Organic Disease and Physiological Disorder Management in Apple Orchards

Effective management of pathogenic diseases and non-pathogenic disorders is crucial to the success of California organic apple production. This manual covers in detail the major diseases and disorders affecting apples in California. Minor diseases and disorders are discussed in the context of having different control measures for organic and conventional production systems. In most cases the biology and monitoring of apple pests are identical for organic or conventional production and are well covered in *Integrated Pest Management for Apples and Pears* (DANR Publication #3340). The publication, *IPM Guidelines – Apples* (DANR Publication #3339) lists registered pesticides including some organic alternatives. *Commercial Apple Production in California*, DANR publication 2456 also specifically describes in greater detail many of the common apple diseases, physiological disorders, and problems associated with postharvest handling of fruit.

Because many of the mineral and botanical pest control products used by organic growers are not as effective as synthetic pesticides, timing of application, planning of long-term suppressive measures, and consistent, up-to-date pest monitoring methods are crucial. Costs of organic pest control materials are usually higher and efficacy more variable than with most synthetic pesticides. However, the benefits of organic materials may include reductions in future pest resistance, secondary pest outbreaks, regulatory uncertainty, and potential health and environmental effects associated with the more toxic chemical pesticides.

We review here the principle diseases and physiological disorders with their organically acceptable control methods that have been tested in California

MAJOR APPLE DISEASES

Apple Scab

Apple scab is a fungal disease caused by the fungus *Venturia inaequalis.* It thrives in moist and temperate climates, and has been a serious problem on the North Coast of California, where winters and springs are mild and wet and summers are often foggy. However, it also occurs in the San Joaquin Valley, Sierra foothills, Central Coast, and other areas of California when rainy weather continues into late spring. Most commercial varieties including Golden and Red Delicious, Granny Smith, Gravenstein, Gala and Fuji are very susceptible to scab.

If left uncontrolled, apple scab can destroy a crop. Severe infections lead to blossom drop, blemished, misshapen, dwarfed fruit, and eventually, total fruit drop and defoliated trees. Moderate infection causes yield loss and fruit blemishes. Mild infections may not have an immediate effect on the current crop but will maintain high inoculum levels that could inflate into damage whenever environmental conditions for infection are met.

Symptoms and Life Cycle

Apple scab first appears in early spring as lesions on new leaves, blossoms, and fruit. The small, olive-green lesions are round, scabby on the upper leaf surface and velvety with an irregular shape on the underside of the leaf. As the lesions grow and spread infected leaves become twisted and cupped, turn yellow, and fall off. Fruit lesions start out as sooty and black sometimes surrounded by a red halo, and eventually turn into dry, corky scabs. It takes about 2-3 weeks during cool spring weather to find visual symptoms of scab after an infection period. Badly infected fruit are malformed and undersized, and often drop off the tree prematurely. Fruit is most susceptible from bloom to about one week after petal fall. After that, they gradually become more resistant to infections. If conditions are favorable, however, scab infection can also occur close to harvest, causing tiny black to red lesions on the fruit lenticels of mature fruit. This is called “pin point” scab.

The scab fungus overwinters on infected fallen leaves, but not in the tree on twigs or branches. During winter the sexual reproductive structures of the fungus mature in these intact and infected leaves. When scab infected leaves become wet with rainfall in early spring during periods with temperatures above 40°F, they emit spores (ascospores) that travel in the wind to new green tissue. The ascospores cause the first (primary) infections, which quickly lead to secondary infections from the asexual spores called conidia and disease of epidemic proportions.

The scab fungus needs free moisture (rain, heavy dew, or drippy fog) for a certain length of time before it can infect. The required length of the wetness period will vary with temperature. Under usual spring and summer temperatures, it only takes 9-15 hours of wetness for infection to begin. Careful monitoring of rainfall and temperatures could theoretically reduce the need for some protectant sprays, however prediction of weather conditions in the orchard is not exact enough to take this risk in most cases for organic growers.

