over-or under-watered. Orient rows with the prevailing wind, if possible, to allow free flow of air through the field. This will allow faster drying of the soil surface when irrigations or rainfall occur. At the end of the fern season, cut and destroy diseased ferns. One of the best solutions is to incorporate the cut fern with a power driven rotary tiller two times, once in each direction. The fern may also be removed from the field. Cut young spears to keep infections from occurring, thus breaking the cycle of the fungus in spring. Destroy volunteer asparagus within 400 yards of commercial asparagus fields.

Organically Acceptable Methods

Cultural control and sulfur dust treatments are acceptable to use in an organically certified crop.

Monitoring and Treatment Decisions

Monitor spears and ferns for the appearance of rust lesions. Begin treatments when rust first appears.

Chemical Control

Chlorothalonil (Chlorothalonil 720) do not apply within 120 days of spear harvest for the following season. Research from Michigan indicates very effective. Myclobutanil (Rally) begin applications to the developing ferns after harvest has taken place. See label for

restrictions. Mancozeb (Penncozeb, Manzate, Dithane) apply at first sign of rust and repeat at 10-day intervals until disease pressure subsides. Do not apply during harvest. Do not apply more than 6.4 lb a.i./season. Apply only on asparagus ferns after spears have been harvested. Micronized sulfur (Thiolux) although this material is registered, it does not provide very effective control. Use after cutting stops. May repeat at 7- to 10-day intervals throughout the season

Fusarium Wilt

Symptoms

Mature plants infected with Fusarium gradually decline in productivity and growth. During the summer, infected plants are characterized by one to several stunted, bright yellow ferns. Areddish brown vascular discoloration, which may extend into the crown, is present at the base of stalks infected by *Fusarium oxysporum*f. sp. *asparagi.* Crowns and belowground portions of stems exhibit reddish flecks or sunken brown lesions, which can be seen by cutting them open. Reddish brown, elliptical lesions occur on storage roots of infected plants. Feeder roots, most of which may be rotted off completely, show reddish brown discoloration.

Comments on the disease

Fusarium crown and root rot is the major disease of asparagus worldwide. The fungus survives in the soil indefinitely, and may spread as a seedborne contaminant. Spread is by movement of infested soil within the field, on transplants grown in infested soil, and on plants grown from contaminated seed. Infection occurs at any point below ground; all three fungi can colonize the crown and roots;*F. oxysporum* f. sp. *asparagi* can also invade the xylem tissue. Adverse environmental factors and the interactions of Fusarium crown and root rot with other diseases or insects add stress to plants and further reduce plant vigor. Excessive cutting periods (greater than 75 days) may also weaken asparagus and increase susceptibility to wilt.

Management

Use clean seed in noninfested soil to produce disease-free seedlings, transplants, or crowns. Long rotations out of asparagus are beneficial. Minimize plant stress as much as possible. Hybrid varieties such as UC 157, Apollo, and Jersey Giant have increased plant vigor, which provides a degree of tolerance but not resistance, to this disease. Avoid extended harvest periods and end harvest when production declines to 70% of the season's highest yield to maintain crown vigor. Maintain crown vigor with proper irrigation and fertilization.

Organically Acceptable Methods

Good field sanitation, resistant varieties, and good cultural practices are all acceptable to use in an organically certified crop

Purple Spot

Symptoms

Purple spot is of major concern when new spears are emerging and being harvested. The pathogen produces elliptical, slightly sunken lesions 0.03 to 0.06 inch across and up to 0.125 inch long. Initially lesions are reddish-purple and later develop a tan-brown center, especially if the lesion is large. Lesions usually appear on the lower half of new spears and are very superficial. The internal tissue of the spear is not affected.

Comments on the disease

Purple spot is worse following cool, wet weather during spear emergence. The disease is usually most intense where debris from the previous year's fern growth is lying on the soil surface. The sexual stage, *Pleospora allii,* develops on this debris. Wounding of the spear is not necessary for infection; however, wounds created by blowing sand can increase the incidence of disease.

Once dry weather conditions develop, the disease subsides.

Management

Good field sanitation is important in managing purple spot and other diseases. Last season's fern growth, which is the primary inoculum source, should be burned (where permitted), chopped and incorporated, or removed from the field before new spears emerge. Destroy volunteer asparagus within 400 yards of commercial asparagus fields. One of the best solutions is to incorporate the cut fern with a power driven rotary tiller two times, once in each direction. Chemical treatments are not recommended in California for this disease.

Organically Acceptable Methods

Cultural control methods and good field sanitation are acceptable for use in an organically certified crop.

Raspberries

Leafhopper

Description of the pests

Both leafhopper species overwinter in the egg stage. Rose leafhopper eggs are laid in young stems on plants of the rose family (including cranberries), and white apple leafhopper eggs are laid in 3- to 4-year-old apple twigs. Eggs of both species cause a pimple like swelling of the bark where they are laid. Overwintered eggs begin to hatch in mid-April. The nymphs develop on their overwintering hosts and disperse as adults in early June. Adults of both species are present by June; both are white, about 1/8 inch (3 mm) long, and cannot be readily distinguished from each other. They rest on the undersides of leaves and fly actively on warm days. There are two generations of white apple leafhoppers and three generations of rose leafhoppers per year.

Damage

Like mites, leafhoppers damage blackberry and raspberry leaves by sucking on leaf tissue and removing green chloroplasts from cells, thus preventing the proper functioning of leaves. Heavily infested leaves are speckled with white markings. They also bear cast skins and tiny specks of black excrement. Leafhoppers do not feed on fruit but can contaminate it with black specks of excrement.

Management

Parasitization of eggs may play a significant role in keeping populations of leafhoppers in check. Another factor is predators, which include green lacewings and minute pirate bugs. If high populations of leafhoppers develop, apply a treatment.

Chemical Control

Malathion 8 highly toxic to honey bees; do not apply if crop or weeds are in bloom. Insecticidal soap target first generation nymphs. Provides only a temporary reduction in the population levels, which generally rebound as a result of immigration.

Raspberry Borer

Description of the pest

Although the adult raspberry borer is a moth, it resembles a yellow jacket wasp. Belonging to the family of clearwing moths, it has a wingspan of about 1 inch and has a black body with four yellow horizontal stripes on the abdomen as well as stripes on the thorax. The legs are yellow, and the feathery antennae, unlike the short antennae of a yellow jacket wasp, curve outward from the head.

The raspberry crown borer takes 2 years to complete its life cycle. The female raspberry crown borer moth lays up to 140 reddish brown eggs most often on the underside edges of cranberry leaflets in late summer. Once hatched, larvae migrate to the base of the cranberry plant where they either dig into the base of cane and form a blister like hibernaculum or find a protected area in the bark and stay there for the winter. With the onset of spring the following year, the larva begins to burrow galleries through the crown of the plant and continues to do so through the first summer. The second winter is spent in the roots; the larva is about 0.4 to 0.9 inches (1.3–2 cm) long at this time. The second summer, the excavation continues in the roots and crown. At midsummer of the second year, the larva is full-grown, measuring 1 to 1.5 inches (2.5–3.3 cm) long. It undergoes a short pupation period of 2 to 3 weeks in the burrow in the crown and emerges as an adult moth. Adult moths are active from early August to late September and may be seen during the day resting on foliage.

Damage

A cranberry plant that is infested with a raspberry crown borer larva will begin to wither and visibly wilt because of the physical damage to vascular tissue, especially in the second

year of infestation. A hole at the base of the plant in the crown with sawdust like frass at the entrance is also indicative of raspberry crown borer activity.

Management

The best way to manage the raspberry crown borer is to prevent its intrusion into the caneberry field through the cultural controls. In the event that this pest establishes itself in the field, the chemical controls below may prove useful.

Biological Control

There is no commercially acceptable biological control for raspberry crown borer in the field at this time.

Cultural Control

The use of clean planting stock is necessary to reduce the movement of infested plant stock from one field to another. The removal of wild blackberries surrounding the field can help reduce populations of raspberry crown borer.

Organically Acceptable Methods

Cultural controls are organically acceptable.

Monitoring and Treatment Decisions

Monitoring this pest is difficult because it is hidden away in the crown of the plant. By the time the damage is noticed, it is too late to do anything effective. If a population becomes established in the planting, treatments may be warranted.

Chemical Control

Diazinon apply in a minimum of 100 gal water/acre drench to crown and lower canes before buds break in early spring. Repeat yearly as necessary. Avoid drift and runoff into surface waters. Where caneberry is grown near waterways, do not use diazinon.

Raspberry Mite

Description of the pest

The red berry mite is a perennial pest of both cultivated and wild blackberries but is not an economic pest of raspberries. These mites belong to a group of microscopic mites known as eriophyid mites. This eriophyid mite has two pairs of legs; it can be seen with a 10 to 20X hand lens but is best seen with a dissecting microscope. The adult is wormlike and translucent white.

Red berry mites overwinter in bud scales or deep in buds. As shoot growth develops in spring, the mites move onto the developing shoots. As flower buds appear, the mites work their way into the unfolding buds, into the flowers, and down among the developing druplets of the berries, especially near the bases and around the core of the fruit.

Damage

Fruit infested with red berry mites do not develop normally colored druplets. Affected druplets usually remain hard and have a green or bright red color. The fruit is unmarketable. Fruit partially affected may have some druplets remain red and hard with the remaining druplets developing proper ripening. If not controlled, red berry mite can spread from isolated infestations to sizable portions of a planting in the next season. Very high populations can result in significant crop loss. The pest is most damaging to late-maturing blackberry cultivars.

Management

The best time to control redmberry mite depends upon variety grown and miticide that will be used. Note that oil and sulfur products should never be tank-mixed because of the risk of phytotoxicity. If oils are used after or before sulfur products, be sure to observe all recommended label precautions.

Lime Sulfur
Timing of lime sulfur applications depends upon variety grown and red berry mite severity. *For blackberry varieties that retain a leaf canopy through the winter,* begin lime sulfur applications at bud break and continue at 3-week intervals up to 12 days before the start of harvest. *For blackberry varieties that naturally defoliate over the winter,* apply lime sulfur before buds break dormancy and then not again until canes have a full leaf canopy and first bloom appears.

Horticultural Oils
Horticultural oils, such as Golden Pest Spray Oil, when used at the rate of 1.2 to 2% volume to volume, applied after green fruit or first pink fruit stage in four consecutive applications spaced 2 or 3 weeks apart give significant control of red berry mite, while causing less harm to fruit yield than sulfur sprays.

Complete plant canopy coverage is important when using horticultural oils, so the minimum amount of water carrier should be 50 gallons per acre.

The potential for phytotoxicity of oil product and/or oil product mixes has not been fully evaluated for all blackberry varieties in all growing areas. Small plot tests are prudent to determine safety margins of particular blackberry varieties for specific environmental conditions in different growing areas.

Chemical Control

Dormant/First Bloom

Lime sulfur apply 200 gallon water/acre

Green Fruit/First pink fruit

Horticultural oils the potential for phytotoxicity of oil products and oil product mixes for all blackberry varieties in all areas has not been fully evaluated. Growers are encouraged to test product and/or product mixes for phytotoxicity before field application to determine safety margins. Check with your certifier for organically acceptable products

Two spotted Spider Mites

Description of the pest

Twospotted spider mites infest the undersides of caneberry leaves, where they may form colonies and produce light webbing when abundant. Two spotted spider mites are very small (about 0.02 inch in length) and are barely visible to the naked eye. Nymphs, adult males, and reproductive females are green to a yellowish hue in color.
Reproductively dormant females are bright orange and should not be confused with the predatory mite, *Phytoseiulus persimilis,* commonly found in mite colonies. Under a hand lens, one can see two dark blotches on either side of the adult two spotted spider mite's body and two red eyespots on the head.

In areas where temperatures are cold in winter, two spotted spider mites overwinter as dormant adult females at the base of the caneberries or weeds in and around the field. With the onset of warm weather, these mites migrate to the foliage of the plant and begin to lay eggs. In the mild winter coastal-growing regions of California, it is unusual for a large percentage of mites to become dormant; instead they continue to grow and lay eggs, although at a slower pace during the winter months than in summer. The two spotted spider mite undergoes one larval and two nymphal stages before becoming an adult. The life cycle, under ideal conditions of hot, dry weather, can take place in 10 days.

Damage

Spider mites feed by sucking juices from the plant and cause a gray stippling on the leaf surface. As the population grows and feeding progresses, leaves turn yellowish brown before drying up and falling off. Feeding by twospotted spider mites on fruiting floricanes reduces plant vigor and fruit yield and size. Mite feeding can also weaken primocanes, predisposing them to winter injury in areas of cold winters and reducing yield the following season.

Management

Two spotted spider mites can be a problem in any caneberry planting if condition are conducive to their development, but they pose a special problem in plantings that use macro tunnels because of the hot, dry conditions that are created by the tunnels. The key to successful management of two spotted spider mites is to monitor populations and to initiate control measures in a timely manner. Once populations are large, much damage has been done, and the mite populations are difficult to control.

Biological Control

The most effective biological control agent of two spotted mite is the predatory mite *Phytoseiulus persimilis*, which is an introduced species. *Phytoseiulus* does best in temperatures of 60° to 80°F and will not do well above 100°F. Because the temperatures in macro tunnels are generally higher than outside, *P. persimilis* does not perform as well inside of the tunnels. This predatory mite has apparently established itself in some locations and provides some natural suppression in these areas. It may also be purchased and released in fields for additional control.

Cultural Control

Normal pruning of primocanes and removal of dead floricanes in caneberries can be helpful in reducing the buildup of two spotted spider mite. Varieties with heavily pubescent leaves can make establishment difficult for two spotted spider mites and may be useful for those situations where two spotted mites are a significant problem. Because the warm, dry conditions within a macro tunnel are very conducive to the population growth of two spotted spider mites, limiting the use of tunnels or venting them to maintain a lower temperature will limit the numbers of this pest mite. Also, controlling dust by watering or oiling surrounding roads is an important factor in limiting two spotted spider mite populations.

Organically Acceptable Methods

Cultural and biological controls including the release of predatory mites, and narrow range oil sprays, such as Organic JMS Stylet oil, are organically acceptable methods.

Monitoring and Treatment Decisions

No precise treatment thresholds have been established for two spotted mites in caneberries. Monitor to keep track of increasing pest mite populations as well as predatory mite populations. A ratio of 1 predator to 10 two spotted mites is considered favorable for biological control. When using chemical controls, it is important to know that good coverage is essential. In many cases, especially with the spray oils, mites that escape contact with the control material will survive.

Root Weevils

Description of the pests

Adult root weevils are beetles. They feed at night and hide around the crowns of plants during the day; they cannot fly. The adults, nearly all females, emerge in late spring or early summer, feed on foliage, and lay their eggs around the crowns about 1 month after emergence. After hatching, weevil larvae work their way into the soil and feed on the roots and crowns of canes. They have curved, white or pink bodies that are about 0.38 inch (9 mm) long when fully grown. They have distinct brown heads but no legs. Root weevils overwinter as larvae, and in spring they resume feeding and can cause extensive damage before they pupate. Root weevils have a single generation each year. The Fuller rose beetle can be distinguished from the other weevils by an oblique, white band on the side of each wing cover. In addition, their larvae have pale, almost white heads. The black vine weevil is the largest and has a distinct black color. The woods weevil is the smallest of the group.

Damage

Larvae feed on the roots of both blackberry and raspberry plants and can completely devour small rootlets and destroy the bark and cortex of larger roots. Soon after feeding begins, plants wilt because the roots can no longer provide moisture for leaves. It is not uncommon to find weevil larvae that have penetrated into the lower portion of the plant's crown. Adults feed on foliage and remove large scallops from the leaves. Such leaf damage is a good indication that weevils are present but is not economically damaging to the plants.

