

POWDERY MILDEW ON FRUITS AND BERRIES

Integrated Pest Management for Home Gardeners

Powdery mildew is a common disease on many types of plants. Different powdery mildew fungi cause similar diseases on different plants (e.g., *Podosphaera* species on apple and stone fruits; *Sphaerotheca* species on berries and stone fruits; *Uncinula necator* on grapevines, see Table 1). Powdery mildew fungi generally do not require moist conditions to establish and grow, and normally do well in warm climates. Thus powdery mildews are more prevalent than many other diseases in California's dry summer weather.

IDENTIFICATION AND DAMAGE

Powdery mildew can be recognized easily on most plants by the white powdery mycelial and spore growth that forms on both sides of leaves, sometimes on flowers and fruit, and on shoots (Fig. 1).

The disease can be serious on woody species such as grapevines, caneberries, and fruit trees where it attacks new growth including buds,

shoots, and flowers as well as leaves. New growth is dwarfed, distorted, and covered with a white, powdery growth. On apple and grape and to a lesser extent apricot, nectarine, and peach, young fruits develop weblike russeted scars and tree fruits sometimes develop a rough corky skin. Grapes with a severe infection may also crack or split and fail to grow and expand.

Symptoms on strawberry include an upward curling of leaf edges. Infected leaves later develop dry, brownish patches along with patches of white powdery fungus on the lower surface and reddish discoloration on the upper surface. When foliage infections are



Figure 1. Powdery mildew on grape leaves, stem, and berries.

severe, flowers and fruit may also be infected.

Table 1. Host Plants and Control Measures for Powdery Mildew Species.

Hosts	Fungus species	Controls
apple, nectarine, peach, quince	<i>Podosphaera leucotricha</i>	tolerant varieties; prune out infections in apple trees during dormant season; fungicides if necessary
cherry	<i>Podosphaera clandestina</i>	fungicides if necessary
apricot, plum, prune	<i>Podosphaera tridactyla</i>	tolerant varieties; fungicides if necessary
strawberry (a different strain infects caneberries)	<i>Sphaerotheca macularis</i>	resistant varieties; removing infected tissue; fungicides if necessary
apricot, nectarine, peach, plum, roses	<i>Sphaerotheca pannosa</i>	fungicides if necessary; remove or treat roses
grape	<i>Uncinula necator</i>	tolerant varieties; water sprays; prune during dormancy; fungicides