Control

The key to scab control is to prevent the disease-causing spores from infecting susceptible tissue. This is done by protecting the first green tissues emerging from buds in the spring from primary infections with organic fungicide sprays, by reducing inoculum levels through sanitation methods, or by not having susceptible tissue present. A number of alternatives are available to the organic grower to fight scab, including disease resistant cultivars, cultural practices, and chemical controls. Biological controls, including botanical extracts and antagonistic fungi, are being investigated and may be available for use by commercial growers in the near future, but are not currently available. The best approach now for growers is to use a combination of all the available control methods. Keep in mind, however, that the organic materials used for apple scab control do not have the preventative residual effect of conventional fungicides and must be applied more frequently. They also do not have the same “kick-back” effect of some conventional fungicides, which can kill newly established infections usually up to 120 hours after an infection period, depending on the material used.

Resistant Cultivars

The only certain way for organic growers to control scab year after year is to grow scab resistant apples. The plant tissue in these varieties is simply not susceptible to the disease. A number of scab resistant cultivars are described in the **Varieties** section in the "Orchard Culture" chapter of this publication (page x). Before planting new cultivars, growers should determine that there is a viable market for the new varieties. Several newer varieties have excellent culinary characteristics, but no name recognition in the marketplace. There is certainly the potential to grow many of these varieties as processing apples as well as gleaning the best fruit for the fresh market. Fresh market sales will be more challenging, however, because of the uncertainties of the variety.

Cultural Controls

Spores that overwinter on leaf litter on the orchard floor cause primary infection in spring. If the overwintering inoculum is reduced or eliminated the potential incidence of scab can be reduced. This will only work, however, in isolated orchards. All of the cultural practices used to limit scab infections will be ineffective where neighboring orchards are full of inoculum that can blow into treated orchards.

The orchard floor can be kept free of leaves by various methods before new bud break in the spring. Fallen leaves can be raked, blown, or vacuumed from beneath trees into the middles and then removed or disked into the soil to decompose before scab ascospores have a chance to mature and develop. Natural decomposition of leaves lying on the surface of the orchard floor usually does not occur sufficiently during winter months because of temperature, moisture, and nutrient constraints to significantly eliminate ascospore development prior to spring bud break.

Nitrogen is often the most important missing ingredient limiting the breakdown of apple leaves by microorganisms that cause decomposition. Proper composting of apple leaves at temperatures of 140° - 160° F will kill scab spores by eliminating the substrate on which the ascospores develop. The compost may need to be made with additions of manures to aid in leaf breakdown, which can later be used as a fertilizer and soil amendment under trees.

Running a mower over fallen leaves to pulverize them and adding compost or some other source of nitrogen like blood or feather meals will speed up leaf decomposition directly on the orchard floor. Because it can take a few months for all the leaves to fall, it may be helpful to defoliate the trees once leaf fall has naturally started. Zinc sulfate provides elemental zinc, but also burns the leaves and causes them to fall prematurely. This practice has been shown to have no detrimental effect on next year's growth, bloom, or production.

A tank mix foliar spray of nitrogen and zinc applied at 10% leaf fall can speed up defoliation and leaf decay, and significantly reduces ascospore production the following year. Sodium nitrate [*] applied at a rate of 150 - 250 lb./acre combined with zinc sulfate at 20 lb./acre has been shown effective. The quantity of nitrogen added (24 to 32 lbs. per acre) could also fulfill a significant portion of the yearly nitrogen requirement for apples.

Cover crops have often been touted as barriers to spore release and as a source of nutrients to help decompose infected apple leaves. In research orchards with winter cover crops there was no reduction in apple scab incidence. If the inoculum is there and spring weather conditions are wet the cover crop will do little to stop the spread or infection by apple scab.

In orchards where overhead irrigation is used, care must be taken not to create conditions ideal for infection. Growers should irrigate only at night, when far fewer ascospores are released than during the day. However, once conidia (asexual spores) are present on infected leaves on the tree, day or nighttime wetness periods make no difference. Irrigation periods should be kept to short duration to prevent infection and spread of the disease. The Mills' chart included in *IPM for Apples and Pears* can be useful in determining how long it is safe to irrigate at particular air temperatures.