Management

Destroy all infested plants and move outward in a circular pattern removing plants that appear healthy. Examine roots and crowns for larvae and pupae until you no longer find weevils. Replant, if necessary, after working the soil well. Sticky barriers can be used to

prevent movement of adult weevils from infested second-year canes and host areas to replanted areas or newly fumigated plantings.

Diazinon is registered and can be effective as a drench application early in the season. Preplant soil fumigation for weed and disease control will destroy larvae and pupae in the soil. An alternative to the use of soil fumigants is the application of commercially available parasitic nematodes, *Heterorhabditis bacteriophora* or *Steinernema carpocapsae.* Apply the nematodes from mid-summer to fall or before adults start emerging in spring, about mid-March for most weevil species in northern California. In hot areas, apply nematodes in early morning or evening. Soil must be warm (at least 60°F) and moist but not soggy before application and for 2 weeks after; if necessary, irrigate every 2 to 3 days during this period.

Chemical Control

Phtoseiulus release mites early in the season before foliage on the canes begins to close the space between canes. Bifenazate (acramite) use permitted on crops that will not bear for 1 year after application. Use minimum of 50 gal water/acre. Horticultural oils amount is for 100 gal/acre; may use up to 150 gal/acre water carrier. Spray with ground equipment for optimum coverage of leaf surfaces. Oil sprays need to be applied frequently to achieve acceptable control, however, frequent applications of oils can damage the plant and compromise fruit yield. Heed label warnings about compatibility with other materials. Hexythiazox DO NOT make more than one application per year. Cinnamaldehyde (cinnacure) apply in 100–200 gal water/acre, apply every 10 days and check for phytotoxicity. Cotton seed/clove/garlic oils good coverage is essential for control; the use of a spreader/sticker may improve contact and efficacy of treatment. Oil sprays need to be applied frequently to achieve acceptable control, however, frequent applications of oils can damage the plant and compromise fruit yield. Apply no more than once in a 7-day period.

Greenhouse White Fly

Description of the pest

Greenhouse whitefly adults lay masses of minute, elliptical eggs on the undersides of leaves. After hatching, the whitefly larva goes through four instars of development, the last of which is often called the "pupal" stage and is most identifiable by long, waxy filaments around the margin of the body and red eyes. The adult emerges from this state and is a tiny, white insect that is about 0.06 inches (1.5 mm) long. It has four membranous wings that are held parallel to the top of the body and covered with white wax. The wings partially fold over one another. Adult whiteflies occur in dense colonies on the undersides of leaves in newer growth of caneberries and fly when the leaves are disturbed.

Development of the greenhouse whitefly from egg to adult takes as little as 18 days, if temperatures and host plant conditions are ideal. Ideal temperatures for fastest development are between 80° and 90°F.

Damage

Greenhouse whiteflies can be a problem in raspberry and blackberry crops. They tend to favor succulent, actively growing plant tissue. They damage plants by feeding on the sap, which reduces plant vigor but most harm is caused by the exudation of sticky honeydew. When this exudate is deposited on fruits, it makes the fruit less attractive and marketable. Honeydew also promotes the growth of black sooty mold on fruits and leaves, which sharply reduces fruit quality. Although greenhouse whitefly is capable of transmitting viruses, it has not been associated with any significant viruses in caneberries grown in California.

Management

A management program in caneberries for whitefly can benefit from an integrated approach that incorporates cultural, biological, and chemical methods. Avoid disruptions of native predator and parasitoid populations, along with applying cultural controls whenever possible.

Biological Control
Natural enemies of whitefly include *Encarsia, Eretmocerus, Prospaltella,* big eyed bugs, minute pirate bugs, and lacewing larvae. Up to 40% of whitefly can be parasitized and predated in certain areas of the Central Coast. However, releases of large numbers of predators or parasites for whitefly control have not been successful in California caneberries.

Cultural Control
Normal pruning of primocanes and removal of dead floricanes in caneberries can reduce the buildup of greenhouse whitefly populations. It is important to note that the host range of greenhouse whitefly is quite broad and includes alfalfa, avocados, beans, cucumbers, eggplants, grapes, lettuce, melons, peas, peppers, potatoes, strawberries, tomatoes, and many ornamental crops. Monitor whitefly activity in adjacent fields, and initiate any control measures when those crops are being destroyed or degraded to the point where whiteflies begin to migrate out.

It can be useful to establish a program that denies whitefly populations any viable host for a period of time. Although such gaps in cropping may be difficult to justify economically, they will significantly reduce whitefly populations.

Organically Acceptable Methods
Cultural and biological controls are organically acceptable methods, as is the use of insecticidal soaps and neem oil.

Monitoring and Treatment Decisions
There is as of yet no treatment threshold for whitefly in caneberry, but chemical treatments may be necessary when there are moderate to large populations of whiteflies, resulting in honeydew on fruit during periods of warmer weather.

Chemical Control

Azadirachtin (aza-direct) apply as a ground application with up to 100 gal water/acre; repeat applications every 7 to 10 days or as the situation warrants. Carbaryl (Sevin) apply with sufficient water carrier to obtain thorough and uniform coverage, repeat applications as necessary up to a total of 5 times of no less than every 7 days. The XLR Plus formulation is the least toxic to honey bees when direct application to bees is avoided and the spray residues have dried. Apply from late evening to early morning when bees are not foraging

Diseases

Armillaria Root Rot

Symptoms and signs

Symptoms of Armillaria root rot on blackberry and raspberry vary depending on how far the disease has progressed. Leaf wilting and cane dieback are common. Infected main roots and crowns often have whitish to cream-colored mycelia just under the bark. The mycelia are fan shaped and about as thick as a piece of paper; they have a characteristic mushroom odor. This is virtually the only fungus that produces these mycelial fans on live or recently alive tissue. If mycelial fans are present under the bark of the roots or in the collar region of live plants, it is a good indication that *Armillaria* is the cause of the decline.

Groups of plants are usually infected and show symptoms, correlating with the location of the inoculum in the soil. If the disease is not controlled, it eventually spreads through the soil by the growth of rhizomorphs. Rhizomorphs are branched structures about 0.12 to 0.16 inch (3–4 mm) in diameter that look like roots but are dark colored. A single rhizomorph is a white mycelial strand encased in a dark red to black rind. It grows through the soil from the roots of infected plants to the healthy roots of neighboring plants. Because rhizomorphs resemble shoestrings, some of the common names for this pathogen are bootlace or shoestring fungus.

Armillaria sometimes produces mushrooms around the base of infected plants in fall. The mushrooms are relatively large and have a yellowish brown cap as well as a ring around the stem just below the cap.

Comments on the disease

The characteristics and severity of an Armillaria root rot infection are influenced by the type and age of the host plant as well as the species of*Armillaria.* Environmental conditions also affect disease severity.

The source of an Armillaria infection is from infected roots in the soil. The disease can occur on land that has been cleared of infected trees. The fungus can survive on dead roots and grow through the soil as rhizomorphs. Infection of plants occurs through the contact of healthy roots with mycelia or rhizomorphs. The importance of rhizomorphs in the spread of the disease varies with species, site, and environmental conditions.

An assessment of plant health should be made in conjunction with the diagnosis of Armillaria root rot because the pathogen often infects plants that have been weakened by stress or other agents.

Management

The potential for infection by *Armillaria* can be reduced by the removal and destruction of infected roots or stumps from the soil. It is very difficult to remove all infected woods and roots from the soil, but the progression of the disease can be slowed by this method. Remove all roots larger than about one half inch in diameter.

While not completely reliable, the installation of barriers to prevent the spread of the rhizomorphs may be used on an area that is adjacent to an infested one. Barriers may consist of vertical buried plastic sheets, ditches, or strips of ground that are regularly cultivated.

Organically Acceptable Methods

Proper site preparation, including the removal of infected roots in the soil and the installation of barriers in the soil to contain the pathogen, are acceptable management tools in an organically certified crop. Trichoderma formulations have been used with some success for delaying pathogen growth in infected roots. Also, the practice of removing soil from around the plant to a depth of about 6 to 8 inches or to a depth that exposes the upper root system has been shown to stop the pathogens progress and allow plant recovery in pears, peaches, plums, and grapes.

Treatment Decisions

Soil fumigants have been used in conjunction with removal of infected material to reduce inoculum; however, most soil fumigants are highly toxic and should only be applied by professional pesticide applicators.

Chemical Control

Preplant

1,3 Dichloroprone (Telone C-35) fumigants such as 1,3-dichloropropene are a source of volatile organic compounds (VOCs) but are minimally reactive with other air contaminants that form ozone. Fumigate only as a last resort when other management strategies have not been successful or are not available.

Botrytis Fruit Rot

Symptoms and signs

Flattened black masses of sclerotia appear on the bleached appearing canes of *Botrytis*-infested blackberry and raspberry plants in late winter. In the presence of free water during spring, sclerotia germinate to form masses of gray mycelium and spores called conidia. Opened flowers may become infected, and the fungus will sporulate on the blighted flowers. On infected druplets, a watery rot may precede the development of grayish brown conidia and hyphae. The conidia and hyphae eventually cover the fruit. Infected berries left on the vines become mummified. If the weather is moist after harvest, the receptacles can be colonized by the fungus and sclerotia can develop. In postharvest storage, white mycelia can cover infected berries.

Comments on the disease

Botrytis fruit rot occurs under cool, wet conditions. The pathogen requires free water for sclerotial germination, spore germination, and infection. Physical damage to the fruit increases disease incidence, especially during the rainy season. The pathogen overwinters as sclerotia on infected canes and as mycelium in infected leaves and canes on the ground. The main sources of primary inoculum are conidia from overwintering sclerotia and dead leaves, and conidia from mummified berries. Conidia are dispersed by wind, rain, and overhead irrigation. Flowers are not susceptible to infection until they are open. Infections generally remain dormant until fruit is nearly ripe or after harvest. Infections can recur

throughout the season by sporulation of the fungus on unpicked, leaky, overripe fruit left on the vine.

Management

To promote air circulation and quicken drying of plant tissue, prune and trellis the plants to open the canopy. A narrow row can be maintained by pruning, minimizing nitrogen fertilizer application, and controlling weeds. Training systems also help to maintain an open canopy. The use of macro tunnels greatly limits the amount of gray mold infestation because of the dry conditions they create for the plants.

Partial resistance to this disease is available for red raspberry cultivars. To prevent postharvest fruit rot, pick fruit when it is in the red ripe stage of development (before reaching full maturity). Avoid fruit injury when picking. Pack fruit directly into containers, and use shallow containers to avoid crushing. Pick fruit often, and pick early in the day when temperatures are cool; cool fruit to 32°F as soon as possible after harvest. Store fruit at 32°F to maintain firmness and to prevent condensation inside the closed basket or clamshell.

Organically Acceptable Methods
Pruning and/or using a training system to open the canopy, proper fertilization, weed control, resistant cultivars, and proper harvest techniques are all acceptable for use in an organically certified crop.

Treatment Decisions
Fungicides are applied as protectant sprays at 7- to 14-day intervals from early bloom up to harvest.

Chemical Control

Iprodione (Rovral) apply in a minimum of 100 gal water/acre. Do not make more than 4 applications/crop/season. Fenhexamid (Elevate) begin application at 10% bloom and reapply every 7 days or when conditions favor disease development. Do not apply more than 6 lb/acre/season. Avoid making two consecutive applications. Pyraclostrobin/boscalid (pinstine) and Cyrodinil/Fludioxonil (switch) are also good chmicals for control.

Cladosporium Fruit Rot

Symptoms and signs

Blackberry and raspberry plants with Cladosporium fruit rot have berries that are covered with a soft, velvety, olive-green mycelial growth. While this growth is unsightly, it does not

often damage the fruit. *Cladoporium herbarum* and *C. cladosporoides* can occur alone or in association with lesions caused by *Botrytis cinerea* (the causal agent of Botrytis fruit rot).

Comments on the disease

Cladosporium fruit rot of caneberry is primarily a postharvest storage disease. Even though these fungi cause little actual damage to fruit, the mycelial growth on the fruit is unappealing, so the fruit is unmarketable. Optimal temperature for the growth of these fungi is between 68° to 77°F (20° to 25°C), but may occur at lower temperatures during normal fruit storage.

This fruit rot is most commonly associated with fruit that is sunburned or damaged in some manner.

Management

Practice good sanitation and manage moisture within the planting to reduce inoculum levels and the risk of infestation. Harvest regularly and carefully, removing damaged and infected fruit. Cool berries as rapidly as possible to an optimum of 32°F (0°C).

Organically Acceptable Methods

Good sanitation and harvest practices are acceptable methods in an organically certified crop.

Treatment Decisions

Treat if weather conditions are favorable for the development of *Botrytis* and *Cladosporium* fungi (i.e., rain).

Chemical Control

Cyprodinil/fludioxonil (switch) and Iprodione (rovral) are both chemical control methods available.

Downy Mildew

Symptoms and signs

Downy mildew initially causes a light green to yellow discoloration on the upper blackberry or olallieberry leaf surface that eventually progresses to red and purple. Mature lesions are often angular and restricted by veins. White to gray mycelia and spore masses also appear on the opposite side of lesions on the leaf underside, but they may be difficult to see.

Primocanes systemically infected by downy mildew are often stunted and have red streaks on the side of the cane that faces the sun, with reddish colored terminal leaves. Downy mildew infected fruit (dry berry) is dull in luster, lacking in turgidity, and dries out rapidly. Early infection of green fruit induces premature reddening, shriveling, and hardening. Fruit infection later in the season causes shriveling, drying, and the fruit splitting into two parts. Downy mildew infected pedicels are dry and red.

Comments on the disease

Downy mildew is most prevalent during wet weather at temperatures of 65°F (18°C). The pathogen overwinters as mycelium inside roots, crowns, and canes. Sporulation is usually found in dense foliage near the cane or at the base of the plant. Airborne spores are produced during cool, wet nights and are disseminated by wind. Symptoms develop within 10 to 11 days after infection.

Weed growth and dense canopies create humid environments that favor the development of the disease on suckers.

Management

Use pathogen-free planting stocks. If possible, avoid planting in sites with a history of this disease. The use of macrotunnels is very limiting to downy mildew infestation, because of the near total lack of free moisture on the leaves and flowers of the plants.

Destroy alternate hosts, such as rose or wild blackberries, that are in close proximity to a planting. Once the planting is established, remove suckers and weeds to reduce humidity at

the base of the plant. Remove and destroy old fruiting canes after harvest. Reducing moisture in the hedgerow by pruning can be key in managing downy mildew.

Organically Acceptable Methods
The use of clean planting stock, careful site selection, proper pruning, maintenance of a dry hedgerow, and some copper sprays are acceptable for use on organically certified produce.

Treatment Decisions
Fungicide sprays may be applied in spring to protect blackberry foliage, flowers, and developing berries from infection.

Chemical Control

Fosetyl-al (allette) do not tank mix with copper compounds, surfactants, or foliar fertilizers. Phosporous acid (fosphite)do not tank mix with copper compounds, surfactants, or foliar fertilizers. Allow 20 days before applying to a copper-treated crop. Copper is also a good chemical control method.

Verticillium Wilt

Symptoms and signs

Leaves on plants infected with Verticillium wilt turn yellow, wither, and fall, beginning at the base of canes and progressing upward. Fruiting canes may take on a bluish black cast and die during summer as fruit are maturing. Symptoms sometimes appear first on only one side of the plant while the opposite side remains healthy before also becoming infected. Small groups of plants throughout the field may be affected. Primocanes (current season's growth) are usually free of the disease; however, a severe infection in newly planted fields may kill the plants the first year.

