

Powdery mildews of stone fruit crops

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Colorado grown fruits, especially peaches, are known for their quality. Major factors in enabling this high fruit quality are the isolation of the fruit production areas in western Colorado and their associated high desert climate. The latter provides low humidity and precipitation, many bright sunny days, and warm summer temperatures and moderate winter weather. The isolation and arid climate combine to keep incidence and severity of pest and disease low and thereby make fruit production easier. However, outbreaks (incidence and severity) of certain pests and diseases still occur in western Colorado in certain years; for example, incidence of powdery mildew, one of the important diseases in fruits, was high in 2009 and other recent years. Incidence and severity of powdery mildew depend on temperature, relative humidity (RH), and carry-over mildew inoculum levels in the area. Monitoring environmental conditions for those favorable to powdery mildew outbreaks (moderately cool temperatures and high RH's) is an integral component of mildew management; it enables the scheduling of timely powdery mildew control sprays. The environmental conditions and winter survival of these mildew fungi may differ with the species. In western Colorado conditions, generally the temperatures required for outbreak of powdery mildew are prevalent during fruit growing season, but RH is low; that might have affected the disease outbreak. However, precipitation and or irrigation water, especially when the average daily temperatures are favorable for mildews, are critical for developing higher RH and rapid outbreak of powdery mildews in a particular orchard. Unlike other foliar diseases, leaf wetting is NOT a requirement for powdery mildew infection. Conidia will not germinate if immersed in water, although high RH is required for infection. Under optimum conditions, powdery mildew will be visible 48 hours after infections; new infections produce spores in about 5 days. Higher RH is generally associated with rain events (scattered in April) throughout the growing season. Moreover, the contribution of irrigation water, especially with the overhead sprinklers, is not considered here as the potential cause of increasing RH . But it should not be ignored in some locations since both microclimate and irrigation practices vary in western Colorado.

Most powdery mildews produce fungal threads (mycelium) that grow only on the plant surface and never invade the internal plant tissues. The fungi feed by sending haustoria, or root-like structures, into the epidermal cells (outside layer) of the plant. Being an obligate parasite, powdery mildew fungi require living plant tissue to grow. Powdery mildews survive from one season to the next in infected buds or as fruiting bodies called chasmothecia that overwinter on leaf litter and on the bark of branches and stems. In the spring, newly developing leaves become diseased as they emerge from infected buds. When overwintering fruiting bodies (chasmothecia) are present, ascospores are released and serve as primary inoculum. Primary inoculum for stone fruit powdery mildew may come from related ornamental plants such as apples or roses that are not treated for powdery mildews; these hosts are the major contributors to the development of powdery mildew on peach. Powdery mildew spores are carried by wind to host plants. Secondary infections are started by wind-disseminated conidia (asexual spores) produced throughout the

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growing season. Spores are the primary means of dispersal and make up the bulk of the powdery growth. Such spores are produced in chains that can be seen with a hand lens; the spore chains are white in color whereas downy mildew spores grow on branched stalks that look like tiny trees and are gray in color. Although humidity requirements for germination vary, many powdery mildew species can germinate and infect their hosts in the absence of water. Moderate temperatures and shade favor powdery mildew development since spores and mycelium are sensitive to extreme heat and direct sunlight. Conidia germinate between 36 ° F (2 ° C) and 99 ° F (37 ° C), and optimum germination takes place at 70 ° F (21 ° C). Conidia can germinate in free water and at relative humidity of 43 percent to 100 percent. Excessive duration of wetness will kill powdery mildew conidia. During periods with warm, humid conditions the disease can quickly develop into an epidemic.

Three powdery mildew species are known to infect stone fruits in Colorado: cherry powdery mildew (*Podosphaera clandestina*), apple powdery mildew (*Podosphaera leucotricha*, causing peach rusty spot), and peach powdery mildew (*Sphaerotheca pannosa*, the cause of rose powdery mildew).

Cherry Powdery mildew is a common disease of cherry . It also is reported to infect peach, apricot, apple, pear, quince, persimmon, and a few ornamental plants in areas outside of Colorado.