Chemical Controls

Organic chemical control of scab depends on copper, sulfur, and lime-sulfur mixtures. Under low to moderate disease pressure, these organic fungicides effectively control scab. This is

[*] Sodium nitrate is a mined product from Chile. Caution, it contains sodium, which can cause toxicity in orchards with sodium buildup problems or existing salt problems.

particularly true when they are used early in the disease cycle and when applications are timed correctly. Their primary disadvantage is that in years when disease pressure is high and orchard access is difficult, the organically acceptable materials, which have a shorter residual and less kick-back, will have to be applied more frequently and may not provide adequate control.

Of the organically acceptable products on the market for apple scab control, copper and sulfur minerals are the most effective. Both copper and sulfur are much better as protectants, and can not significantly eradicate an infection once it has occurred. To be effective, they must be on the plant tissue just prior to and during the infection period. This means that growers must spray when conditions are right for infection, which is just before rain when temperatures are above 40°F and there is susceptible tissue on the tree.

Fixed copper and micronized sulfurs have been shown to protect against scab as effectively as many of the conventional synthetic fungicides. However, if applied after bloom fixed copper sprays can cause russetting[1] on the fruit even at very low rates.

Copper has a better residual than sulfur and is best applied as the first scab spray of the season prior to bloom, usually at the green tip stage. Rates can go as high as 4-8 lbs per acre. For processing fruit, where russetting is not a major concern, copper can be used after bloom quite effectively.

Micronized sulfur applied at 10-15 lbs/acre (most materials expressed as 80% sulfur) effectively prevents apple scab infections. It can be applied from green tip through fruit set and fruit development without phytotoxic effects or fruit russetting. The residual for protection is about one week, so under conditions for scab development sulfur sprays need to be applied weekly.

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[1] Russetting on apples is complex and caused by several factors including the susceptibility of the variety, weather, humidity, wetness, and spray materials applied. It is very difficult to predict accurately and programs that appear safe may without explanation prove damaging in other years.
Concentrate sprays usually produce less fruit russetting than dilute sprays.
Note that in repeated and large dosages, fixed coppers are phytotoxic, toxic to animals and can persist in the soil.

Sulfur is a mild irritant and gradually acidifies the soil. Sulfur and oil are incompatible and phytotoxic to leaves even when applied separately 2-3 weeks apart due. They should never be tank mixed unless applied to dormant wood. Care must be taken if oil was or is to be used for control of other pests such as aphids or codling moth within 2-3 weeks of any sulfur application once leaf development has occurred.

Tank mixes of copper and sulfur together have been tested and evaluated scientifically. When used together, lower rates of each were neither synergistic nor effective, so no particular benefits were observed. However, at full rates, an early application of fixed copper at green tip followed by micronized sulfur after bloom has been effective and does not cause fruit russetting.

Liquid lime sulfur can also be used to prevent apple scab, and is the only mineral substance that will burn out primary scab infections with repeated applications. This is called "kick-back" action. It can, however, be phytotoxic and can burn leaves and blossoms if applied during hot weather. Handle liquid lime sulfur with care because it is highly caustic. It is also potentially harmful to mite predators, possibly causing spider mite outbreaks later in the season.

Application rates of up to 12 gallons per acre can be applied dilute (3 gal /100 gal of water) in the delayed dormant, up to green tip stage alone or mixed with dormant oil. High rates of lime sulfur alone or when mixed with oil applied later than green tip can cause severe phytotoxicity. Lime sulfur alone at rates of 1-2 gal / 100 can be applied up to 10% bloom, in cool weather, without leaf burn. Low rates of lime sulfur have been used for many years as a scab control material prior to and after bloom without detrimental effects on fruit set or fruit finish. Care must be taken, however, because applications during or just after bloom have caused blossom and fruit thinning. Lime Sulfur Solution is 29% Calcium polysulfides.

Other organic spray materials have been evaluated for scab control on apples. Soaps and oil sprays, while very effective against powdery mildew they somewhat reduce scab lesions, but are not nearly as effective as copper and sulfur. These less effective materials might provide adequate control of apple scab where disease inoculum is kept low and when weather conditions

are less favorable for the disease. Seaweed extracts, fish fertilizers, and compost tea were completely ineffective against apple scab in several trials on the West Coast.