Comments on the disease

In California, Verticillium is only rarely found on raspberries and never on blackberries.

The fungus persists in the soil in an actively growing state when susceptible crops or weeds are present or otherwise as dormant resting structures (microsclerotia). It often occurs in

soil that was formerly planted to tomatoes, potatoes, strawberries, cotton, eggplants, peppers, cucurbits, and many other plants. Infection occurs when roots come into contact with the microsclerotia. The disease is favored by cool, wet spring weather and can infect through either healthy or wounded roots and root hairs. After the initial infection, the fungus grows into the water-conducting tissues of the root (xylem) and spreads upward into the cane xylem. Eventually, the xylem tissues become plugged by the growth of the fungus or by the plant's internal defense mechanisms, such as the deposition of gums or the development of tyloses (overgrowths of parenchyma cells that are adjacent to xylem vessels), and the canes wilt and die. The fungus is then returned to the soil as the dead roots decompose and microsclerotia become available to infect new plants.

Management

Verticillium wilt can be a difficult disease to manage. Avoid planting in fields that have a recent crop history of highly susceptible plants such as vegetable crops; such fields are likely to contain high levels of the *Verticillium* microsclerotia. Fields that have been infested with such weeds as pigweed, nightshade, and lambsquarters are also likely to contain high levels of the fungus. Plant a nonhost crop in such fields for 20 or more years before planting caneberries and use clean planting stock.

When planting a field, always use clean planting stock. Practice crop rotation with a nonsusceptible crop. In Central Valley locations, soil solarization can be used to reduce the level of inoculum in the soil before the canes are planted. (See *Soil Solarization: A Nonpesticidal Method for Controlling Diseases, Nematodes, and Weeds*, UC ANR Publication 21377.)

Organically Acceptable Methods

The use of clean planting stock, crop rotation, and soil solarization are acceptable management methods in an organically certified crop, but soil solarization has not worked well in the coastal valleys.

Treatment Decisions

Preplant fumigation reduces the levels of inoculum in the soil.

Chemical Control

1,3-Dichloropropene (Telone C-35) fumigants such as 1,3-dichloropropene are a source of volatile organic compounds (VOCs) but are minimally reactive with other air contaminants that form ozone. Fumigate only as a last resort when other management strategies have not been successful or are not available.

Powdery Mildew

Symptoms and signs

Caneberry leaves infected with powdery mildew develop light green (chlorotic) spots on the upper surface, often with white mycelial growth on the lower leaf surface. Upper surfaces of leaves have a mottled appearance similar to that caused by mosaic virus infection. Infected shoot tips and fruit may also become covered with white, mycelial growth. Severely infected shoots become long and spindly with dwarf leaves that curl upward. Severely diseased plants may be stunted.

Comments on the disease

In California, the powdery mildew pathogen overwinters as mycelium in buds or on the surface of first-year canes (primocanes). Later, conidia are produced abundantly on the surface of infected tissue and serve as secondary inoculum for repeated cycles of infection throughout the growing season. The spores are airborne and the development of disease is favored by warm, dry weather.

Management

Blackberries and varieties of red, black, and purple raspberries vary in their susceptibility to powdery mildew. Where powdery mildew is a serious problem, avoid planting highly susceptible cultivars. The blackberries from the Arkansas breeding program such as Navaho, Apache, and Arapaho tend to have very low susceptibility to powdery mildew as well as other diseases.

Practices that allow good air circulation have been reported helpful in limiting the spread of the disease. These include proper plant spacing, cane thinning, and maintaining narrow rows. Removing late-forming suckers with powdery mildew symptoms and cutting back of floricanes (second-year canes) to a horticulturally desired height may reduce primary sources of inoculum.

Incidence and severity of powdery mildew tends to be higher in macro tunnels because the warm, dry conditions found inside the tunnels favor disease development. Free water is not necessary for the disease to develop, but higher humidity favors the disease.

Organically Acceptable Methods

The use of resistant varieties, maintaining good air circulation in the planting, and sprays of sulfur or potassium bicarbonate are acceptable for use in organically certified crops.

Treatment Decisions

Treat when disease is first evident.

Chemical Control

Micronized sulfur (Microthiol Disperss, Sulfur 90w) and Pyraclostrobin/boscalid are acceptable chemical control methods. Triadimefon (Bayleton) is for use raspberries only. Apply in not less than 20 gal water/acre using ground equipment. Make additional applications at 4- to 6-week intervals as needed, not to exceed 7 applications in one year or 2 applications within the same 30-day period. Myclobutanil (Rally) initiate applications as early as bud break and continue at 10- to 14-day intervals; shorter intervals may be used under heavy disease pressure. Do not apply more than 10 oz/acre/season. Potassium Bicarbonate (Kaligreen) apply with sufficient water (25 gal/acre) to ensure complete and thorough coverage of the foliage and crop. Alternate application with other effective fungicides for resistance management on a 7- to 10-day interval. Can burn some varieties more easily than others; always test first when applying to a variety for the first time

Cole Crops

Insect Problems

Aphids

Description of the pests

Several other aphids may occur on cole crops. The most common is the green peach aphid, which is a yellow-green aphid with prominent tubercles at the base of the antennae. None of the other aphids occurring in cole crops have the waxy coating that characterizes the cabbage aphid. Green peach aphid and turnip aphid also tend to be more randomly dispersed around the plants than the dense colonies of the cabbage aphid. The turnip aphid, a species that is a worldwide foliar aphid pest, occasionally infests the roots of cole crops in coastal California. These aphids are dark to olive green and unlike other root aphids, have visible cornicles.

Damage

When populations are heavy, green peach aphid can stunt seedlings; however, economic damage rarely occurs on older plants because green peach aphids tend to feed on older leaves and rarely enter heads of broccoli, cauliflower, cabbage, or Brussels sprouts. Turnip aphids on the roots of cole crops can seriously stunt and even kill plants.

Management

These aphids rarely require treatment in cole crops. Because they remain mostly on the older, nonmarketable leaves of cole crops, low-to-moderate populations can be tolerated on older plants. High numbers of green peach aphid can kill young seedlings or transplants, so treat infested young plants if they show stress from feeding by this aphid. The same general predators and parasites that attach cabbage aphids also attack these aphids.

Biological Control

Many predators and parasites attack aphids, especially in fields that are not sprayed or sprayed

with less toxic materials. These natural enemies, including general aphid predators and the parasites *Lysiphlebus testaceipes, Aphidius matricariae, Aphelinus semiflavus,* and *Diaeretiella rapae*, may provide adequate control under certain circumstances.

Cultural Control

Remove infested culls and weedy species around fields that may harbor the aphid between crops. Turnip aphid problems tend to recur in the same fields. Long term rotation to other crops may be advised.

Organically Acceptable Methods

Biological and cultural controls as well as sprays of insecticidal soap, which can give partial control of aphids, are organically acceptable methods. Insecticidal soap sprays, however, may be phytotoxic under some conditions and rates, especially in Brussels sprouts and cabbage.

Monitoring and Treatment Decisions

No special monitoring is needed for green peach or turnip aphids in cole crops; keep notes on them as you monitor the cabbage aphid. Treat seedling plants if they appear to be stressed by aphid populations. Older plants can tolerate low to moderate populations. If applications are made for cabbage aphid just before heading, other foliar aphid species will be controlled as well.

Chemical Control

Imidacloprid (provado) is the only chemical control method, thorough and uniform coverage is important for good control.

Cabbage Looper

Description of the pest

Looper caterpillars can be distinguished from most other common caterpillars in cole crops by their distinctive looping movement in which they arch the middle portion of their body to bring the prolegs or hind legs forward to meet the front legs. Loopers are green, usually with a narrow white stripe along each side and several narrow lines down the back. Loopers are smooth-skinned with only a few long bristles down the back; they may grow up to 1.5 inches

long. Mature larvae spin silken cocoons and pupate, usually attached to leaves. Adults are brownish moths with a distinctive silvery figure-8 on the front wings. Eggs are ridged and dome-shaped and usually laid singly on the undersurface of leaves. Loopers may have numerous generations and continue to develop all year long in cole crops growing areas of California with the highest populations usually occurring in fall.

Damage

Although seedlings are occasionally damaged, most injury occurs after heading. Loopers eatragged holes into leaves, bore through heads and contaminate heads and leaves with their bodies and frass. Young plants between seedling stage and heading can tolerate substantial leaf damage without loss of yield.

Management

Cabbage loopers have many natural enemies that frequently keep loopers below economic levels, at least until heading, if they are not killed by insecticide treatments for other pests. Monitor to determine population levels of loopers and natural enemies and to determine the need for treatment following heading. If treatment is needed, use a selective material such as *Bacillus thuringiensis.*

Biological Control

Important parasites include the egg parasite*Trichogramma pretiosum*, the larval parasites*Hyposoter exiguae, Copidosoma truncatellum,*and *Microplitis brassicae*, and the parasitictachinid fly *Voria ruralis.* A nuclear polyhedrosisvirus disease is also important under certain circumstances; the bodies of diseased caterpillars turn into shapeless sacks of dark liquid and can often be spotted hanging from leaves. Be sure to monitor for natural enemies; if looper populations are close to treatment thresholds but you find a significant percentage of parasitized or disease-killed individuals, delay treatment for a few days to see if these natural controls will bring populations down on their own. If treatment is necessary, use of *Bacillus thuringiensis*insecticide will minimize injury to natural enemies.

Organically Acceptable Methods

Biological control and sprays of *Bacillus thuringiensis* and the Entrust formulation of spinosad are organically acceptable management tools.

Monitoring and Treatment Decisions

Check 25 plants selected randomly throughout the field. Look for eggs and small larvae on the underside of lower leaves. If you find holes, search the general area for the caterpillar, opening damaged heads as necessary. Although damage can give you a general idea of where loopers may be and the seriousness of the infestation, do not base treatment on damage levels. Base

treatment on numbers of healthy larvae present (include imported cabbageworms in counts, too, if they are also present). Treat seedlings or small plants if populations of medium-sized to large caterpillars are large enough to stunt growth. Before heading, well-established plants do not need to be treated unless you find more than 9 small- to medium-sized larvae per plant. Treat just before heading or at Brussels sprouts formation if counts show more than one looper or other caterpillar in 25 plants.

Where possible, use a selective insecticide to avoid adverse impacts on natural enemies.*Bacillus thuringiensis* and most other selective insecticides are very effective against cabbage loopers, especially when applied to early-instar caterpillars (i.e., very young). Cabbage loopers are also controlled with the more toxic materials recommended for use against other lepidopterous (caterpillar) pests. If significant numbers of other caterpillars (armyworms or diamondback moths) are present, the use of a carbamate or pyrethroid may be warranted.

Chemical Control

There are several chemical controls that are effective such as Bacillus Thuringiensis, Emamectin Benzoate (Proclaim), Indoxacarb (Avaunt), Spinetoram (Radiant), Spinosad (Success and Entrust), Chlorantraniliprole (Corgan), Flubendiamide (Synapse), and Methoxyfenozide (Intrepid). All the chemicals above you should avoid runoff and drifting to avoid harming water ways and natural predators.

Cutworms

Description of the pests

Cutworms include a number of species of dull gray to brown, medium-sized to large (up to 2 inches when full grown) caterpillars. Most cutworms curl up into a C-shape when disturbed. All normally feed close to the soil surface cutting off seedlings or damaging leaves resting on the ground. Most feeding occurs at night; during the day cutworms are usually found just below the soil surface or under dirt clods. First instar cutworms of some species may be found feeding on the leaf surface.

Adult cutworm moths have dark gray or brown front wings with irregular spots or bands and lighter hind wings. Females lay hundreds of white eggs, either singly or in clusters, depending on species, on leaves or stems close to the ground. After hatching, young larvae may feed on leaf surfaces for a while, but older larvae drop to the ground, tunnel into the soil, and emerge at night to feed.

Damage

Seedlings or young plants are cut off at or just below ground level; often several plants in a row will be wilted or cut off. Losses can be especially severe in fields seeded to a stand or recently thinned. Occasionally cutworms will bore into cabbage heads, but this is not common. Damage often recurs in the same fields and same parts of fields from year to year; damage is worst where large numbers of cutworms are present before planting.

Management

Cutworms migrate into newly planted crops from surrounding weeds or infested crops. Check for cutworms in weeds around the edges of the field before you plant. Remove weeds from field margins and plow fields at least 10 days before planting to destroy larvae, food sources, and egg-laying sites. Cutworms have numerous natural enemies, but none can be relied on to bring a damaging population down below economic levels.

Organically Acceptable Methods

Cultural practices such as removal of adjacent weeds are an essential part of an organic management program.

Monitoring and Treatment Decisions

After the crop is up, check for a row of four or more wilted plants with completely or partially severed stems. If you find damaged plants, look for cutworms by digging around the base of plants and sifting the soil for caterpillars. If you find substantial numbers of cutworms, you can use bait to control most species, except the glassy cutworm, which occurs in the southern San Joaquin Valley. Baits are more effective when food is limited, so get it out before the crop emerges. If unexpected damage occurs after crop emergence, treat as soon as you find several severed plants in the same row.

Chemical Control

Spinosad is an insecticide derived from natural metabolites produced under fermentation conditions by *Saccharopolyspora spinosa.* It has a high level of contact and oral activity and a rapid speed of action. It also has a low to moderate impact on beneficial insects.

Diamond Back Moth

Description of the pest

Diamondback larvae are small (about 0.33 inch when full grown) compared to other caterpillars in cole crops. The larval body is wider in the middle and tapering at both ends with two prolegs on the last segment forming a distinctive V-shape at the rear end. When disturbed the larvae wiggle frantically or rapidly attach a silken line to a leaf and drop over the edge. They feed mostly on outer or older leaves of older plants chewing out small holes or at the growing points of young plants. They will also feed on floral stalks and flower buds. Larvae mature in 10 to 14 days and spin a loose cocoon on leaves or stems for pupation. Adult moths lay their tiny, roundish eggs singly on the undersides of leaves; eggs are difficult to find. Although they may occur all year round, especially in coastal areas, diamondback moths are often abundant in spring and early summer, and populations may rise again in fall.

Damage

Diamondback moth infestations are most serious when they damage the crowns or growing points of young plants or Brussels sprouts. This injury can severely stunt growth. Sometimes diamondback moth caterpillars may also bore into heads of broccoli or cauliflower, or in the flower buds of stalks, causing economic injury and contamination. Injury to leaves is not usually serious, except when the wrapper or cap leaves of cabbage are injured.

Management

Natural enemies and insecticides applied to control other pests keep the diamondback moth under satisfactory control in most fields in California, but keep records of diamondback moth as you monitor for other caterpillars.

Biological Control

Natural enemies often effectively control diamondback moth in California. In southern California, the ichneumonid wasp, *Diadegma insularis*, has been identified as the most common parasite. *Trichogramma pretiosum* may also attack diamondback eggs. Various predators such

as ground beetles, true bugs, syrphid fly larvae, and spiders can be important factors in controlling populations. Microbial diseases are not known to be a significant mortality factor.

Organically Acceptable Methods

Biological control and sprays of *Bacillus thuringiensis* and the Entrust formulation of spinosad are organically acceptable management tools.

Monitoring and Treatment Decisions

Check fields during the seedling stage, at thinning, and just before heading. Also, record diamondback larvae numbers when you make your twice-weekly samples for other caterpillar pests. In cabbage fields, regularly monitor wrapper leaves for damage after heading. Adult moths frequently migrate from fields being harvested or disced under, so carefully check border rows if populations were high in adjacent fields. No treatment levels have been developed for diamondback moth in California; however, treatment may be required if significant injury to growing points is occurring.