Life Cycle: The cherry powdery mildew overwinters as chasmothecia on leaf litter on the orchard floor and trapped in tree crotches or bark crevices. Ascospores are released from the chasmothecia in response to rain or irrigation and provide the primary or first inoculum that infects cherry leaves or shoots in the spring. In Washington, ascospore release was found to begin one month before bud break, and continued until after bloom. Unlike in apple mildew, there is no evidence that cherry mildew survives as mycelium in dormant buds. Once mildew colonies have become established, asexual spores (conidia) are produced. Conidia are produced throughout the summer, potentially resulting in a rapid build-up of the disease. Fruit infections are caused by conidia that are produced on the leaves. Immature fruit is much more susceptible than mature fruit, and susceptibility decreases as sugar content increases. This mildew is favored by moderate to warm and humid conditions, with optimal temperatures of 59 ° F (15° C) to 77 ° F (25 ° C). Conidia are not produced below 50 ° F (10 ° C) or above 86 ° F (30 ° C). Mildew severity is greater in years with frequent showers in late spring and early summer as the chasmothecia in the orchards rehydrate, swell, and release their ascospores when there is high humidity in orchard in early spring.

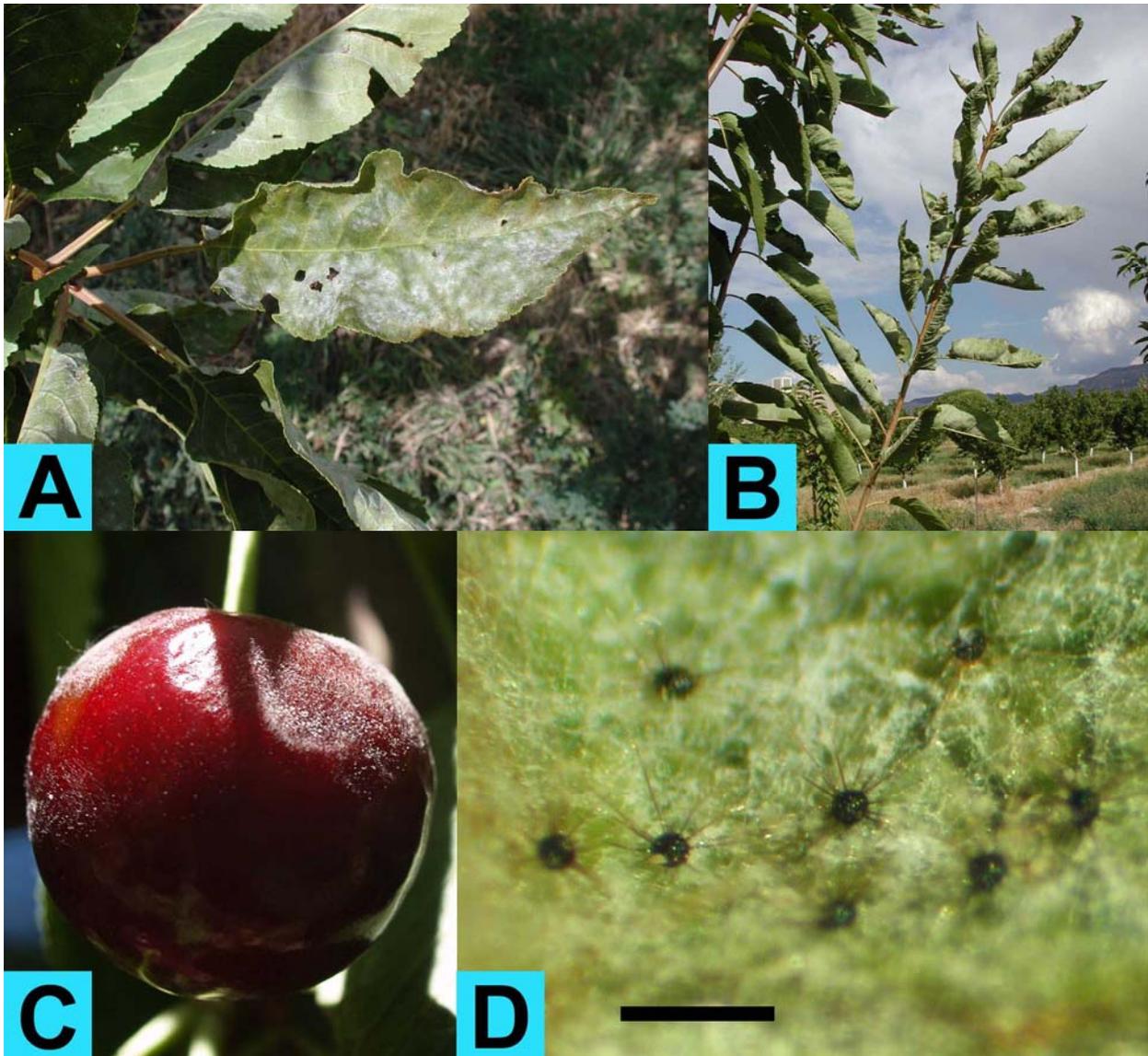


Figure 1. Cherry powdery mildew A) mildew colonies on leaves; B) cherry shoot with inrolled, upward-pointed leaves characteristic of powdery mildew infection; C) fruit infections (note dimpled areas with thin, cobwebby mycelium); and D) chasmothecia produced by the powdery mildew fungus on infected leaves later in the season (bar = 0.5 mm). [Photos by H. Larsen]