Timing of Chemical Applications

The essential timing for scab control is from green tip through bloom. New tissues produced by rapidly growing trees must be covered at all times to prevent infection. Copper should be used for at least the first spray at green-tip, and perhaps up to tight cluster, followed by applications of micronized sulfur. Sulfur lasts only 5- 10 days and must be applied before or during every primary infection period (i.e., rain, dew, and fog) on a weekly basis as long as rain threatens. If there are severe infections, lime sulfur may be used to kill infections if they have not become well established. Two or three applications should "burn out" the lesions and then micronized sulfur can be used again for the rest of the season. Care should be taken not to apply lime sulfur if weather turns hot.

Judgment of inoculum levels can also be a factor in determining the need to spray and the specific timing. Orchards with little or no scab history and dry spring weather can delay sprays until much later, i.e., apply treatments only after infection or when rain is forecast. The Mills' chart included in *IPM for Apples and Pears* can also help time sprays based on temperature and duration of wetness.

Eastern US researchers have developed a system for predicting Potential Ascospore Dose (PAD) based on a disease and leaf litter assessment and expressed as the number of ascospores per square meter of orchard floor. They have effectively delayed and or eliminated early season sprays without detrimental effects. Trials to validate the PAD system have not been conducted in California. It is clear that orchards with a history of disease and frequent spring rains require an aggressive, early, preventative spray program.

In orchards where scab has been kept under control, the grower can wait until tight cluster to start the copper spray. However, if the orchard is near any apple trees, that can provide an external source of inoculum, it might be wise to spray earlier - at green-tip - as a precaution.

Orchards heavily infested by scab the year before should also receive earlier preventative sprays to reduce the risk of infection.

Table 1. Organic Chemical Controls for Apple Scab

MATERIAL	BRAND NAME	LABEL RATE/Acre or /100 gal	TIMING	PROTECTIVE EFFICACY	CLEAN UP INFECTION
				As A Protectant	*Kickback*
Fixed Coppers	Kocide	4 - 8 lb./A	green-tip to tight cluster	7 - 10 days	none
	COCS	4 - 8 lb./A	green-tip to tight cluster	7 - 10 days	none
	Nu-Cop	4 - 8 lb./A	green-tip to tight cluster	7 - 10 days	none
Micronized Sulfurs	Thiolux	10-30 lb./A	green-tip to harvest	5 - 7 days	none
	Microthiol Special	10-20 lb./A	green-tip to harvest	5 - 7 days	none
Calcium Polysulfides	Lime Sulfur Solution	2-3 gal/100	green-tip to pre bloom	5 days	Can burn out lesions, can burn leaves in warm weather
	Lime Sulfur Solution	2-2.5 gal/100	green-tip to bloom	5 days	
	Lime Sulfur Solution	1 gal/100	green-tip to small fruit	5 days	

Biological Controls

Researchers worldwide are investigating the potential of certain biological organisms and botanical extracts to control scab. Several interesting possibilities include extract of ivy (*Hedera helix*) and fungi antagonistic to scab. Researchers in Switzerland showed that leaf extracts of ivy inhibited conidia germination under greenhouse conditions. Scientists have also identified at least two species of fungi that attack *Venturia inaequalis.* These fungi, *Athelia bombacina* and *Chaetomium globosum*, have been shown to suppress scab ascospore production by up to 100% when applied to infected apple leaves under controlled conditions. Neither of these potential biological controls has been tested under field conditions in California, however, and their availability for commercial use is still unknown.

Flamers

Propane flamers that heat and or burn leaves after they have fallen can significantly reduce apple scab primary inoculum (ascospores) leading to reduced disease pressure for several weeks. Research in the Eastern US and Midwest has demonstrated the potential success of this technique, which should also be effective in California. Flaming is expensive and to be effective the ground must be free of any obstructions such as cover crops, prunings, or weeds and the leaves must be heated to very high temperatures.

Fire Blight

Fire blight is caused by the bacterium *Erwinia amylovora*. It is classified here as a major disease because periodic epidemics triggered by ideal temperature, humidity, tree growth stage, and varietal interaction can devastate trees. The pathogen overwinters in cankers in bark on the tree and usually attacks blossoms and kills fruiting spurs, but can also infect new succulent shoots and spread rapidly down the tree. Shoots and scaffolds can be lost, and young vigorous trees killed. Apples are far less susceptible than pears and coastal areas are much less affected than the Central Valley because of temperature differences during bloom.