Chemical Control

There are many differnet chemicals that are effective including Bacillus Thuringiensis, Diazion, Emamectin Bensoate (Proclaim), Indoxacarb (Avaunt), Spinetoram (Radiant), Spinosad (Entrust), Chlorantraniliprole (Coragen), and Flubendiamide (Synapse).

Flea Beetles

Description of the pests

Flea beetle adults are small (about 0.125 inch or 1 mm long), shiny, hard beetles with enlarged hind legs that allow them to jump like fleas. Different species vary in color and markings. Adults do most of the damage; flea beetle larvae may mine leaves or feed on roots, but this activity is not of economic concern.

Damage

Flea beetles feed on the undersides of leaves, creating small pits or irregularly shaped holes. Large populations can kill or stunt seedlings. Older plants rarely suffer economic damage although their older, lower leaves may be damaged.

Management

Flea beetles occasionally infest cole crop seedlings. They are most common in spring but can occur any time, especially in fields that are weedy or surrounded by weeds. Remove weeds along field margins and deeply disk plant residue in infested fields after harvest. Regular monitoring of seedlings for these pests will help detect problems and treatment needs.

Organically Acceptable Methods

Cultural control is acceptable in an organically certified crop. Insecticidal soaps applied at cotyledon stage may provide partial control.

Monitoring and Treatment Decisions

Check newly emerged seedlings twice weekly for flea beetle damage until plants are well established. Relatively low populations can cause economic damage when plants are in the cotyledon or first-leaf stages. Treat if you find several damaged rows; spot treatment of outside rows or borders may be sufficient. Baits are not effective.

If populations are high, treat infested fields just before thinning to prevent post-thinning damage. Once plants have 5 leaves they can tolerate several beetles per plant without damage. Older plants are even more tolerant. One insecticide treatment should be all that is required.

Chemical Control

Carbrayl (Sevin), Chlorpyrifos (Lorsban Advanced), Diazinon (Diazinon), Esfenvalerate (Asana), Insecticidal soap, and Cryolite (Cryolite) are all acceptable chemical control messures.

Diseases

Alternaria Leafspot

Symptoms and signs

The two *Alternaria* species, *A. brassicae* and *A. brassicicola,* cause similar symptoms;small, dark specks first develop on leaves and later enlarge into circular, tan spots (0.25-0.5 inch in diameter). The spots caused by *A. brassicicola* tend to be darker than those caused by *A. brassicae.* If conditions are favorable, dark green spores of the pathogen will grow on the spots. Such growth causes the spots to have concentric rings in them. Old leafspots become papery in texture and may tear. When the dry tissue falls out, a shothole effect results.

Comments on the disease

Alternaria leafspot is usually not an economic concern on cole crops. It occasionally is a problem on cabbage during cool, rainy months. The pathogen can also infect Brussels sprouts, broccoli, and cauliflower. Leafy crucifers that are harvested for their leaves (red mustard, Chinese cabbage, tat tsoi, and Mizuna mustard) are also susceptible to *Alternaria brassicae* and can be seriously damaged by this pathogen. Disease is favored by moist conditions. Spores are spread by winds and splashing water. The fungus does not survive in soil, but is carried over in crucifer seed, on weed or volunteer hosts, or on undecomposed crop residue.

Management

Use clean seed and practice crop rotation. Fungicides applied as foliar sprays will control this disease.

Chemical Control

Iprodione (Rovral) and Chlorothalonil are both acceptable chemical control methods.

Bacterial Blight

Symptoms and signs

Bacterial blight infections start as small, angular-shaped, water-soaked specks on leaves that are often surrounded by yellow borders. As the disease develops, specks enlarge and coalesce together into larger, irregularly shaped gray-to-tan spots. Leafspots are visible from both top and bottom sides of leaves. Symptoms may resemble those of the more familiar bacterial leafspot disease.

Comments on the disease

Recent research has identified this bacterial disease, which is caused by a pathogen related to, but distinct from, the bacterium that causes bacterial leafspot. For cole crops, bacterial blight has been found on broccoli, cauliflower, and Brussels sprouts. Other crucifer hosts include rappini, arugula, and rutabaga. The pathogen is seedborne and is splashed from plant to plant by rain and sprinkler irrigation. Bacterial inoculum may persist for short periods of time in soil.

Management

Plant clean and disease-free transplants. Rotation away from fields where the disease has recently occurred may reduce inoculum levels in soil or infected debris. A change from sprinkler to furrow or drip irrigation may limit its spread.

Bacterial Leaf spot

Symptoms and signs

Bacterial leafspot infections start as small, dark specks on leaves. As disease develops, numerous water-soaked leafspots appear. Leafspots remain small (0.125 inch or 3 mm in diameter). Older leafspots turn tan and may or may not have a purple border around them. Leafspots are visible from both top and bottom sides of leaves. Symptoms on transplants may resemble downy mildew symptoms.

Comments on the disease

Bacterial leafspot is most often seen under greenhouse conditions. Occasionally it also occurs on cauliflower in coastal valleys, but its occurrence in production fields is sporadic. The pathogen is seedborne and is splashed from plant to plant by rain and sprinkler irrigation.

Management

Plant clean seed and disease-free transplants. Rotation away from fields where the disease has recently occurred may reduce inoculum levels in soil or infected debris. A change from sprinkler to furrow or drip irrigation may limit its spread. Cultivars vary in susceptibility.

Black Leg

Symptoms and signs

The most serious symptoms occur on stems near the soil line where elongated, sunken, brown lesions form. These lesions may girdle the stem, resulting in stunting, wilting, and general poor growth of the plant. If the lesions enlarge, the stem may break, causing the plant to fall over. Lesions usually contain minute, spherical, dark structures that are thefruiting bodies of the pathogen. If conditions are right, pink masses of spores exude from these structures. If seedlings are infected early, they may die. Less important are the leafspots that may develop on foliage. Leafspots are circular, light tan, and contain the dark, spherical fruiting bodies of the pathogen. The disease damages the water-conducting tissue, and blackened streaks of xylem can be seen by cutting open the stem.

Comments on the disease

Of particular importance is the ability of this pathogen to be carried in and on seed. This is how the fungus is introduced into greenhouse and field plantings. The pathogen can live in crop

debris if such material is not fully decomposed. Cool, moist conditions enhance disease development. Spores are spread with splashing water. A second spore type may occur that can be blown long distances on wind currents.

Management

Black leg can be managed by using disease-indexed seed, by cultural practices, and with foliar sprays. Remove cruciferous weeds and volunteer plants that may harbor the pathogen. Plow under debris in diseased fields to allow for more rapid and thorough decomposition. Practice crop rotation; rotate infested fields out of cruciferous crops for 1 or 2 years.

Chemical Control

Iprodione(Rovral) is the only chemical control available for cole crops with black leg. It is registered for broccoli only.

Downy Mildew

Symptoms and signs

Infections begin as irregular yellow patches on leaves; these chlorotic lesions later turn tan to light brown. If conditions are favorable, whitefluffy growth of the fungus develops on the undersides of leaves. If disease development is extensive, leaves may take on a blighted effect as a result of numerous infection sites. Systemic infections can cause internal black streaks and patches to form in stems and floret branches of broccoli and cauliflower. Early symptoms on transplants may resemble bacterial leafspot symptoms. Severely diseased seedlings may be stunted or die.

Comments on the disease

Peronospora parasitica requires cool, moist weather for infection and disease development to take place. The pathogen survives between crops on weed hosts or as resilient oospores in crop residue. Spores are airborne. This disease is most serious on young seedlings; if cotyledons and the first true leaves are severely infected, the young plant may die.

Management

A few broccoli varieties are available that are resistant to downy mildew. Fungicide treatment of susceptible varieties is needed when the disease occurs on transplants or early in crop development in the field; repeated applications may be required, depending on weather. Treatment during early flowering is required on seed crops.

Organically Acceptable Methods

Resistant varieties and some copper sprays are suitable for organically grown crops.

Chemical Control

Chlorothalonil, Mefenoxam (Ridomil Gold/Bravo), Fosetyl-Aluminum (Aliette), and Copper are all acceptable chemical control methods but copper is the only organic accepted method.

Verticillium Wilt

Symptoms and signs

The older, lower leaves of plants turn yellowand wilt. These leaves eventually turn brown and drop off the stem, usually when plants approach maturity. The water-conducting tissues (xylem) of the stems and roots become black. Overall growth of the plant may be stunted.

Comments on the disease

Verticillium wilt is usually a minor problem on cole crops. However, a more serious Verticillium problem occurs on cauliflower in coastal areas. Verticillium wilt symptoms are more prevalent on late summer and early autumn crops; cool soil temperatures favor infection and disease symptom development. The pathogen forms resistant structures (microsclerotia) that enable it to survive in soil for a decade or longer.

Management

Known infested fields should be planted to cauliflower only in winter or early spring. Some cauliflower cultivars may be more tolerant to Verticillium wilt than others. Avoid introducing the pathogen into clean fields. Planting broccoli, a nonhost of *V. dahliae,* may help reduce pathogen levels through a process called biofumigation: decaying broccoli residue, when disced into the soil, either gives off natural chemicals that can kill *V. dahliae* or alters the soil microflora so that *V. dahliae*survival is reduced.

Sclerotinia Diseases

Symptoms and signs

Two species of *Sclerotinia* cause disease on cole crops. *Sclerotinia minor* only infects stems or leaves in close contact with the soil. Once infection takes place, water-soaked, brown necrotic areas develop on these structures. The necrotic areas rapidly turn into soft, watery rots. Plants then wilt and collapse. Profuse amounts of white mycelial growth and numerous small (up to 0.125 inch or 3 mm), black, hard resting bodies called sclerotia, form on the outside and inside of the stems.*Sclerotinia sclerotiorum* can also infect lower leaves and stems, causing the same type of symptoms as *S. minor.* In addition, *S. sclerotiorum* forms tiny, brown, mushroomlike bodies (apothecia) that release aerial spores, which can infect any of the upper leaves and flowers. If conditions are right, these spores cause a watery, soft rot of these tissues as well. *Sclerotinia sclerotiorum* forms sclerotia that are larger (0.25–0.5 inch) on average than those of *S. minor.*

Comments on the disease

Sclerotia of both species enable the pathogens to survive in soil for a number of years without susceptible hosts. Wet soil conditions favor disease development. On crucifers, *S. sclerotiorum* tends to be the more important pathogen, while *S. minor* is only found infrequently. For *S. sclerotiorum,* cool and moist conditions are necessary for development of and infection by the spores. The aerial spores usually only infect injured or senescing leaves and flowers.

Management

Crop rotations and deep inversion plowing may be helpful in reducing severity of *S. minor*infections. Deep plowing or soil inversion reduces the number of sclerotia of *S. sclerotiorum* in the particular field, but has no effect on incoming aerial spores from surrounding fields and from long distances.

Chemical treatments are usually not required for Sclerotinia diseases in fresh market cole crops, but may be necessary in seed production fields. Currently only iprodione (Rovral) is registered for use on broccoli.

Peppers

Insect

Green Peach Aphid

Description of the pest

Green peach aphid is among the most common aphid species found on peppers. It may be present at any time throughout the year but is most common from March through May and September through November. Generally its color is pale green, although at times individuals may be present that are pinkish. During cool weather, individuals are usually more deeply pigmented. Both winged and wingless forms of the green peach aphid have prominent cornicles on the abdomen that are markedly swollen and clublike in appearance. The frontal tubercles at the base of the antennae are very prominent and are convergent. Winged forms of the green peach aphid have a distinct dark patch near the tip of the abdomen; wingless forms lack this dark patch.

Damage

The green peach aphid transmits a number of destructive viruses in pepper including pepper potyviruses and cucumber mosaic cucumovirus. In addition, it can also damage the plant by sucking plant sap. Damaging levels are characterized by large numbers of aphids found on the underside of leaves. Extensive feeding causes plants to turn yellow and the leaves to curl downward and inward from the edges. Honeydew produced by the aphids can be a problem, especially on fresh market peppers. Aphid damage is most prominent on newer, younger leaves in the center of the plant.

Management

Biological and cultural controls can be useful for limiting damage from this aphid. For instance, removing old crop debris from the field will reduce sources of virus and thereby its transmission by aphids, and using reflective mulches early in the season will repel aphids from young plants. Heavy infestations on seedling and young plants may require treatment with insecticides.

Biological Control

The green peach aphid is attacked by a number of common predators, including lacewings, lady beetles, syrphid flies, and parasites, including the parasitic wasps *Lysiphlebus testaceipes, Aphidius matricariae, Aphelinus semiflavus,* and *Diaeretiella rapae,* and is susceptible to the fungus disease, *Entomophthora* spp., that commonly attacks aphids. Aphid sampling should always include an evaluation of the presence and activity of natural enemies.

Cultural Control

An important factor in reducing virus spread is good field sanitation, especially the chopping or discing of crop debris immediately after harvest and destruction of alternate host plants. While field sanitation helps control the incidence and spread of viruses transmitted by green peach aphid, it does little to control the aphid itself. The spread of the virus within a geographical area can be reduced by not planting peppers near other pepper fields.

If peppers are planted near large areas of rangeland, it may not be possible to prevent the influx of green peach aphid. Studies have shown, however, that aluminum foil or silver reflective plastic mulches can be effective in repelling aphids from plants.

Organically Acceptable Methods

Biological and cultural controls and sprays of insecticidal soap or pyrethrum are acceptable for use on organically certified crops.

Monitoring and Treatment Decisions

Treatment thresholds for green peach aphid, as a pest in its own right are not well established. Heavy populations can do extensive damage, particularly on seedlings or young plants. If seedlings or young plants show signs of stress because of aphid feeding, an application of insecticide may be needed.

Chemical Control

Winged aphids are repelled by silver- or aluminum-colored mulches. If there is a probability of severe virus pressure, place reflective polyethylene mulches on planting beds before seeding or transplanting to significantly reduce rate of colonization by winged aphids and delay the buildup of damaging numbers of aphids by 4 to 6 weeks. While this approach is mainly effective

in delaying or reducing the incidence of virus diseases transmitted by winged aphids and whiteflies, reflective mulches can also delay the buildup of wingless aphids that arise as a result of colonization by winged individuals. The mulches lose their effectiveness when more than 60% of the surface is covered by foliage. Therefore, they are effective only for the first few weeks after seedling emergence or transplanting of either spring or fall tomatoes.

Leafminer

Description of the pest

Liriomyzid leafminer adults are small, shiny, black flies with a bright yellow, triangular spot on the upper thorax. Eggs are white and oval and laid within the leaf. Larvae feed between leaf surfaces, creating meandering tracks or mines. Mature larvae leave the mine and drop to the ground to pupate. The life cycle takes only 2 weeks in warm weather; there can be many generations a year.

Damage

Larvae mine between upper and lower leaf surfaces, creating winding, whitish tunnels that are initially narrow, but then widen as the larvae grow. Leaves injured by leafminers drop prematurely; heavily infested plants may lose most of their leaves.

Management

Regular monitoring for leaf mines is important in detecting damaging populations of this pest. Avoid the use of early season applications of broad-spectrum insecticides (dimethoate, endosulfan, esfenvalerate, methomyl) for control of other pests in order to conserve natural enemies of the leafminer.

Biological Control

Natural enemies, primarily parasitic wasps in the *Diglyphus* genus, often control leafminers. When parasites are killed by pesticides, leafminer outbreaks are common.

Organically Acceptable Methods

Biological control and sprays of azadirachtin and the Entrust formulation of spinosad are acceptable for use on organically certified produce.