Symptoms: Leaves, buds, green shoots, and fruit are commonly infected by the powdery mildew fungus, but flower infections are rare. Symptoms include circular, white, web-like colonies that become powdery once masses of asexual conidia are produced in chains on all tissues (Fig. 1A). Leaves may then inroll, curl, or become stunted (Fig. 1B). Severe infections commonly cause leaf chlorosis, necrosis, and leaf drop. Infected leaves may be covered by fungal mycelium. This mildew may be a serious disease in the nursery by causing stunting and defoliation. White powdery spots appear on fruit (Fig. 1C). Chasmothecia (Fig. 1D) are produced in early fall. Powdery mildew is commonly observed in sweet cherry in western Colorado, and it is very important in tart cherry in Utah and other parts of the nation.

Rusty Spot is caused by apple mildew (*P. leucotricha*) which infects young peach fruit up to 5 cm in diameter (up to pit hardening) and develops symptoms typical of rusty spot. The infection in peach comes from neighboring infected apple trees. Peach leaves and young shoots are rarely susceptible to *P. leucotricha* whereas the peach (rose) mildew infects peach leaves, shoots, and young green fruit. However, fruit infection is common in susceptible peach cultivars planted next to apples with uncontrolled powdery mildew. Peach rusty spot can be economically important on peach (*Prunus persica* var. *persica*) as it russets the fruit. The long suspected link to the apple powdery mildew pathogen, *Podosphaera leucotricha*, as the cause has only recently been proven by molecular studies in France. Other host plants include pear, crabapple, and quince. Susceptible peach (and pear) cultivars are at a higher risk of disease development if planted next to infected apple orchards. Susceptible peach cultivars include: Early Red Haven, Jim Wilson, Loring, Redskin, Rio Oso Gem, & Sweet Sue; cvs. Flamecrest, Flavorcrest, and Suncrest are moderately susceptible. Cvs. that have only occasional problems with peach rusty spot include: Cresthaven, Glohaven, Newhaven, Redglobe, Redhaven, Roza, and Topaz, among others. Young apricot fruit infected by the apple mildew fungus can develop minor fruit russet that has minimal impact on fruit salability and which can even be attractive if not too severe.