Symptoms – Affected plant parts appear scorched by fire. In the early stages of blossom blight, the flower clusters are water soaked in appearance. Infected flowers and leaves remain attached to shoots and turn gray to brown to black as they die. Infection of succulent vegetative shoots often results in a characteristic crook at the tip as they turn black and dry up. A brownish, sticky fluid containing the bacteria often oozes from infected tissue. Cankers (dead areas in the bark) are difficult to detect but appear as irregular shaped sunken and dark areas. There are often reddish streaks in the tissue beneath the bark.

Disease Cycle

Optimum temperatures for growth and spread of fire blight are between 75 - 80°F, but the bacterium will grow at temperatures between 41 – 86°F. As temperatures rise in spring bacteria begin to multiply at the margins in some of last year's bark cankers. Rain and insects, primarily honey bees, disperse the bacteria to open blossoms and succulent growth. It can quickly become widespread throughout the orchard. If favorable temperatures (above 62°F in March, 60°F in

April, or 58°F in May) occur during bloom along with rainfall or very high humidity, control measures will likely be very necessary.

Control

A five-phase approach is useful in controlling fire blight:

1. Reduce inoculum through pruning out infected branch, shoot, and spur cankers as soon as they appear
2. Moderate growth of tender shoots by limiting water and nitrogen, if possible, especially in early spring
3. Prevent infections with timely applications of bactericides
4. Apply biocontrol agents
5. Grow resistant varieties and rootstocks.

Pruning - Infected spurs and shoots should be removed as soon as observed. Pruning cuts should be at least 12 inches below the infected tissue, and the shears or saw cleaned between cuts with a disinfectant. Blight bacteria can be spread by the shears or saw if a cut is made through diseased tissue.

Vigor management - Because organic orchards rely primarily on low concentration, slow-release nitrogen from organic sources such as composts and cover crops, rapid and more succulent shoot growth is naturally avoided. If specific conditions occur where irrigation water can be moderated until after bloom this will control vegetative growth somewhat and limit fire blight.

Bactericides - Traditionally, fire blight prevention has included one or more blossom applications of certified organic antibiotics (streptomycin sulfate) or fixed copper sprays. Late bloom is particularly susceptible and should be protected; however, sprays have not been shown to prevent shoot infections.

Streptomycin sulfate has a very short residual and should be applied every 3-5 days during bloom. Antibiotic use, however, should be limited in order to avoid and delay bacterial resistance. Treatment requirements should be based on the existence of ideal temperature,

humidity, and rain conditions during bloom. Fixed copper sprays are an important tool for controlling fire blight and were used for many years before the development of the antibiotic treatments, however, they can cause severe fruit russetting in some years. When using copper sprays, avoid high rates of copper in the postbloom period in order to reduce the potential for russetting the fruit (as described under apple scab control). Copper is generally not as effective as the antibiotics. It also has a short residual and must be applied every 3-7 days to maintain preventative control under blight conditions.

Biocontrol - Fire blight bacteria first become established on the stigma of the flower. Antagonistic (biocontrol) microorganisms occupying the stigma of the flower, exclude, or resist the fire blight pathogen and prevent infections from becoming established. *Pseudomonas fluorescens*, a bacterium antagonistic to the pathogen is currently registered for use as BlightBan A506. It must be present in sufficient numbers and well dispersed to be effective. It is applied every week during bloom to make sure newly opening flowers are colonized by the bacterium. A monitoring technique for determining the presence of *Pseudomonas fluorescens* has recently been developed to help determine if additional sprays are needed. There are a number of other potential biocontrol agents that offer promise for future fire blight control including strains of the bacteria, *Erwinia herbicola* (C9-1) and several other bacteria and yeasts.