Monitoring and Treatment Decisions

Regularly check peppers approaching maturity for leafmines. Most mines occur on older bottom leaves. Some mines are most obvious from the underside of the leaf. If leafminer populations build to high levels, a chemical treatment may be necessary. Avoid early season

applications of broad-spectrum insecticides for other insects because they may cause leafminer outbreaks to occur

Chemical Control

Several Chemicals are available for chemical control including Abamectin (Agri-Mek), Spinetoram(Radiant), Spinosad(Entrust or Success), Cyromazine(Trigrad), and Azadirachtin(Neemix). It is important to watch for runoff and drifting with chemicals.

Pepper Weevil

Description of the pest

The pepper weevil is a common pest in southern California where it can migrate in from areas with warm winters or survive year round in years when winters are mild. The adult pepper weevil is a small beetle, about 0.125 inch (3 mm) long, with a dark body that has a brassy luster to it. Larvae are off-white grubs with a brown head and are about 0.25 inch (6 mm) when mature.

Adult females lay eggs in holes they create in pepper buds or in the base of young pepper pods. Larvae develop and feed inside on the seed core or tissue of the pod wall. The pepper weevil has three larval instars and larval development requires 2 to 3 weeks. Pupation occurs within the pepper pod and requires 3-6 days. There are multiple generations a year. Peppers are the primary host, but feeding also occurs on nightshades, especially silverleaf nightshade, *Solanum elaeagnifolium.*

Damage

Adult weevils feed on fruit and leaf buds. Larvae feed inside the pods and cause young fruit to drop prematurely, reducing yields. Larger fruit often do not drop when infested, resulting in crop contamination.

Management

Manage pepper weevils in areas where they have occurred using field sanitation. Monitor with pheromone-baited sticky traps to determine the need to treat.

Biological Control

Parasitic wasps have been observed on the weevil larvae, but their impact in controlling this pest appears to be minimal.

Cultural Control

Immediately following harvest, destroy pepper plant residue. Remove infested fruit from field and destroy. Inspect pepper transplant to make sure they aren't infested and remove nightshade plants from the pepper field and its margins.

Organically Acceptable Methods

Cultural controls and sprays of pyrethrin are acceptable for use on organically certified produce.

Monitoring and Treatment Decisions

Monitor pepper weevil adults with pheromone-baited sticky traps. Place traps in fields before bloom to detect first adult emergence or migration into the field. Place traps on the field perimeter to detect migration.

Traps are mounted on poles, the height of which can be adjusted as the crop grows so that the traps are just below the tops of the plants. Check traps twice a week or more frequently if adults are known to be present. Apply treatments when the first adult is captured.

Chemical Control

There are several chemicals avaialbe such as Esfenvalerate(Asana XL), Carbaryl(Sevin 4F or XLR Plus), Endosulfan (Thionex 3EC), Permethrin (Ambush, Pounce 3,2 EC, Pounce 25 WP), and Pyrethrin(Pyganic).

Thrips

Description of the pests

Thrips are very small, slender insects that are best seen with a hand lens. Mature western flower thrips are 0.06 inch (1.5 mm) long, while onion are slightly smaller at 0.05 inch (1.3 mm) long. The most distinctive characteristic of thrips is two pairs of wings that are fringed with long hairs. Adults are pale yellow to light brown in color. Immature stages have the same body shape as adults but are lighter in color and are wingless. Western flower thrips adults have red-colored pigment in their simple eyes (ocelli) while onion thrips simple eyes are gray.

Thrips have a very extensive host range, including cereals, onions, garlic, and broadleaved crops, but it is only the species of plants that are infected by *Tomato spotted wilt virus* and on which the thrips can complete their entire life cycle that play an important role in the disease cycle. In California, the key crop hosts include tomato, pepper, lettuce, radicchio and fava bean. Important weed hosts include cheese weed *(Malva parviflora)*, sowthistle*(Sonchus oleraceus),* and prickly lettuce *(Lactuca serriola)*.

The adults are the only life stage that can fly, but they are not strong fliers. Adult thrips can be carried on wind currents, on clothing, and in association with plants. The length of the thrips life cycle (from egg to adult) varies depending on environmental conditions but is generally 30-45 days, though it can be as little as 14 days.

Damage

The primary damage caused by thrips to peppers is the vectoring of *Tomato spotted wilt virus.* The virus can only be acquired by the immature stage of thrips, whereas plant-to-plant transmission primarily occurs by adults. The adult thrips can transmit the virus for the remainder of their lives, which can last 30 to 45 days. However, the adults do not pass the virus to their progeny (through the egg).

High populations of thrips can cause damage with their feeding, which distorts plant growth, deforms flowers, and causes white-to-silvery patches on emerging leaves that often have tiny black fecal specks in them.

Management

If possible, avoid planting peppers next to onions, garlic, or cereals, because thrips often build up to large numbers on these crops. Also, avoid fields near greenhouses where ornamentals (cut flowers) are grown as these plants serve as hosts for the virus and thrips.

Insecticide treatments for thrips are usually not warranted in the Imperial Valley but may be needed for suppression of *Tomato spotted wilt virus* in the San Joaquin Valley and coastal growing areas. Treat transplants with imidacloprid before placement in the field and at planting. Treatment with foliar insecticide sprays through the season as needed may limit in-field spread of *Tomato spotted wilt virus* to some extent. Rotate classes of insecticides to minimize insecticide resistance in thrips.

Chemical Control

Chemicals such as Imidacloprid(Provado), Imidacloprid(Admire Pro), Spinetoram(Radiant), Spinosad(Entrust or Success), and Methomyl(Lannate SP) are all acceptable chemicals for treatment.

Aphids

Description of the pests

Several other aphids may occur on cole crops. The most common is the green peach aphid, which is a yellow-green aphid with prominent tubercles at the base of the antennae. None of the other aphids occurring in cole crops have the waxy coating that characterizes the cabbage aphid. Green peach aphid and turnip aphid also tend to be more randomly dispersed around the plants than the dense colonies of the cabbage aphid. The turnip aphid, a species that is a

worldwide foliar aphid pest, occasionally infests the roots of cole crops in coastal California. These aphids are dark to olive green and unlike other root aphids, have visible cornicles.

Damage

When populations are heavy, green peach aphid can stunt seedlings; however, economic damage rarely occurs on older plants because green peach aphids tend to feed on older leaves and rarely enter heads of broccoli, cauliflower, cabbage, or Brussels sprouts. Turnip aphids on the roots of cole crops can seriously stunt and even kill plants.

Management

These aphids rarely require treatment in cole crops. Because they remain mostly on the older, nonmarketable leaves of cole crops, low-to-moderate populations can be tolerated on older plants. High numbers of green peach aphid can kill young seedlings or transplants, so treat infested young plants if they show stress from feeding by this aphid. The same general predators and parasites that attach cabbage aphids also attack these aphids.

Biological Control

Many predators and parasites attack aphids, especially in fields that are not sprayed or sprayed with less toxic materials. These natural enemies, including general aphid predators and the parasites *Lysiphlebus testaceipes, Aphidius matricariae, Aphelinus semiflavus,* and *Diaeretiella rapae*, may provide adequate control under certain circumstances.

Cultural Control

Remove infested culls and weedy species around fields that may harbor the aphid between crops. Turnip aphid problems tend to recur in the same fields. Long term rotation to other crops may be advised.

Organically Acceptable Methods

Biological and cultural controls as well as sprays of insecticidal soap, which can give partial control of aphids, are organically acceptable methods. Insecticidal soap sprays, however, may be phytotoxic under some conditions and rates, especially in Brussels sprouts and cabbage.

Monitoring and Treatment Decisions

No special monitoring is needed for green peach or turnip aphids in cole crops; keep notes on them as you monitor the cabbage aphid. Treat seedling plants if they appear to be stressed by aphid populations. Older plants can tolerate low to moderate populations. If applications are made for cabbage aphid just before heading, other foliar aphid species will be controlled as well.

Chemical Control

Imidacloprid (provado) is the only chemical control method, thorough and uniform coverage is important for good control.

Two Spotted Spider Mite

Description of the pest

Eggs of the twospotted spider mite are round, clear, and colorless when laid, but become pearly white when ready to hatch. Nymphs and adults are egg-shaped and generally yellow or greenish in color. On each side of their bodies are one or more dark spots; the top of the abdomen is free of spots.Twospotted mites are generally found in small colonies on the underside of mature pepper leaves in late summer.

Damage

Twospotted mites are not damaging to peppers in California production areas. They seem to prefer other solanaceous crops, such as eggplant, more than peppers.

Management

Mites are not a major problem on peppers and treatments are generally not required.

Whiteflies

Description of the pests

Several species of whiteflies may infest peppers. Silverleaf whitefly is also known as sweetpotato whitefly B biotype. Properidentification of silverleaf whiteflies and greenhouse whiteflies is important because other whitefly species do not cause economic damage in pepper. Use a hand lens to examine both immatures and adults. Whitefly adults are tiny (0.06 inch, 1.5 mm long), yellowish insects with white wings. Silverleaf whiteflies hold their wings somewhat vertically tilted, or rooflike, over the body; the wings do not meet over the back but have a small space separating them.Greenhouse whitefly adults are very similar in appearance to the silverleaf whitefly but hold their wings flatter over the back and there is no space between the wings where they meet in the center of the back.

Whiteflies are found mostly on the undersides of leaves. They fly readily when plants are disturbed. The tiny, elongated eggs hatch into a first larval stage that has legs and antennae and is mobile. Both legs and antennae are lost after the first molt and subsequent stages remain fixed to the leaf surface. The last nymphal stage, often called the pupa or the red-eye nymph, is the stage that is easiest to identify. Silverleaf whitefly pupae are oval, whitish, and soft. The edge of the pupa tapers down to the leaf surface and has few to no long waxy filaments around the edge. In contrast, greenhouse whitefly pupae have many long waxy filament around the edge and the edge is somewhat vertical where it contacts the leaf surface.

Damage

Whiteflies damage peppers by sucking enormous quantities of sap and covering plants with sticky honeydew. Black sooty mold grows over the honeydew, lowering the photosynthetic capacity of the plant and making the fruit unattractive. Feeding by high populations may result in stunting, poor growth, defoliation, and reduced yields.

Management

Whitefly population are not consistent from year to year, so monitoring is important in detecting and preventing the development of populations in any given year. In addition, an integrated pest management program for whiteflies includes following good cultural practices, such as host-free periods, conserving natural enemies, and using pesticides only when necessary.

Biological Control

Several wasps, including species in the *Encarsia* and *Eretmocerus* genera, parasitize whiteflies. Whitefly nymphs are also preyed upon bybigeyed bugs, lacewing larvae, and lady beetle larvae. Silverleaf whitefly is an introduced pest that has escaped its natural enemies. Some indigenous native parasites and predators do attack it, but do not keep it below damaging numbers. The parasitic wasp, *Encarsia formosa,*has been used successfully to control greenhouse whitefly in greenhouses or protected crop situations elsewhere in the world where peppers are more commonly grown in this manner.

Cultural Control

The best control for silverleaf whiteflies is to maximize the distance and time interval between host crops. When possible, plant peppers at least one-half mile upwind from key silverleaf whitefly hosts such as melons, cole crops, and cotton. Maintain good sanitation in areas of winter/spring host crops and weeds by destroying and removing all crop residues as soon as possible. Control weeds in noncrop areas including head rows and fallow fields and harvest alfalfa on as short a schedule as possible. In addition, allow the maximum time between silverleaf whitefly host crops and produce vegetables and melons in the shortest season possible.

Adult silverleaf whiteflies are repelled by silver- or aluminum-colored mulches. Place reflective polyethylene mulches on planting beds before seeding or transplanting to significantly reduce rate of colonization by whiteflies and delay the buildup of damaging numbers of whiteflies by 4 to 6 weeks. The mulches lose their effectiveness when more than 60% of the surface is covered by foliage. Therefore, they are effective only for the first few weeks after seedling emergence or transplanting.

Greenhouse whiteflies are often induced by applications of broad-spectrum pesticides. Avoid such materials early in the season.

Organically Acceptable Methods

Cultural and biological control as well as sprays of insecticidal soaps and certain oil sprays are acceptable for use on organically certified produce.

Monitoring and Treatment Decisions

Routinely check field margins for whiteflies; these areas are usually infested first. Be especially alert for rapid population build up when nearby host crops are in decline. During these critical periods, check pepper fields twice weekly. Sticky traps may be useful in detecting initial whitefly migrations into fields.

Allow beneficials an opportunity to control light silverleaf whitefly infestations. If higher populations are present at the field margins than the field centers, then treat only the field margins. This approach will reduce treatment costs and help preserve beneficials in the field. The treatment threshold for silverleaf whitefly is about 4 adults per leaf in a random 30-leaf sample of healthy leaves. Thresholds have not yet been established for greenhouse whitefly.

Insecticidal soaps and oils are not as effective as the other materials and require frequent application and good coverage.

Chemical Control

There are many chemical controls for whiteflies including Imidacloprid(Admire Pro), Pyriproxfen(Knack), Acetamiprid(Assail), Insecticidal soap, Dinotefuran(Venom), Spiromesifen(Oberon), Spirotetramat(Movento), and Narrow Range oils(Safe-T-Side, Ultra-Fine oil).

Diseases

Bacterial Spot

Symptoms and signs

Bacterial spot appears as spots that form on leaves, stems, and fruit. Leaf spots first appear as small, angular spots on the undersurface of the leaf. The spots, which are about 0.25 inch in diameter, are initially water soaked and later turn brown. Elongated raised cankers form on the

stems. Fruit spots are circular, brown, and raised with a cracked, roughened, and wart like surface.

Comments on the disease

The bacterium is seed borne and can occur within the seed and/or on the seed surface. The pathogen is disseminated with seed or on transplants. Bacterial spot is a relatively minor disease that is favored by high relative humidity and free moisture on the surface of the plant. Symptoms develop 5 to 15 days after inoculation and develop most rapidly at temperatures of 68°F or above. The bacteria do not survive in soil after the infected plant residue decomposes. Some strains of the bacteria favor pepper, others favor tomato, and others are equally pathogenic on both tomato and pepper.

Management

Use indexed pathogen-negative seed, treated seed, or disease-free transplants. Rotate out of peppers for at least 1 year. Use furrow or drip irrigation instead of overhead irrigation. Treatment with copper spray is justified only under high pressure as might occur with sprinkler irrigations. Resistance to copper is known to occur in California populations of this pathogen.

Curly Top

Symptoms and signs

The internodes of infected plants shorten, resulting in extremely stunted plants. The upper portion of infected plants resembles a rosette or small flower bouquet. Leaves turn yellow or light green and may roll upward. Fruit are small and remain upright instead of drooping. Plants infected at an early age may die.

Comments on the disease

The virus has a very large host range that includes many vegetables, field crops, and weeds. It is transmitted by the sugarbeet leafhopper, *Circulifer tennelus,* from susceptible host plants such as Russian thistle, which thrives in the coastal ranges or in desert areas. Curly top usually appears on scattered plants in pepper fields.

Management

Resistant varieties are available for beans and sugarbeet, but not for pepper or tomato. A statewide program to control the leafhopper vector with insecticide sprays on its breeding grounds limits the number of leafhoppers that move to agricultural areas. Control measures are not recommended for individual fields.

Pepper Mosaic Diseases

Symptoms and signs

Symptoms on plants affected with potyvirus mosaic diseases can vary, but in general, plants show an overall lighter color along with mosaic patterns (alternating light and dark green areas) on at least some leaves, especially on the younger leaves. Plants will often show stunting, leaf curling, and fruit distortion along with the mosaic pattern on leaves. Symptoms may be similar to those caused by cucumber mosaic virus.