Life Cycle: The fungus overwinters as fungal strands (mycelium) in leaf or fruit buds of apples which were infected in the previous season. Temperatures below 11°F (-11.0 ° C) will kill fungal mycelia in these buds. Infected buds start to die at -11°F (-23 ° C); however, healthy buds can survive at that and even lower temperatures. Infected buds that survive winter open later than healthy buds and are already covered with conidia. Young and new tree growth is infected by wind-borne conidia and result in new colonies. New terminal growth on apple trees is particularly susceptible. Temperatures of 86° F (30 ° C) halt conidial germination in the summer. The fungus also produces small black structures called chasmothecia on apple, but the spores from chasmothecia do not play a major role in new infections. New infections occur in the spring when infected buds open and the dormant fungus resumes growth on the developing tissues. These primary infections result in a white, powdery mass of conidia which are easily spread by wind and splashing rain. Secondary infections result when these spores infect developing terminals. Late summer infection of buds results in overwintering inoculum inside the buds. That requires winter sprays and or early spring mildew sprays. Conidia germinate in the high relative humidity usually available on the leaf surface at temperatures of 50 to 77 ° F (10 to 25 ° C) with an optimum of 66 to 72 ° F (19 to 22 ° C). Early-season mildew development is affected more by temperature than by relative humidity. Abundant sporulation from overwintering shoots and secondary lesions on young foliage leads to a rapid buildup of inoculum. Secondary infection cycles may continue until susceptible tissue is no longer available

Symptoms: This disease is observed in susceptible peaches planted near severely to heavily infected apple varieties. Under conditions of extended periods of high humidity (such as in greenhouses), peach shoots can be covered with white masses of fungal mycelium and spores. Such shoot infections may cause deformed tip growth (Fig. 2A). This condition occurs only rarely under western Colorado conditions.

Peach rusty spot infections only affect immature fruit, typically between shuck split and pit hardening (Fig. 2B). They first appear as whitish or grayish spots on the peach fuzz, but quickly become rusty brown-orange in color. The fruit skin beneath the spot can become hard and leathery beneath the affected fuzz, which is easily removed by wind / rain as time passes to

produce a slick fruit surface (Fig. 2C). The fruit skin beneath the spot becomes russeted, and this reduces the marketability of fruits. Young apricot fruit infected by the apple mildew fungus develop a spider-web-like russet pattern which becomes red as the fruit ripen and change color (Fig. 2D). The incidence of rusty spot has decreased in recent years in western Colorado as apple blocks in the primary peach production areas have been replaced with peaches or grapes.