Resistant Varieties & Rootstocks – Almost all of the currently grown commercial varieties are susceptible to fire blight, though some are more severely affected than others. Part of a variety's susceptibility is the quantity of out-of-season or rat-tail bloom, which usually occurs in late spring during warmer weather. Varieties with rat-tail bloom should be avoided in fire blight prone areas. Very susceptible varieties include Fuji, Pink Lady, Jonathan, Jonagold, Rome Beauty, and Gala. Somewhat less susceptible varieties include Granny Smith, Red Delicious, Golden Delicious, McIntosh, Stayman Winesap, Williams Pride, and Pristine. These apple varieties may sustain multiple infections but they usually do not progress into bigger wood or kill trees.

The commonly used rootstocks, M 26, and M 9 are very susceptible to fire blight and easily killed when infected; seedling rootstock is also very susceptible. These rootstocks should be

avoided in areas prone to severe fire blight or as understock to very susceptible varieties. M7 is very resistant and M111 and M106 are somewhat resistant.

MINOR APPLE DISEASES

Powdery Mildew

Powdery mildew is caused by the fungus *Podosphaera leucotricha* and is a common foliage disease of apples in California. Control can be obtained by removing infected shoots during dormant pruning and new shoot and blossoms as they become infected. Applications of lime sulfur, micronized sulfur, M-pede (soap), or summer oil at pink bud and petal fall will usually control this disease, although additional sprays may be needed under some conditions for susceptible varieties. These "soft" organic materials have been very effective against powdery mildew, especially in years with low disease pressure. Some materials that are not effective include, compost tea, seaweed extracts, and liquid fish fertilizer.

Spray applications for the control of apple scab will usually control powdery mildew at the same time. Oil and sulfur sprays should not be applied together or within 2-3 weeks of each other because of potential leaf burn and fruit russetting.

Phytophthora Root & Crown Rot

Phytophthora sp. root and crown rot kills and stunts trees by attacking and destroying primarily trunk and root tissue just below the soil line. Several species of *Phytophthora* are soil-inhabiting fungi, requiring the presence of free water (saturated soil conditions) to reproduce and infect the host plant. Prevention is achieved through the avoidance of saturated soil conditions. This can be accomplished by providing good surface drainage away from low areas before planting and installing subsurface drainage. Drip emitters should be placed 18-24 inches away from tree trunks to avoid constant moisture near the trunks. Planting trees on ridges or mounds can dramatically help reduce crown rot. Weeds should also not be allowed to grow around the crown because they maintain high humidity, however, cover crops in row middles will help eliminate excessive soil moisture compared to clean cultivated ground. In some other tree species, heavy organic mulches have been shown to reduce the incidence of *Phytophthora* rots. In those trials

3-4 inches of fresh wood chips was placed around the base of trees for weed control and simultaneously reduced the incidence of root rot. All apple rootstocks currently in use are susceptible. However, M 111 shows some resistance to common *Phytophthora* species in the Central Valley, while M 106 shows some resistance to the more common coastal *Phytophthora* species.

Oak Root Fungus

Caused by the soil inhabiting fungus *Armellaria melia*, oak root fungus, spreads slowly from tree to tree through root grafts and soil movement in a circular pattern. Apples have some resistance to this disease, but will succumb if inoculum is high or the strain is particularly virulent.

Prevention from the start of orchard planning is the key to controlling oak root fungus, which is almost impossible to control in an existing organic planting. Start with land that was not previously growing woodland trees or the site of an orchard. If an old orchard is being removed take extra time to remove all the roots possible. In an existing orchard, remove the diseased tree(s) and all healthy adjacent trees as well; infection of the latter may have already begun. Dig up and burn all remaining roots greater than 1 inch in diameter; do not allow infected roots to spread to noninfested areas. Solarization, heavy applications of compost, or use of the Trichoderma (beneficial fungi) will not prevent, eradicate, or control oak root fungus, but should help replants to get off to a good start and may delay infection.

Dematophora Root Rot

The fungus *Roselinia necatrix* causes Dematophora root rot primarily in the Central Coast area. It is a root rotting disease that causes yellowing of foliage and poor branch growth while below ground, the fibrous roots are rotted. There are no satisfactory control methods once the tree has the disease. Prevention by avoiding soils where it has occurred is the key to control.