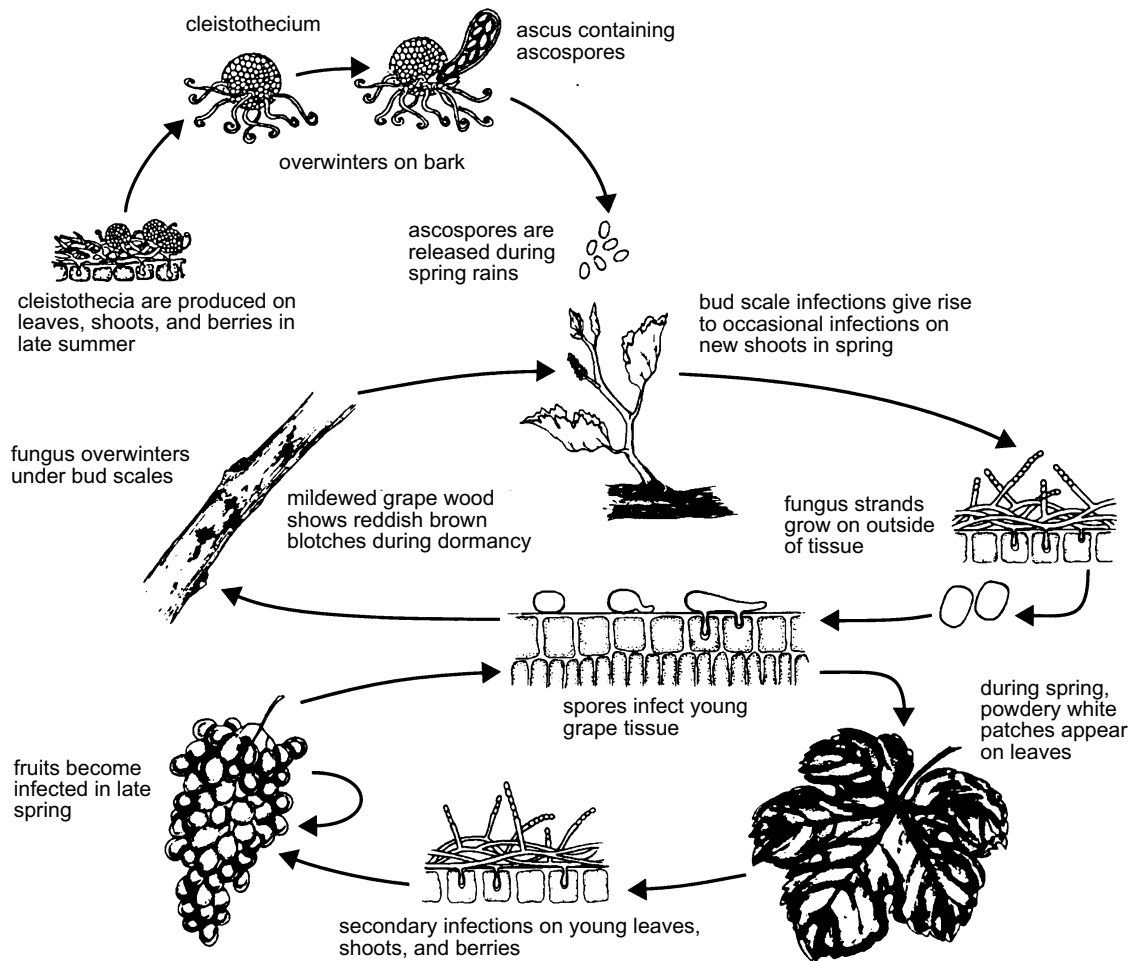


Figure 2. Powdery mildew life cycle on grape.

LIFE CYCLE

All powdery mildew fungi require living plant tissue in order to grow. On deciduous perennial hosts such as grapevine, raspberry, and fruit trees, powdery mildew survives from one season to the next in infected buds or as fruiting bodies called cleistothecia, which reside on the bark of cordons, branches, and stems. On strawberry the fungus can survive on leaves that remain on the plants through winter.

Most powdery mildew fungi grow as thin layers of mycelium on the surface of the affected plant part (Fig. 2). Spores, which are the primary means of dispersal, make up the bulk of the powdery growth and are produced in chains that can be seen with a hand lens. In contrast, spores of downy mil-

dew grow on branched stalks that look like tiny trees. Also downy mildew spores are usually darker—a gray purplish color—and occur mostly on the lower leaf surface.

Powdery mildew spores are carried by wind to new hosts. Although humidity requirements for germination vary, many powdery mildew species can germinate and infect in the absence of water. In fact, spores of some powdery mildew fungi are killed and germination and mycelial growth are inhibited by water on plant surfaces. Moderate temperatures and shady conditions are generally the most favorable for powdery mildew development. Spores and mycelium are sensitive to extreme heat and direct sunlight.

MANAGEMENT

The best method of control is prevention. Avoiding the most susceptible varieties and following good cultural practices will adequately control powdery mildew in many situations. However, where conditions are favorable, susceptible fruit trees and berries may require protection with fungicide sprays. Fungicide applications are most often needed on susceptible varieties of apple and on almost all grape varieties.

Resistant Varieties

Where possible, choose resistant varieties that meet your growing requirements and personal preferences. Be aware that control actions will probably be necessary when planting more susceptible varieties.