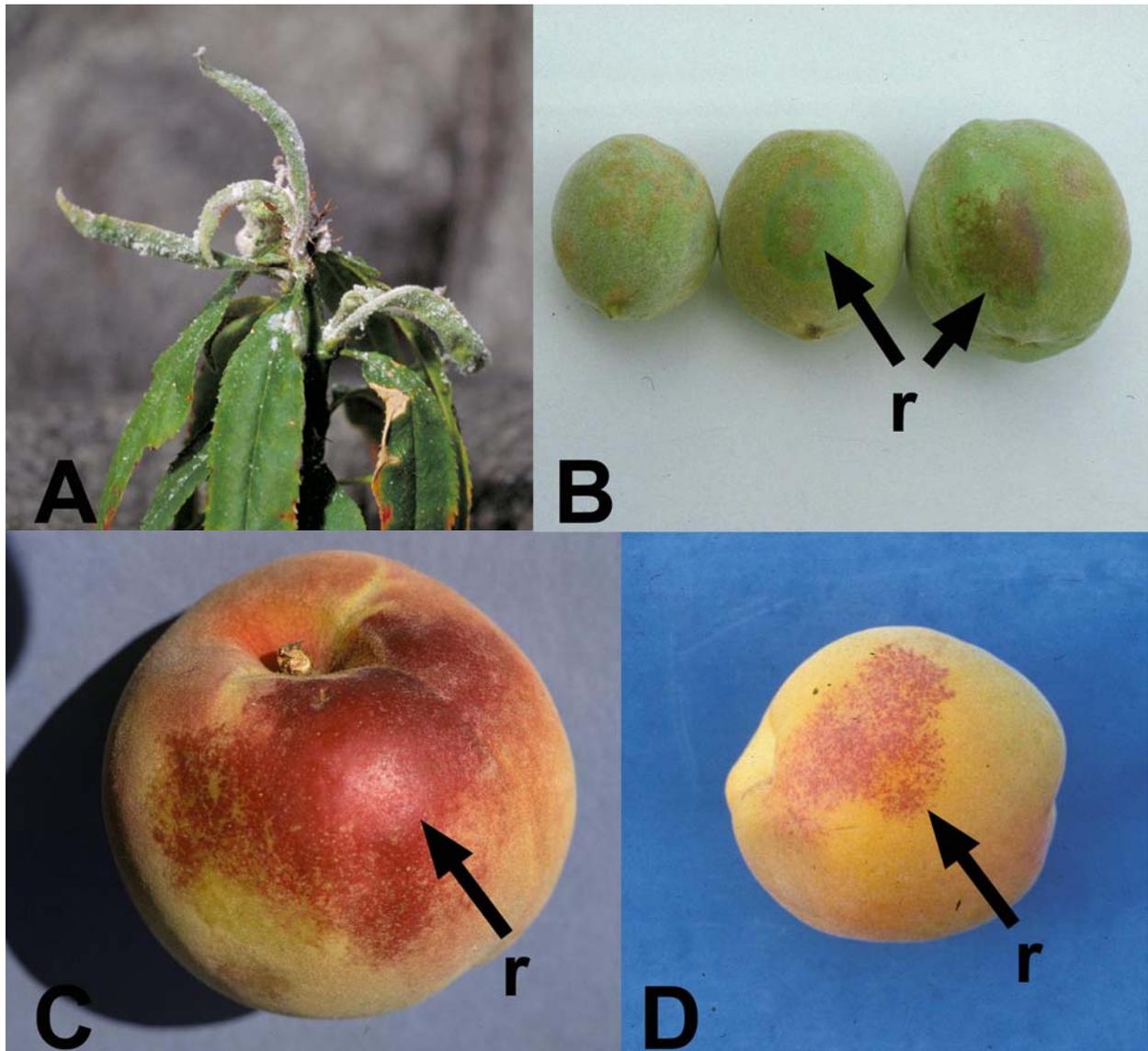


Figure 2. A) Shoot infection on a potted, greenhouse grown peach seedling. B) Fruit infections on peach; left fruit, early infections (note rusty-orange color of the peach fuzz); middle and right fruit, older infections in which the fuzz has dropped off /been rubbed off to reveal the skin russet damage (arrows). C) Mature peach fruit in which the fuzz has all dropped off to reveal the slick, russeted surface (arrow). D) Maturing apricot fruit with early fruit growth infection that produced the spider-web-like russet that turns red as the fruit matures. [Photos by H. Larsen]

Peach (Rose) Powdery Mildew: The causal fungus, *Sphaerotheca pannosa*, attacks young shoots, leaves, and fruit of woody ornamentals including peach and other stone fruits and can cause serious economic loss due to cullage of infected fruit.

Life cycle: The fungus overwinters as mycelium in inner bud scales of dormant infected buds on rose and peach (in some climates). Chasmothecia are rarely found on peach, but have recently been observed on peach in California. Infected peach buds often do not survive the winter. As leaf buds expand in spring, young leaves become infected and the spores produced on the leaves serve to infect young fruit, new shoot growth, and newly expanding leaves. Secondary infection occurs in foliage. Foliage is most susceptible to infection during night when humidity is high and osmotic pressure of leaves is low. Germination of fungal conidia occurs from 35.6 ° F (2 ° C) to 98.6 ° F (37 ° C) with an optimum of 69.8 ° F (21 ° C).