Comments on the disease

All of the potyviruses affecting pepper are transmitted from plant to plant by several species of aphids. Aphids are able to transmit these viruses for very short periods of time (minutes to a few hours). The type of aphid activity that promotes virus spread occurs when aphids are actively moving through the pepper crop and are probing the plant tissues before they begin feeding. Once aphids colonize plants, settling down to feed, transmission is greatly reduced. Thus, spread is often very rapid. In general, field spread of potyviruses occurs when aphid activity in fields is high.

All of the potyviruses that affect peppers have wide host ranges that include other crops and many weed species, particularly those within the Solanaceae family (tomato, potato, eggplant, nightshades). Various strains of the potyviruses exist, some of which differ in their specific pathogenicities. It is very common to find plants simultaneously infected by more than one of the pepper potyviruses and also by cucumber mosaic virus. While spraying for the aphid vector will not prevent virus infections from occurring, growers should still attempt to manage vector populations when possible.

Management

Some resistance, derived from various plant species closely related to peppers, is currently available and efforts are under way to develop more resistant varieties. In general, sources of

genetic resistance in bell types is greater for*Potato Y potyvirus,* followed by *Tobacco etch potyvirus,* followed by *Pepper mottle potyvirus.*

No effective chemical control practices have been developed for potyvirus mosaic diseases in California. The incidence of these viruses is unpredictable between years and locations. Insecticides are not effective in controlling the spread of these viruses because they do not kill aphids before the aphids can acquire and transmit the viruses to plants.

Silver reflective plastic mulches applied at planting have been shown to be effective in repelling aphids from plants, thereby reducing or delaying virus infection.

Pepper Tobamovirus Disease

Symptoms and signs

Symptoms on plants infected with *Tobacco mosaic tobamoviruses* vary among cultivars and with specific viruses or strains. Symptoms can include necrosis on any plant part, defoliation, leaf distortion, and/or mosaic symptoms on leaves, stems, and fruit.

Comments on the disease

An important source of primary inoculum is contaminated seed. The virus is carried on the seed coat, and thus can be removed from contaminated seeds by washing seed with dilute solutions of tri-sodium phosphate. The tobamoviruses on pepper are readily spread mechanically within the field by handling and mechanical damage to plants, but not by insect, nematode or fungal vectors.

The tobamoviruses are very stable viruses. They can survive in plant debris for many years.

Management

The best control is to use seed that has been treated to eliminate the seedborne inoculum. Minimizing plant handling and damage also is important for reducing field spread of tobacco mosaic virus. Good sources of plant resistance genes (L1-L4 genes) to various tobamoviruses also exist and are present in commercially available cultivars. No chemical strategies are effective.

Powdery Mildew

Symptoms and signs

Powdery mildew primarily affects leaves on pepper plants. Although the disease commonly occurs on older leaves just before or at fruit set, it can develop at any stage of crop development. Symptoms include patchy, white, powdery growth that enlarges and coalesces to cover the entire lower leaf surface. At times the powdery growth is present on the upper leaf surface as well. Leaves with mildew growing on the undersurface may show a patchy yellowish or brownish discoloration on the upper surface. The edges of infected leaves may roll upwards exposing the white, powdery fungal growth. Diseased leaves drop from the plants and leave the fruit exposed to the sun, which may result in sun burning.

Comments on the disease

Powdery mildew can be severe during the warmest part of summer and can cause heavy yield losses. The pathogen has a very wide host range and inoculum from one host plant species can cross infect other host plants. In California, powdery mildew inoculum can come from crops such as onion, cotton, tomato, all varieties of peppers, and weeds such as annual sowthistle and groundcherry.

This powdery mildew pathogen differs from powdery mildew pathogens in other genera in that it primarily occurs inside the leaf rather than on the leaf surface. Cleistothecia (sexual spores) of the *Leveillula* perfect stage rarely occur in California, but asexual spores (conidia) are produced and disseminated by wind. In general, high humidity favors germination of conidia. Infection of plants can occur over a wide temperature range (64° to 91°F or 18° to 33°C) under both high and low humidity. Under favorable conditions, secondary infections occur every 7 to 10 days, and disease can spread rapidly. Temperatures over 95°F that commonly occur in the interior valleys of the state can temporarily suppress development.

Management

Regular monitoring to detect powdery mildew, especially during warm weather, is important to time fungicide applications early enough to prevent damage. Powdery mildew is managed primarily with fungicides.

Cultural Control

The fungi that cause powdery mildew can survive between crop seasons on other crops and on weed species. The degree of survival depends on environmental conditions. Because of the wide host range of the fungus, it is difficult to control the amount of inoculum that overwinters in California. Thus, simple sanitation methods in and around pepper fields may not provide a sufficient reduction in the primary inoculum to provide disease control.

Most pepper cultivars used in California do not possess acceptable levels of resistance to powdery mildew. Currently, there are no breeding programs aimed at developing resistant cultivars to pepper powdery mildew.

Organically Acceptable Methods

Sprays of sulfur and potassium bicarbonate are acceptable for use on organically grown peppers.

Treatment Decisions

Fungicides can provide satisfactory control and prevent economic loss if applied during the early stages of the infection. Effective control requires spraying with high pressure and high volume of water for optimum penetration of the crop canopy by the fungicide. Good coverage is necessary for satisfactory control; ground applications give better coverage than air.

Chemical Control

Only Milstop should be used for powdery mildew on peppers.

Verticillium Wilt

Symptoms and signs

Verticillium dahliae can infect pepper plants at any growth stage. Symptoms include yellowing and drooping of leaves on a few branches or on the entire plant. The edges of the leaves roll inward on infected plants, and foliar wilting ensues. The foliage of severely infected plants turns brown and dry. Growth of pepper plants inoculated with aggressive strains of *V. dahliae*in greenhouse or of pepper plants infected early in the season under field conditions is severely stunted with small leaves that turn yellow-green. Subsequently, the dried leaves and shriveled fruits remain attached to plants that die. Brown discoloration of the vascular tissue is visible when the roots and lower stem of a wilted plant are cut longitudinally. Another important soilborne disease of pepper in California, Phytophthora root rot, causes similar foliar symptoms; however, Phytophthora root rot causes extensive browning and rotting of the root cortex, while the roots of *V. dahliae*-infected pepper plants show no external discoloration or decay.

Comments on the disease

Verticillium wilt, caused by *Verticillium dahliae,*is a soilborne fungus that colonizes the vascular tissues of plants. *Verticillium dahliae*has a broad host range, causing vascular discoloration and wilt of many economically important crops. Microsclerotia produced by *V. dahliae* may survive under field conditions for up to 14 years in the absence of a host. The microsclerotia germinate in the vicinity of host roots and cause infection. Verticillium wilt is favored by cool air and soil temperatures. Peppers are resistant to isolates of *V. dahliae*from many hosts, and only certain strains of *V. dahliae,* such as those from eggplant and pepper, are pathogenic on peppers. In recent years, an increase in the incidence of Verticillium wilt on many types of pepper has been observed in the central coast of California, resulting in significant reduction in yields.

Management

There are no effective controls methods once the disease has occurred in the field, therefore management strategies should concentrate on avoiding the problem. Resistance in peppers to Verticillium wilt is not common in commercial cultivars and is difficult to identify in pepper

germplasm. Because of the longevity of microsclerotia and the broad host range of *V. dahliae,* crop rotation is usually not a feasible option for control of Verticillium wilt in many crops. However, rotations with broccoli, corn, wheat, barley, sorghum or safflower for a period of at least 2 years (the longer the rotation, the better) can reduce inoculum and subsequent plant infection. These crops are not hosts for the *Verticillium* pathogen, and populations of the pathogen will decline in fields where host plants are not present. In severe cases, do not replant peppers in the field for a minimum of 3 years.

Use of soil fumigation with metam sodium is usually not economically viable for controlling Verticillium wilt in peppers. However, when metam is applied to the soil for weed control, concurrent reductions of *Verticillium*propagules often occur.

Tomato Spotted Wilt

Symptoms and signs

The symptoms of tomato spotted wilt in pepper vary depending on the stage of growth that the plant is infected, the cultivar, co-infections with other viruses, and other factors such as environmental conditions. Certain symptoms of TSWV infection—the spotting, bronzing, and necrosis of leaves and the ringspots on fruit—are fairly typical.

Seedling Infection

Plants infected at the early stages of growth (e.g., as transplants) are stunted. Leaves will be stunted with necrotic spots or rings. Severely infected plants may die.

Early Infections in the Field

One of the earliest initial symptoms is a bronze appearance on infected leaves, along with a drooping or wilting of the infected plant. This is associated with development of necrotic spots on leaves, which may include vein necrosis, as well as necrosis of the stems and petioles.

Eventually the entire plant becomes stunted and may show a drooped or wilted appearance; necrosis becomes more pronounced on infected leaves, petioles, and stems. Developing green fruit will be bumpy and show diagnostic spots and concentric rings that are initially pale or yellow but may become necrotic. Ripe fruit are distorted and often show extensive necrotic rings or etching.

Late Infections in the Field

When plants are infected later in development, only a part of the plant may develop symptoms, whereas the rest of the plant will remain healthy (this is because of the inability of the virus to move into mature parts of the plant). The initial symptoms in leaves include curling, pale green to yellow discoloration, and purpling of the leaves. Fruits on such infected shoots may become bumpy, deformed, and often develop spots, ringspots, and necrosis.

Comments on the disease

Tomato spotted wilt virus is transmitted by various species of thrips, including the western flower thrips, *Frankliniella occidentalis,* the onion thrips, *Thrips tabaci,* and the chili thrips,*Scirtothrips dorsalis. Tomato spotted wilt virus*also infects the thrips vector. This virus is not seed-borne and it is not spread by contact; it is only spread from plant-to-plant by thrips.

Nymphs that acquire the virus by feeding on infected plants will retain the ability to transmit it for the remainder of their lives. *Tomato spotted wilt virus* cannot be passed from infected females through the eggs.

TSWV has a wide host range, and can infect hundreds of species of plants, including monocots and dicots. These plants include crops, ornamentals, and weeds. However, it is important to emphasize that all plant hosts are not equally important in contributing to the development of tomato spotted wilt disease in crop plants. It is only the species of plants that are infected by TSWV and on which the thrips can complete their entire life cycle that play an important role in the disease cycle. In California, the key field crop hosts include tomato, pepper, radicchio, and lettuce. Important weed hosts include cheese weed*(Malva parviflora)*, sowthistle *(Sonchus oleraceus),* and prickly lettuce *(Lactuca serriola)*, among others.

Management

Effective management of tomato spotted wilt in areas where it is known to occur in California requires an integrated pest management (IPM) approach that targets the thrips vector and the virus.

This IPM strategy can be divided into three parts:

Before the Growing Season

- Use virus- and thrips-free transplants (ideally from transplant houses that monitor for thrips and inspect for disease).
- Manage thrips populations on transplants if necessary (for more information, see THRIPS).
- Practice good weed management in and around fields to be planted with pepper.
- Note that TSWV-resistant pepper cultivars, suitable for use in California, are not yet available.

During the Growing Season

- Avoid planting new fields near older fields (especially those fields confirmed to have TSWV infection).
- Monitor fields for the presence of thrips and manage populations (see THRIPS for more information).
- Monitor for TSWV using a number of tests including the enzyme-linked immunosorbent assay (ELISA) and immunostrip tests that are based on antibodies that recognize TSWV proteins and the polymerase chain reaction test (PCR) that detects the virus genetic material. The immunostrip is a rapid result test for plant viruses that involves the use of 'dip-sticks' that are put in bags with sap prepared from plant samples; the results are obtained in 5-10 minutes. TSWV immunostrips and buffer bags are commercially available from companies such as AgDia (www.agdia.com) and EnviroLogix (www.envirologix.com).
- Consider roguing plants infected at the seedling stage.
- Practice good weed management in and around fields.

After the Growing Season

- Sanitation is very important; it is important to promptly remove and destroy old crops/volunteers after harvest (e.g., plowing/physical removal). Ideally this practice is followed on a regional basis.
- Control weeds and any volunteers on fallow fields or unused land nearby where tomato crops will be planted.

Phytophthora Root and Crown Rot

Symptoms and signs

Aboveground symptoms of Phytophthora root and crown rot include rapid wilting and death of affected pepper plants. Close examination of the roots and stems of affected plants is necessary to confirm the cause of disease. The disease can develop at any stage of pepper plant growth. Tap roots and smaller lateral roots show watersoaked, very dark brown discoloration of cortical and xylem tissue. Very few lateral roots remain on diseased plants and the tap roots may also be shorter compared to those of healthy plants. The most striking difference between healthy and diseased plants is the total amount of root tissue. Stems are usually infected at the soil line. Stem lesions are first dark green and watersoaked, then dry and turn brown. The lesions may girdle the stem and result in wilting of plants above the lesions and subsequent death.

Another important soilborne disease of pepper in California, Verticillium wilt, causes similar foliar symptoms; however, Verticillium wilt does not cause any browning or rotting of the root cortex. In contrast, the vascular tissues of main stems and roots of *Verticillium dahliae*-infected pepper show black streaking and discoloration.

Comments on the disease

The fungus can survive on and in seed and in soil. The fungus also produces thick-walled oospores that can survive prolonged periods of adverse conditions. Contaminated seed and transplants, or soilborne inoculum are sources of primary infections. Irrigation water often disseminates fungal propagules from infested areas to other parts of the field. Thus, irrigation can significantly increase the incidence and severity of root and crown rot in pepper. Increased frequency and duration of irrigation favor disease development.

Water, temperature, and soil texture are the major factors affecting the development of root and crown rot. The presence of water is mandatory; soil saturation for as little as 5 to 6 hours can result in infection, and susceptible varieties can become severely diseased in as little as 5 days. Optimum temperature for plant infection is 75° to 92°F (24° to 33°C). Symptoms usually appear following a warm, wet period. The disease is severe in fine-textured (clay) soils that

drain slowly and in highly compacted soils. Severely infected fields may have nearly complete loss of plants.

Infections that occur late in the season may reduce vigor and yield of plants without killing them. However, the foliage wilts during the hottest time of day, exposing fruit to sunburn.

Management

Phytophthora fungi survive in soil as oospores for several years. Factors that influence the development of root and crown rot in peppers in a given season include varietal susceptibility, amount and frequency of irrigation, and soil compaction and drainage. Crop rotation, proper irrigation, and clean seed and transplants are critical in managing this disease. Fields that have a history of Phytophthora rots may need fungicide treatments at planting.

Cultural Control

The disease can be effectively prevented by a program integrating crop rotations of 2 years that exclude susceptible plants, irrigation management, and clean seed and transplants. In heavy soils that are poorly drained, root and crown rot may be reduced by irrigating every second furrow at one irrigation and the alternate furrows at the next, or by carefully managed drip irrigation. Practices that reduce or alleviate soil compaction may improve control; for example, growing plants on raised beds. Commercial cultivars with acceptable levels of resistance to the disease are available. However, in general peppers are very susceptible to this disease.

Treatment Decisions

Fungicides are sometimes used in fields with histories of root rot or problems with drainage.

Chemical Control

Mefenoxam(Ridomil Gold), Fluopicolide(Presidio), and Phosphorous Acid are all chemicals available for control.

Cucubrits

Insects

Beet Armyworm

Description of the pest

Larvae are usually dull green and have wavy, light-colored stripes running lengthwise down the back and broader stripes on each side. Eggs are laid in a mass covered with hair like scales.

DAMAGE

Primarily a foliage feeder, the beet armyworm will also attack fruit, creating single or closely grouped circular or irregular holes. In many cases, feeding is superficial and little loss would result if not for decay organisms that enter wounds and rot fruit. The caterpillars occasionally develop inside the fruit.