Sappy Bark

Sappy bark is a condition caused by a fungus *Trametes versicolor*. It is common in many growing districts especially on old trees. The fungus spreads in wet windy weather and infects pruning wounds and sunburned areas. The disease spreads slowly within the tissue moving a

few inches each year. Dead limbs have soft bark that is spongy in wet weather and peels off in paper-thin pieces in dry weather. Control is achieved by removing diseased limbs below the infected area, preventing sunburning of limbs and, avoiding large pruning cuts, which provide infection points. Avoid pruning during wet weather and make clean cuts that are less likely to become infected. Treating large pruning wounds with Bordeaux paste or a strong detergent has shown some preventative potential.

Southern Blight

The fungus *Sclerotium rolfsii* causes Southern blight disease. It has killed young trees (under four years old) in southern California, but has not yet appeared in the northern part of the state. Older infected trees, however, can sometimes overgrow the disease and recover. Infected trees often have a web of white mycelium on the soil at the tree base. The fungus girdles the trunk and rapidly kills the tree usually leaving brown leaves attached. Later sclerotia are present and appear as round hard spore structures that are initially whitish, gradually becoming reddish brown when mature. Sclerotia persist in the soil for several years especially those containing a large quantity of organic matter.

Avoid planting in soils containing five or more sclerotia per kilogram of soil. Sclerotia usually come from previously infected crops such as tomatoes, carrots, potatoes, lettuce, alfalfa, clovers, or beans. Soil removal and replacement with clean soil in the planting hole will prevent infection of newly planted trees because the sclerotia must be within 3 cm of the trunk to cause infection. Some control can be achieved by deep plowing and allowing the field to be fallow for at least one year before planting. Weed control next to tree trunks also helps by reducing humidity because *S. rolfsii* grows profusely in humid conditions.

European Canker

Frequent outbreaks of this disease, caused by the fungi *Nectria galligena,* have occurred in coastal orchards. Infections occur through leaf scars during autumn rains. Cankers later develop and slowly girdle and kill the branch. Existing cankers should be pruned out. Infection can be prevented if a fixed copper fungicide is applied before autumn rains begin and during early leaf

fall usually in late October. The treatment could be combined with zinc and sodium nitrate to reduce apple scab inoculum, defoliate the tree faster, and provide nitrogen and zinc.

Postharvest Rots

There are several disease organisms that attack apple fruits after harvest and during storage. The more common are *Alternaria, Stemphillium, Penicillium, Phomopsis, Botrytis, Mucor piriformis,* and *Pezicula malicorticis.* Most cause the fruit flesh to turn soft and brown in color. Careful handling during harvest, transit, storage, and packing control these diseases. Bruises, cuts, or punctures provide entry for most of these organisms. Cold temperature storage (33° F) will reduce the likelihood of infection and spread. Care should be taken to thoroughly clean the dump tank at the beginning and end of the season to prevent the introduction of contamination of fruit. Direct sunlight exposure of empty bins for 30 minutes will kill *Mucor piriformis* if present on the wood or plastic.

In recent research, several biocontrol agents have been shown to reduce many of the postharvest rotting organisms such as *Botrytis cinerea, Penicillium expansum,* and *Mucor piriformis.* Three new organically acceptable products, Bio-Save 100, Bio-Save 110 and Aspire, work by covering the fruit with a beneficial organism that competes with harmful pathogens for nutrients and space at the sites of wounds in fruits.

Viruses

Several viruses have occurred in apples and their rootstocks primarily from a non-certified (unclean) budwood source. Virus symptoms include mosaic-patterned chlorotic leaves, distorted branches, irregular markings within the fruit color, necrotic line at the graft union, or deformed fruit with wart like swellings. Virus-infected rootstocks are less vigorous and dwarf the scion portion of the tree.

Since most viruses are transmitted through propagation wood that contains the virus, control is achieved in most cases by selecting certified virus free trees and rootstocks from a reputable nursery and avoiding grafting or budwood from infected trees. Once a virus disease is present the only control is to remove the tree. Most viruses will not spread from tree to tree with the

exception of the Apple Union Necrosis virus, which is transmitted by the dagger nematode (Xiphinema americanum).