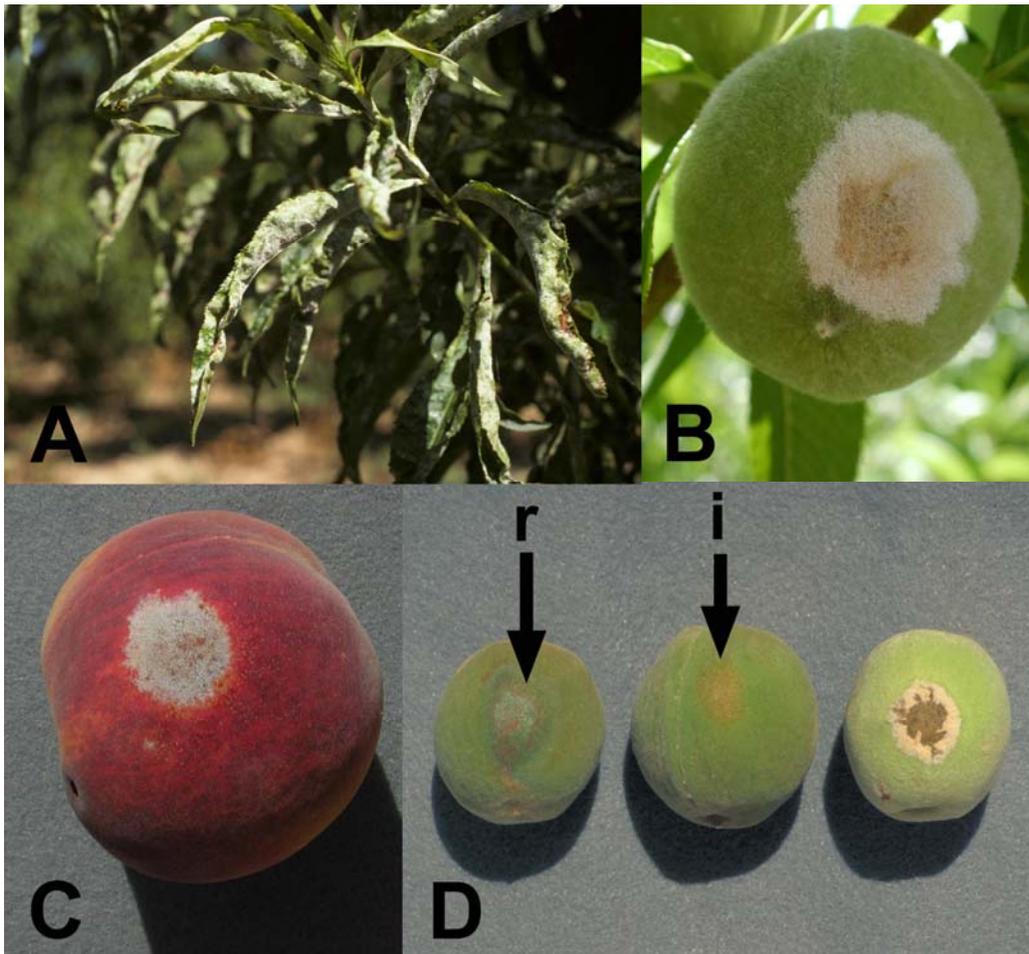


Figure 3. Peach powdery mildew (*S. pannosa*) infection symptoms on peach. A) Shoot infections on peach; note the in-curved leaves and white powdery colonies. B) Fruit infection on immature peach fruit; note the thick, felty, creamy white colony. C) Fruit infection on maturing peach fruit. D) Comparison of peach rusty spot infections (left two fruit) with *S. pannosa* infection (rightmost fruit) on immature peach fruit; note the obvious mycelial patch of the peach mildew in contrast with the less obvious rusty-orange discoloration of the peach fuzz caused by the apple powdery mildew fungus, *P. leucotricha*. [Photos by H. Larsen]

Symptoms: Young shoots and fruits in peaches and nectarines are susceptible to infection. Infected leaves may be covered by fungal mycelium, heavy infection may cause leaves to curl and stunt (Fig. 3A). On older leaves, the mycelium is white and patchy. Fruit are susceptible from early stage of development until just before harvest. White circular spots develop to produce thick, felty pad-like colonies (Fig. 3B and 3C) which may enlarge, coalesce, and cover the entire fruit. Young fruits may be deformed with slightly depressed or elevated areas. On older fruit, infected areas may be scabby and necrotic as the mycelial pad is sloughed off. Fruit infections by peach mildew differ from those by apple mildew in the density of the mycelial patch (Fig. 3D).