Management

While populations of this pest tend to build up in alfalfa and weedy areas around the field, beet armyworm only needs to be controlled if it is feeding on the crop. Keep crop residue and weeds in field and surrounding areas to a minimum to lessen the attraction of the field.

Biological Control

The parasitic wasp, *Hyposoter exiguae*, is important in controlling populations of this pest. Beet armyworm larvae can be easily checked for the presence of this wasp by pulling the larva apart and looking for theparasite larva.

Organically Acceptable Methods

Sanitation in the field and surrounding areas along with biological control and sprays of *Bacillus*

thuringiensis or the Entrust formulation of spinosad are acceptable to use in an organically certified crop.

Monitoring and Treatment Decisions

Beet armyworm may be present in and around the field feeding on bindweed and little mallow(malva). Monitor weed and crop foliage for larvae and treat the crop before there is economically important feeding damage to fruit. If young instars are found, consider treating with a low impact product such as*Bacillus thuringiensis*, methoxyfenozide (Intrepid), or spinosad (Entrust).

Chemical Control

Several chemicals such as Spinetoram(Radiant), Spinosad(Entrust), Chlorantraniliprole(Corgen), and Methoxyfenozide(Intrepid) are all acceptable chemicals for use on cucumbers.

Cabbage Looper

Description of the pest

Looper caterpillars can be distinguished from most other common caterpillars in cole crops by their distinctive looping movement in which they arch the middle portion of their body to bring the prolegs or hind legs forward to meet the front legs. Loopers are green, usually with a narrow white stripe along each side and several narrow lines down the back. Loopers are smooth-skinned with only a few long bristles down the back; they may grow up to 1.5 inches long. Mature larvae spin silken cocoons and pupate, usually attached to leaves. Adults are brownish moths with a distinctive silvery figure-8 on the front wings. Eggs are ridged and dome-shaped and usually laid singly on the undersurface of leaves. Loopers may have numerous generations and continue to develop all year long in cole crops growing areas of California with the highest populations usually occurring in fall.

Damage

Although seedlings are occasionally damaged, most injury occurs after heading. Loopers eatragged holes into leaves, bore through heads and contaminate heads and leaves with their bodies and frass. Young plants between seedling stage and heading can tolerate substantial leaf damage without loss of yield.

Management

Cabbage loopers have many natural enemies that frequently keep loopers below economic levels, at least until heading, if they are not killed by insecticide treatments for other pests. Monitor to determine population levels of loopers and natural enemies and to determine the need for treatment following heading. If treatment is needed, use a selective material such as *Bacillus thuringiensis.*

Biological Control

Important parasites include the egg parasite*Trichogramma pretiosum*, the larval parasites*Hyposoter exiguae, Copidosoma truncatellum,*and *Microplitis brassicae*, and the parasitictachinid fly *Voria ruralis.* A nuclear polyhedrosisvirus disease is also important under certain circumstances; the bodies of diseased caterpillars turn into shapeless sacks of dark liquid and can often be spotted hanging from leaves. Be sure to monitor for natural enemies; if looper populations are close to treatment thresholds but you find a significant percentage of parasitized or disease-killed individuals, delay treatment for a few days to see if these natural controls will bring populations down on their own. If treatment is necessary, use of *Bacillus thuringiensis*insecticide will minimize injury to natural enemies.

Organically Acceptable Methods

Biological control and sprays of *Bacillus thuringiensis* and the Entrust formulation of spinosad are organically acceptable management tools.

Monitoring and Treatment Decisions

Check 25 plants selected randomly throughout the field. Look for eggs and small larvae on the underside of lower leaves. If you find holes, search the general area for the caterpillar, opening damaged heads as necessary. Although damage can give you a general idea of where loopers may be and the seriousness of the infestation, do not base treatment on damage levels. Base treatment on numbers of healthy larvae present (include imported cabbageworms in counts, too, if they are also present). Treat seedlings or small plants if populations of medium-sized to large caterpillars are large enough to stunt growth. Before heading, well-established plants do not need to be treated unless you find more than 9 small- to medium-sized larvae per plant. Treat just before heading or at Brussels sprouts formation if counts show more than one looper or other caterpillar in 25 plants.

Where possible, use a selective insecticide to avoid adverse impacts on natural enemies.*Bacillus thuringiensis* and most other selective insecticides are very effective against cabbage loopers, especially when applied to early-instar caterpillars (i.e., very young). Cabbage loopers are also controlled with the more toxic materials recommended for use against other lepidopterous (caterpillar) pests. If significant numbers of other caterpillars (armyworms or diamondback moths) are present, the use of a carbamate or pyrethroid may be warranted.

Chemical Control

There are several chemical controls that are effective such as Bacillus Thuringiensis, Emamectin Benzoate (Proclaim), Indoxacarb (Avaunt), Spinetoram (Radiant), Spinosad (Success and Entrust), Chlorantraniliprole (Corgan), Flubendiamide (Synapse), and Methoxyfenozide (Intrepid). All the chemicals above you should avoid runoff and drifting to avoid harming water ways and natural predators.

Cucumber Beetles

Description of the pests

The western spotted and the western striped cucumber beetles occur throughout California and are major pests of cucurbits; the banded cucumber beetle occurs primarily in southern California. Cucumber beetles overwinter as adults and are active by the time the earliest melons are planted in spring. Adults lay eggs at the base of plants. As soon as they hatch, larvae begin to feed on plant roots. They complete their development in the soil. There are about three generations a year.

Cucumber beetles are about 0.36 inch (9 mm) long and either have a greenish yellow background with black spots or alternating black and yellow stripes. They fly readily and migrate into cultivated areas from alfalfa and other crops and from uncultivated lands. Cucumber beetles like moisture and dislike heat; consequently, melon fields are especially attractive in hot weather during and after an irrigation.

Western striped cucumber beetle larvae feed exclusively on cucurbit roots, whereas western spotted cucumber beetle larvae feed primarily on grasses, corn, and legumes, and do not damage cucurbits.

Damage

Cucumber beetles are serious pests of smooth-skinned cucurbits, especially melon varieties such as honeydew, 149lliptic, and casaba. They prefer tender, succulent portions of plants, including the flowers, which they may destroy with their feeding. The beetles chew holes in leaves and scar runners and young fruits. Adults tend to avoid heat and thus feed mainly on the underside of young melons. After the skin hardens, melons are much less subject to attack. Scarring in the crown of the plant is also typical of adult damage. Feeding on stems of young plants, followed by sustained winds, may result in severe stand reductions making replanting necessary. In some situations, larvae may cause serious injury by feeding on roots, and young plants can be killed. Cucumber beetles also spread squash mosaic virus.

Management

Damaging populations of cucumber beetles are usually treated with insecticides.

Biological Control

Cucumber beetles are attacked by a variety of natural enemies, the most important being a parasitic tachinid fly, *Celatoria diabroticae.*Natural enemies are rarely effective enough, however, to reduce populations below economically damaging levels.

Cultural Control

There are no effective cultural controls for these pests. Because spotted cucumber beetle larvae also feed on corn, avoiding planting cucurbits next to corn may help.

Monitoring and Treatment Decisions

Cucumber beetles are difficult to control. Sprays must be directed at adult beetles. Larvae of western spotted cucumber beetle develop outside of cucumber fields. Striped cucumber beetle larvae are located on roots where they cannot be controlled.

Treatment of adults may be necessary if there is an average of one beetle a plant during the seedling-to-4-inch-tall stage. Infestations that develop late in the season are usually not as damaging as those that begin earlier because the population levels tend to be lower. Apply treatments before beehives are introduced into the field; typically, treatment is often made the day before bees are put in the field.

Chemical Control

Carbaryl(Sevin) you should plant injury, do not apply when foliage is wet or when rain or excessive humidity is expected during the 2 days after application. May cause increased spider mite problems. The XLR Plus formulation is less hazardous to honey bees than other formulations if applied from late evening to early morning when bees are not foraging. Esfenvalerate(Asana XL) use control adults; repeat as necessary to maintain control. Do not exceed 0.25 lb a.i./acre/season. Highly toxic to honey bees. Endosulfan(Thionex) do not exceed 3 applications per year. Cryolite(Kryocide) labeled for use on cucumber, squash, melons, and pumpkins. Can be applied as a spray or dust. Thorough coverage using ground equipment is necessary for adequate control. Do not apply immediately before harvest. Remove excess residues on edible portions by washing, brushing, or other effective means. Effectiveness of this material is lower than materials listed above. PHI is 7 days for summer squash and 14 days for winter squash, cucumber, melons, and pumpkins. Prokil Cryolite 96 is labeled for use on cantaloupe, squash, and watermelon. Applied as a spray. Thorough coverage using ground equipment is necessary for adequate control. Do not apply immediately before harvest. Remove excess residues on edible portions by washing, brushing, or other effective means. Effectiveness of this material is lower than materials listed above. PHI is 7 days for summer squash and 14 days for winter squash, cantaloupe, and watermelon.

Cutworms

Description of the pests

Cutworms include a number of species of dull gray to brown, medium-sized to large (up to 2 inches when full grown) caterpillars. Most cutworms curl up into a C-shape when disturbed. All normally feed close to the soil surface cutting off seedlings or damaging leaves resting on the ground. Most feeding occurs at night; during the day cutworms are usually found just below the

soil surface or under dirt clods. First instar cutworms of some species may be found feeding on the leaf surface.

Adult cutworm moths have dark gray or brown front wings with irregular spots or bands and lighter hind wings. Females lay hundreds of white eggs, either singly or in clusters, depending on species, on leaves or stems close to the ground. After hatching, young larvae may feed on leaf surfaces for a while, but older larvae drop to the ground, tunnel into the soil, and emerge at night to feed.

Damage

Seedlings or young plants are cut off at or just below ground level; often several plants in a row will be wilted or cut off. Losses can be especially severe in fields seeded to a stand or recently thinned. Occasionally cutworms will bore into cabbage heads, but this is not common. Damage often recurs in the same fields and same parts of fields from year to year; damage is worst where large numbers of cutworms are present before planting.

Management

Cutworms migrate into newly planted crops from surrounding weeds or infested crops. Check for cutworms in weeds around the edges of the field before you plant. Remove weeds from field margins and plow fields at least 10 days before planting to destroy larvae, food sources, and egg-laying sites. Cutworms have numerous natural enemies, but none can be relied on to bring a damaging population down below economic levels.

Organically Acceptable Methods

Cultural practices such as removal of adjacent weeds are an essential part of an organic management program.

Monitoring and Treatment Decisions

After the crop is up, check for a row of four or more wilted plants with completely or partially severed stems. If you find damaged plants, look for cutworms by digging around the base of plants and sifting the soil for caterpillars. If you find substantial numbers of cutworms, you can use bait to control most species, except the glassy cutworm, which occurs in the southern San Joaquin Valley. Baits are more effective when food is limited, so get it out before the crop emerges. If unexpected damage occurs after crop emergence, treat as soon as you find several severed plants in the same row.

Chemical Control

Spinosad is an insecticide derived from natural metabolites produced under fermentation conditions by *Saccharopolyspora spinosa.* It has a high level of contact and oral activity and a rapid speed of action. It also has a low to moderate impact on beneficial insects.

Darkling Beetles

Description of the pests

Darkling beetle adults are from 0.13 to 0.25 inch long (3 to 6 mm) and vary from black or bluish black to rusty brown. Do not confuse beetles (Tenebrionidae) with predatory ground beetles (Carabidae), which prey on various soil dwelling pests. Darkling beetles generally have clubbed antennae whereas carabids do not. Darkling beetles may be hidden by dust or a thin layer of soil. Larvae are cylindrical, wirewormlike, soil-inhabiting worms that are light yellow to dark brown and range from 0.03 to 0.33 inch (1–8 mm) in length. They are often referred to as false wireworms.

Damage

Darkling beetles are generally not a problem unless large populations build up when the plants are in the seedling stage. Young plants may be girdled or cut off at or below the soil surface. After the plants reach a height of 5 to 6 inches, darkling beetles are usually not a problem. However, further feeding may occur on flower blossoms during bloom, on the undersides of leaves, and on the netting of mature melons. They can also bore into fruit where it rests on the ground.

Management

Keep fields and ditches free of weeds. Water barriers can aid in stopping migrating populations. Reduce organic matter in soil by fallowing. Treat whenever beetles are observed feeding on

plants, flowers, or fruit. Also treat when beetles are observed moving into cucurbits or melons from fallow or alfalfa hay fields.

Chemical Control

Only two chemicals are effective Carbaryl and Malathion.

Aphids

Description of the pest

The green peach aphid is rather slender in form, light green or yellowish in color. Winged adults of the green peach aphid are pale or bright green and black, with a large dusky blotch on the dorsum of the abdomen. The immature forms are yellow, pinkish, or pale green. The mature wingless forms are pale or bright green and have no waxy covering. The tubercules at the base of the antennae grow towards each other. Populations tend to start on lower leaves and move up the plant. The green peach aphid occurs throughout California and has a wide host range.

Damage

In desert areas, watermelon mosaic virus, zucchini yellow mosaic, and papaya ringspot virus are transmitted chiefly by the green peach aphid. This aphid moves into melon fields in large numbers from surrounding vegetation, carrying viruses as it moves and feeds from one plant to another. In the San Joaquin Valley, cucumber mosaic, zucchini mosaic, and watermelon mosaic are often the most important viruses transmitted by this aphid.

Management

Silver reflective mulches have successfully been used to repel aphids from plants, thus reducing or delaying virus transmission. In some areas of the state, row covers have also been

successfully used. Biological control can have a significant impact on aphid population so be sure to evaluate predator and parasite populations when making treatment decisions.

Biological Control

Naturally-occurring populations of the convergent lady beetle, *Hippodamia convergens,* may provide effective control in early spring. Releases of this beetle are not effective, however, because it generally does not remain in the field following release. Other general predators, such as lacewing and syrphid larvae, and parasitic wasps, including Aphidius, Diaeretiella, and *Aphelinus* species, also attack aphids. Biological control is not effective in reducing virus transmission by this aphid.

Cultural Control

To exclude green peach aphid, place row covers over the seed bed following planting and leave them in place until first bloom. Row covers are not recommended in the San Joaquin Valley. Silver reflective plastic mulches applied at planting are effective in repelling aphids from plants, thereby reducing or delaying virus infection. Mulches help plants get off to a healthy start, and are effective until expanding foliage covers the reflective surface. Mulches may need to be removed in the desert areas when summer temperatures are excessive for optimal growth of plants. However, in the Central Valley and cooler areas, mulches have not caused plant damage in the summer; in fact, they improve soil moisture and nutrient retention, which may further aid plant productivity.

Control weeds along ditch banks, roads, in farmyards, and other noncultivated areas that contribute directly to the aphid problem. Planting a habitat for beneficial insects, such as sweet alyssum, around the field may be helpful. Delay planting until warm temperatures (80° to 85°F) occur and the spring flight of aphids is over. Do not overfertilize with nitrogen.

Organically Acceptable Methods

Biological and cultural controls and treatments of insecticidal soaps and certain narrow range oils are acceptable to use in an organically certified crop.

Monitoring and Treatment Decisions

The decision to treat for aphids is based mainly on visual counts; measurable thresholds have not been researched. It is important to treat early to insure that the aphids do not build up to high levels. Early treatment does not prevent virus introduction; treating, however, may help reduce spread of the virus if aphid colonies are present. Be aware, however, that parasites and predators, if present, may prevent an infestation from becoming established throughout a field, thus eliminating the need to treat.

Chemical Control

Imidacloprid (provado) is the only chemical control method, thorough and uniform coverage is important for good control.