MAJOR PHYSIOLOGICAL DISORDERS

Bitter Pit

Bitter pit is a common physiological disorder that usually appears just before harvest or during early storage. It is essentially a calcium deficiency of the fruit that is encouraged by excessive tree vigor, over fertilization with nitrogen, extreme fluctuation in soil moisture, light crops, large fruit, or unfavorable soil chemistry. Harvesting immature fruit, cooling delays after harvest and prolonged storage periods also aggravates it. Mutsu, Golden Delicious, Yellow Newtown, Jonathan, Red Delicious, and Granny Smith are especially susceptible although any young, rapidly growing variety may exhibit symptoms.

Symptoms **–** Dark, sunken spots (1/4 to 3/8 inch in diameter) appear on the fruit, especially near the calyx end. It is sometimes seen on the trees just before harvest, but more frequently, it appears after a period of cold storage.

Control – There are eight procedures that will help reduce or eliminate bitter pit:

1. Correct soil pH
2. Add calcium to soil
3. Reduce excess vigor
4. Set a moderate to heavy crop load
5. Good water management
6. Foliar calcium sprays
7. Post harvest calcium fruit dip
8. Rapid post harvest fruit cooling

Most California soils have adequate calcium for apple production. However, soil pH below 6.0 can reduce calcium availability and should be adjusted by adding a liming material to bring the pH up to 6.0-6.5. Do not use dolomite lime as its high magnesium content can also interfere with calcium uptake. If the soil has an exchangeable calcium to magnesium ratio of less than 5:1, it may be advisable to add a low magnesium – high calcium lime product. Gypsum

(Calcium sulfate) can also be used to increase the available calcium when a pH adjustment is not needed since it will not affect pH.

Calcium movement in apples occurs with the movement of water in the trees, so adequate calcium is better provided in trees that are never water stressed. Irrigate frequently (daily) for drip irrigated trees and periodically with surface or sprinkler irrigation to maintain a steady moisture (and calcium) supply to the trees.

Adjust growing practices to reduce excessive vigor and encourage a normal to heavy fruit set in susceptible varieties. Be prudent with leguminous cover crops, manures, and other fertilizers. Too much nitrogen can lead to rank growth and too much potassium can interfere with calcium uptake. Provide proper conditions for a good fruit set (bees and pollenizer varieties) and careful thinning, if needed, to regulate the crop load. Too light a crop set and over thinning, will encourage larger fruit and more bitter pit. Do not prune trees heavily in the dormant season as this can encourage excessive vegetative growth. Delayed dormant or summer pruning may help to reduce excessive vigor from pruning.

When these practices do not provide sufficient control, it may be necessary to apply foliar sprays of calcium during the growing season. Not all calcium-containing compounds are effective or acceptable under state and federal organic standards, but there are now several organically acceptable forms of calcium on the market. Those that have been tested and found effective are Calcium 25, Stoma Feast, and This Calcium.

Usually, at least three applications are made (in mid-June, mid-July, and mid-August), depending on the variety. Applications may be made at 30-day intervals if using dilute solutions (300-400 gallons/acre and handgun sprayers. Up to eight applications may be necessary with low-volume (100-200 gallons/acre) speed sprayer applications, particularly if bitter pit is severe. In most cases, calcium can be added to the tank mix when applying other sprays, but check the label for compatibility.

If the disorder appears in storage rather than in the field, a postharvest calcium dip may be substituted for the orchard sprays. A 60-second dip into a 2% calcium chloride solution (Calcium 25) has been shown to be effective in reducing bitter pit in storage.

Rapid cooling of harvested fruit before packing is critical in reducing bitter pit. A delay of even 24 hours before fruit is properly cooled can increase the incidence of bitter pit showing up in storage by 25% or more.

MINOR PHYSIOLOGICAL DISORDERS

Water Core

Water core is a physiological disorder that appears as a water soaked area in and around the core. It is more prevalent under intense heat and sunlight conditions especially near harvest. The most susceptible varieties are Red Delicious, Granny Smith, and to a lesser extent, Fuji. Harvesting fruit before it develops attains control.

Apple Measles (Internal Bark Necrosis)

This disorder is caused by magnesium toxicity in acid soils. It appears as reddish brown pustules on the bark of young branches and stunts tree growth. It is controlled through lime applications that raise soil pH to over 6.0.