Monitoring:

According to the models developed for East Coast growers for peach (rose) powdery mildew, monitor ten sample trees regularly for white, mycelial growth on young leaves in ten shoot terminals. Incidence of such colonies in the sample trees indicates the need for pesticide sprays or another management option unless the humidity and temperature are low. A total of one to ten and more than ten infections indicate moderate and high risk, respectively. During two to four weeks after shuck fall, monitor 25 fruit on each sample tree for the presence of round, whitish, powdery spots on the fruit surface. A total of ten to 20 fruit infections and greater than 20 fruit infections indicates moderate and high risk, respectively. However, this has not been tested in western Colorado and may not hold true in case of high disease pressure.

Facts to be considered for the management of powdery mildew.

1. Mildews need high humidity for successful spore germination, infection, and growth, but four or more hours exposure to free water will damage the spore.
2. Powdery mildew infection increases plants susceptibility to cold and other stresses such as pests, nutritional and pH related issues.
3. For peach rusty spot and peach (rose) mildew: Previous year infections overwinter in infected tissues of apple and of rose and possibly peach (for peach mildew), respectively. Thus a dormant spray with lime sulphur during the dormant period in an infected orchard can help manage the disease. Appearance of mildew in summer indicates the presence of overwintering populations. Early sprays especially after long hours of sprinkler irrigations help to kill the overwintering fungus.
4. Identify the mildew type, monitor temperature, RH, and overwintering mildews and schedule sprays accordingly.
5. Eglandular (without glands at the leaf base) peach cultivars are more susceptible to peach (rose) mildew than glandular cultivars. Furthermore, in some cultivars, tissues also vary in their susceptibility with fruit being more or less susceptible than leaves, depending on the mildew species involved and maturity of host tissue.
6. Avoid growing peaches near apple varieties that are highly susceptible to powdery mildew such as Jonathon, MacIntosh, and Rome Beauty.
7. Because of high risk of developing a resistant population, do not repeat the same chemistry more than twice in the same orchard without rotating to a different chemistry.

Management:

Organic options:

- To minimize problems with peach rusty spot, avoid planting powdery mildew susceptible peach cultivars (e.g, Loring, Redskin, Sweet Sue, etc.) near mildew-susceptible apple cultivars (e.g., Gala, Jonathan, MacIntosh, Rome Beauty, etc.); where such situations occur, monitor both the apple and peach blocks carefully for powdery mildew and apply spray treatments on a timely basis.
- Provide good air circulation by pruning excess foliage and avoid over fertilization with nitrogen because lush foliage and shade favor the disease, especially powdery mildew in cherry.
- In peaches, apply wettable sulfur at the beginning of shuck split and continuing at 8 to 10-day intervals. Controlling mildew in adjacent apple orchards will help minimize incidence of rusty spot in peach orchards and is a more effective means for control of rusty spot. Switch to micronized or flowable formulations of sulphur when temperatures will exceed 85 ° F, but discontinue sulphur sprays when temperature exceeds 90 ° F.
- Armicarb, Kaligreen, MilStop (see the label for rates)
- Use “Trilogy” , clarified extract of neem oil (see the label for rates)
- Potassium bicarbonate + horticultural oil (see the label for rates): It is considered the most effective option as preventative organic application. Potassium bicarbonate must be applied every 5-7 days while wet weather persists to prevent infection.
- JMS Stylet Oil at 1-2 gal/100gal water/ per acre. Do not use this oil below 55 ° F temperature or when foliage is wet. 4-Hr reentry.

Conventional options:

All options listed in the organic management section are reduced risk options. In addition, the following options are considered as reduced risk.

- Abound (azoxystrobin) at the rate of 11-15 oz per acre or see the label for dosage.
- Pristine (boscalid + pyraclostrobin), Regalia (extract of *R. sachalinensis*), Serenade ASoO, Serenade Max. See the label for rates.

Chemicals for Powdery Mildews:

See our Tree Fruit Production Manual 2011 for details of chemical. The manual also can be found on our website.