Squash Bug

Description of the pest

The adult squash bug is 0.65 inch (1.5 cm) in length. It is brownish yellow but appears black because of a dense covering of black hairs. Protruding margins of the abdomen are orange or orange and brown striped, and the margins of the pronotum are yellow. Shiny, 155lliptical reddish brown eggs are laid singly or in groups of 15 to 40 on the underside of leaves or on stems. Young nymphs are pale green, while later instars have a blackish thorax and brownish abdomen; they are often covered with white powder.

Damage

Injury occurs on squash, pumpkins, and melons. Adults and nymphs cause damage by sucking plant juices. Leaves lose nutrients and water and become speckled, later turning yellow to brown. Under heavy feeding, plants begin to wilt, and the point of attack becomes black and brittle. Small plants can be killed completely, while larger cucurbits begin to lose runners. The wilting resembles bacterial wilt, which is a disease spread by another pest of squash, the cucumber beetle. The wilting caused by squash bugs is not a true disease. Squash bugs may feed on developing fruits, causing scarring and death of young fruit.

Management

Good field sanitation and other cultural practices help to prevent damage by this pest. Treatments may be warranted if the insect is causing damage in the field.

Cultural Control

Destroy crop residues and reduce overwintering hiding places. Row covers applied at planting and removed at first bloom exclude squash bugs. Some plant varietal preferences occur: pumpkins, watermelons and squash are the most seriously damaged; zucchinis are less susceptible.

Because squash bugs have a preference for squash, a squash planting can be used as a trap crop near other cucurbits plantings such as watermelon to concentrate an infestation. Treat the trap crop with an insecticide to control the infestation.

Organically Acceptable Methods

Cultural controls are acceptable to use in an organically certified crop along with sprays of PyGanic, insecticidal soaps, and certain oils.

Monitoring and Treatment Decisions

Squash bugs overwinter as adults under dead leaves, rocks, wood, and crop debris. In spring, search for squash bugs hidden in these places, near buildings, and in perennial plants. Inspect young plants daily for signs of egg masses. While no threshold has been established in California, in the Midwest one eggmass per plant is used to make treatment decisions. If the squash population exceeds the threshold, apply an insecticide early when most eggs are hatching because young nymphs are more susceptible than older nymphs or adults. Squash bugs will feed on and damage young and mature fruit, therefore, control may be needed at later crop maturity.

Chemical Control

There are many chemicals available such as Dinotefuran(Venom), Esfenvalerate(Asana XL), Endosulfan(Thionex), Pyrethrin(PyGanic), Insecticidal soaps, and Narrow range oils.

White Flies

Description of the pests

Several species of whiteflies infest cucurbits. Proper identification of the whitefly species is important because the silverleaf whitefly, and occasionally the greenhouse whitefly, represent the greatest damage potential to cucurbits. Silverleaf whitefly is relatively new to California and has all but displaced the sweetpotato whitefly, which was a problem in cucurbits because of its ability to vector viruses. Silverleaf whitefly is a major problem in California's southern desert and an increasing problem in the southern San Joaquin Valley.

Distinguishing whitefly species is difficult; use a hand lens to examine both immatures and adults. Whiteflies are small insects that are about 0.06 inch (1.5 mm) long. The body and wings of adults are covered with a fine, whitish powdery wax that is opaque in appearance. Silverleaf whitefly adults hold their wings somewhat vertically tilted, or rooflike, over the body and generally the wings do not meet over the back but have a small space separating them. Greenhouse whitefly *(Trialeurodes vaporariorum)* adults, the species that are most similar in appearance, hold their wings flatter over the back and there is no space where the two wings meet in the center of the back.

Whiteflies colonize the underside of leaves; adults and eggs are commonly found on the lower surface of younger leaves and the scalelike nymphal stages on somewhat older leaves. The tiny, oval eggs hatch into a first larval stage that has legs and antennae and is mobile. The legs and antennae are lost after the first molt and subsequent stages remain fixed to the leaf surface. The last nymphal stage, often called the pupa or the red-eye nymph, is the stage that is easiest to identify.Silverleaf whitefly pupae are oval, whitish, and soft. The edge of the pupa tapers down to the leaf surface and has few to no long waxy filaments around the edge. In contrast,greenhouse whitefly pupae have many long waxy filaments around the edge and the edge is somewhat vertical where it contacts the leaf surface. Most other whiteflies found on cucurbits produce a lot of white wax in their colonies; silverleaf whitefly has almost none.

Damage

Desiccation of plants occurs with moderate to heavy populations and the production of honeydew gives rise to sooty mold. The plant becomes unthrifty and nonproductive, and the fruit is rendered unmarketable. Sweetpotato whitefly has historically been a serious problem in cucurbits by transmitting lettuce infectious yellows virus and squash leaf curl virus. Recently, sweetpotato whitefly has all but disappeared in California, displaced by the silverleaf whitefly. The silverleaf whitefly has become especially damaging in southern California growing areas and also threatens cucurbits in northern California. In light to moderate infestations of silverleaf whitefly, leaves show no distinctive symptoms as a result of their feeding; however, copious quantities of honeydew are deposited on leaves, resulting in a sticky, shiny appearance. Silverleaf whitefly has become a serious pest because of its high reproductive capability, wide

host range, high rate of feeding, and exudation of sticky honeydew. Its feeding on squash frequently causes crop leaves to turn whitish or silver, hence the name silverleaf whitefly.

Management

Whiteflies, with the exception of the silverleaf whitefly, rarely require chemical control. Natural or introduced biological controls provide the best long-term solution to keeping most of the whitefly species at low levels along with crop host absence in the areas of heavy infestations. Key cultural controls to prevent the buildup of this pest include the use of host-free periods, row covers in the low deserts, silver reflective mulches, noninfested transplants, and good field sanitation.

Biological Control

Several wasps, including species in the *Encarsia* and *Eretmocerus* genera, parasitize whiteflies. Whitefly nymphs are also preyed upon by bigeyed bugs, lacewing larvae, and lady beetles. Silverleaf whitefly is an introduced pest that has escaped its natural enemies. Some indigenous native parasites and predators do attack it, but do not keep it below damaging numbers. The lady beetle *Delphastus pusillus* is being introduced into southern California to assist in biological control.

Cultural Control

Populations peak in late summer and begin to decrease by November. Delaying planting or using host-free periods may decrease severity of attack. Host-free periods are valuable for controlling several of the whitefly species. Do not plant melons during fall in the low deserts of southern California unless row covers are applied to beds at planting and removed at first bloom. Row covers are not recommended in the San Joaquin Valley. Silver reflective plastic mulches applied at planting have been shown to be effective in reducing the number of silverleaf whiteflies landing on melon leaves. This, in turn, delays the buildup of whitefly populations on melons. Mulches help plants off to a healthy start and are effective until expanding foliage covers the reflective surface.

Avoid whitefly infested transplants; this is how the silverleaf whitefly has been transported to other areas of the state. When possible, plant cucurbits at least one-half mile upwind from other key whitefly hosts such as cole crops and cotton. Maintain good sanitation in winter/spring host plants and weeds. Remove field bindweed and other weeds in and adjacent to the crop field as well as crop residues. Attempt to produce the crop in the shortest season possible; proper management of irrigation and nitrogen will assist in this.

Organically Acceptable Methods
Biological and cultural controls, as well as soap and certain oil sprays are acceptable to use in an organically certified crop.

Monitoring and Treatment Decisions
If you treat for silverleaf whitefly, make applications before pests build up and honeydew contaminates fruit. A soil application of imidacloprid (Admire) or thiamethoxam (Platinum) at planting and foliar treatments with bifenthrin (Capture) or spiromesifen (Oberon) during the growing season effectively controls whiteflies.

Chemical Control

There are many chemical controls for whiteflies including Imidacloprid(Admire Pro), Pyriproxfen(Knack), Acetamiprid(Assail), Insecticidal soap, Dinotefuran(Venom), Spiromesifen(Oberon), Spirotetramat(Movento), and Narrow Range oils(Safe-T-Side, Ultra-Fine oil).

Thrips

Description of the pests

Thrips are small, slender insects with mouthparts developed primarily for sucking and rasping. The adults measure about 0.04 inch (1 mm) in length and have two pairs of fringed wings, carried lengthwise over the back.

Damage

Western flower thrips is both a beneficial insect (it feeds on spider mites) and a pest (it can damage flowers and shoot tips during the early growth stages or occasionally, if populations are severe, immature fruit). Both the young and adults cause damage by rasping and puncturing

surface cells. This results in a silvering, and sometimes deformation, of the leaves: edges of leaves tend to curl downward.

Management

Discing weeds before they flower can lessen attraction of the field to thrips. Do not disc after weeds have flowered as thrips will move to crop plants. Monitor with yellow or blue sticky traps placed in field from seedling through flowering period to determine the magnitude of the thrips population. Be sure to determine that thrips-related damage is occurring and consider treating only if the population is causing serious damage to shoot tips, flowers, or fruit. Unnecessary treatments can cause spider mite buildup.

Organically Acceptable Methods

Weed management and sprays of the Entrust formulation of spinosad are acceptable in an organically certified crop.

Chemical Control

Chemicals such as Imidacloprid(Provado), Imidacloprid(Admire Pro), Spinetoram(Radiant), Spinosad(Entrust or Success), and Methomyl(Lannate SP) are all acceptable chemicals for treatment.

Spider Mites

Description of the pests

Examine leaves with a hand lens for spider mites. Frequently, infestations include a mixture of spider mite species. Adult mites are about 0.06 inch in length, have four pairs of legs, are greenish to pink or cream colored, and have various sized black spots on the body. Under warm conditions spider mites move rapidly within the colony area. Spider mites have four stages of development: (1) the oval, somewhat translucent egg; (2) a six-legged translucent immature stage; (3) aneight-legged immature stage; and (4) the eight-legged adult stage. A generation

may pass in as few as 5 to 7 days in mid-summer, or in a month during cool periods. Spider mites produce webbing that is often filled with cast skins, dust, and other debris.

Damage

Mite feeding results in the destruction of chlorophyll; leaves become pale, stippled, and in later stages of infestation dry up and die. Loss of color is pronounced on the under surface of leaves before it becomes apparent on the upper side. Light infestations can be tolerated, but when heavy, can result in lowered yield and reduced quality of fruit.

Management

Biological control is an important component of mite management. Take measures to ensure the survival of predators and parasites.

Biological Control

Several predators play an important role in regulating spider mite populations, including the western predatory mite *(Galendromus*[*Metaseiulus*] *occidentalis)*, six spotted*(Scolothrips sexmaculatus)*, western flower thrips *(Frankliniella occidentalis)*, lady beetles*(Stethorus* sp.), minute pirate bug *(Orius tristicolor)*, and lacewing larvae *(Chrysoperlacarnea)*. The western predatory mite is the same size as spider mites but lacks spots and ranges in color from cream to amber red. It is available commercially, but research has not been done on the effectiveness of releasing these predators in cucurbits. Sixspotted thrips and western flower thrips are also effective predators, but naturally occurring populations of these insects generally do not develop to high enough levels that they can provide significant control until damage has already taken place. Both species are tiny, slender insects about 1 mm or less in length. Sixspotted thrips has three dark spots on each forewing; western flower thrips ranges in color from clear lemon yellow to dark brown. Monitor western predatory mites and the two species of thrips to determine if they are present in the field and their relative population density in comparison with pest mites.

Cultural Control

Minimize dust and encourage naturally occurring predators and parasites by limiting chemical rates and the number of applications. Control field bindweed growing in or at the edges of a cucurbit field. Good water management increases plant tolerance to these pests. After runners are 14 inches long, natural enemies such as sixspotted thrips or predaceous mites usually control pest mite populations.

Organically Acceptable Methods

Biological and cultural controls and sulfur sprays (not for use on sulfur sensitive varieties) are acceptable to use in an organically certified crop.

Monitoring and Treatment Decisions

No threshold is established, but when buildup is observed either spot or completely treat the field before webbing occurs or before runners are 14 inches in length, providing no predatory thrips or predaceous mites are present. After the rows close over, ground equipment cannot get in the field and chemical treatment must be applied by aircraft. Such treatments are less effective because it is difficult to obtain good coverage by aircraft.

Chemical Control

There are several chemicals available for control including Bifenazate(Acramite), Abamectin(Agri-Mek), Dicofol(Kelthane), and Sulfur.

Diseases

Charcoal Rot

Signs and symptoms Charcoal rot affects all cucurbits. First symptoms are yellowing and death of crown leaves and water-soaked lesions on the stem at the soil line. As the disease progresses, the stem of infected plants ooze amber-colored gum, and the stem eventually becomes dry and tan-to-brown in color. The stem may be girdled by the lesion, resulting in plant death. Numerous microsclerotia, visible as black specks, are embedded in the dead plant tissue.

Management Start looking for charcoal rot during the vegetative growth stage, and note infections to make management decisions for the next crop. Rotation to a nonhost crop for 2 to 3 years can be an effective disease management strategy in some crop production systems. However, avoidance of drought stress throughout the growing season is paramount to disease management. Leaching soil to reduce salinity levels, particularly at soil surface layers, may help reduce the incidence of disease in drip-irrigated fields. Further, destruction of infected plant tissue before the pathogen reproduces at the end of the growing season will prevent a buildup of soil inoculum. The use of grafted transplants (i.e., susceptible scions grafted onto resistant cucurbit rootstock) has been proposed as an effective management strategy for the control of charcoal rot as well as many other soilborne root-infecting pathogens where the use of

chemicals is not feasible. No preplant or postplant chemical control measures have been reported. Solarization is not promising for diseases favored by heat like charcoal rot.

Downy Mildew

Signs and symptons

Downy mildew first appears as small, pale green to yellow, angular spots delimited by leaf veins that give the foliage a mottled appearance. Eventually the spots coalesce and the leaf will turn brown. During moist weather, the lower surface of the leaf may be covered with a white to purple growth. Older leaves become infected first.

Management

Use resistant cucumber varieties. There are low levels of resistance in some varieties of melons and watermelons. Avoid overhead irrigation. Start monitoring for downy mildew during the vegetative growth stage and continue through fruit development. Apply a treatment when disease symptoms first occur and repeat if symptoms worsen. Planting early may help to avoid conditions conducive to the disease later in the season.

Chemical control

There are several chemical sfor control including Triflumizole (Procure 480sc), Myclobutanil(rally 40w), Micronized sulfur (microthiol),, Potassium Bicarbonate (milstop), and Cinnamaldehyde (cinnacure)

Verticillium Wilt

Signs and symptoms

Verticillium wilt can affect all cucurbits. The first symptoms are wilting and yellowing of crown leaves, which eventually dry up. Wilting gradually progresses out toward the runner tips; in severe cases, the plant dies. Death may take weeks. A light brown vascular discoloration in roots is sometimes seen in cross section. Aboveground vascular tissue is also discolored and can be seen by cutting through a node near the base of the plant. Tolerant or resistant varieties may show symptoms but seldom die.

Management

Start looking for Verticillium wilt during the vegetative growth stage. Note infections to make management decisions before the next crop. Use tolerant or resistant varieties. Most shipping varieties of cantaloupes grown in California have a moderate degree of resistance, and honeydew melons have greater resistance than cantaloupes. The Persian cultivar is highly susceptible. Do not plant highly susceptible melon varieties in fields with high populations of *V. dahliae.* For example, avoid fields where cotton was growing if it was severely infected by this disease. Soil solarization has been used experimentally to control this disease in cotton and tomato, but has not been tested in cucurbits because of its expense. Incorporating broccoli residue into the soil can reduce populations of *V. dahliae.* Also, preplant fumigation with chloropicrin effectively controls this disease but generally is not cost effective.