Apple. The most susceptible varieties include Gravenstein, Jonathan, Rome Beauty, and Yellow Newtown. Moderately susceptible varieties include Braeburn, Golden Delicious, Granny Smith, Jonagold, and McIntosh. Least susceptible varieties are Red Delicious and Stayman Winesap.

Caneberries. Highly susceptible raspberry varieties include Glen Clova, Latham, Ottawa, and Viking. Resistant varieties include Chief, Marcy, Malling Orion; the variety Logan is immune. Blackberry is not affected by powdery mildew.

Cherry. The most susceptible varieties are Bing, Black Tartarian, and Rainier.

Grapevines. Most varieties are susceptible.

Nectarine. Most varieties are susceptible.

Peach. Freestone varieties such as Crest, Flame Crest, Flavor Crest, and O'Henry are less susceptible than varieties such as Elegant Lady, Fairtime, Fay Elberta, and Summerset.

Plum. Some highly susceptible varieties of plum that may need protection are Black Beaut, Gaviota, Kelsey, and Wickson.

Strawberry. Day-neutral (everbearing) varieties such as Fern, Seascape, Sequoia, and Yolo are more susceptible than short-day varieties (those that fruit in May and June only) such as Chandler.

Cultural Practices

Shade and moderate temperatures favor most powdery mildews. Plant in sunny areas as much as possible, provide good air circulation, and avoid applying excess fertilizer. A good alternative is to use a slow-release fertilizer. Overhead sprinkling may actually reduce active powdery mildew infections because spores are washed off the plant. As new shoots begin to develop on perennial plants, watch closely for the appearance of powdery mildew.

Where infection is limited, prune out and bury or discard diseased tissue as soon as it appears. If powdery mildew has been present during the season on woody species, prune out infected tissue during the dormant season.

Prune grapevines during dormancy and position shoots during the growing season to allow exposure of fruit to sunlight and good air flow through the canopy. Pruning and training are also helpful in controlling Botrytis bunch rot.

Because one common powdery mildew fungus, *Sphaerotheca pannosa*, often spreads disease from roses to stone fruits, try to avoid planting apricot or plum trees near highly susceptible rose bushes. If roses are nearby and can't be removed, control powdery mildew infections on them.

On apple trees, look carefully for infected shoots and buds in the dormant season and remove them. Infected buds are flattened or shriveled in appearance compared to normal buds. The buds and infected shoots have a thin layer of fuzzy white fungus on their surfaces that usually is easy to see. Where practical, remove and dispose of overwintering leaves on strawberry plants that are infected. If raspberry canes develop powdery mildew, remove the canes down to the roots during the dormant season. Infected canes of berries and grapevines have distinctive weblike russetting. Remove infected prunings from the garden area and destroy them.

Fungicide Applications

Where powdery mildew has been a problem in the past or when growing grapes, fungicides may be needed. Fungicides function as protectants, eradicants, or both. A protectant fungicide can only prevent a new infection from occurring, whereas an eradicant will kill an existing infection. Apply protectant fungicides to highly susceptible plants before the disease appears. Eradicants should be used at the earliest appearance of the disease. Once mildew growth is extensive, con-

trol with fungicides becomes more difficult.

Fungicides. Several least-toxic fungicides are available, including horticultural oils, neem oil, jojoba oil, sulfur, potassium bicarbonate, bicarbonate of soda (baking soda), and the biological fungicides AQ10 and Serenade. With the exception of the oils, these materials are primarily preventive, although potassium bicarbonate has some eradicant activity. Oils work best as eradicants but also have some protectant activity.

Oils. To eradicate mild to moderate powdery mildew infections, use a horticultural oil such as JMS Stylet Oil, Saf-T-Side Spray Oil, Sunspray Ultra-Fine Spray Oil or one of the plant-based oils such as neem oil (e.g., Powdery Mildew Killer) or jojoba oil (e.g., E-rase). *Be careful, however, to never apply an oil spray within 2 weeks of a sulfur spray or plants may be injured.* Some plants may be more sensitive than others, however, and the interval required between sulfur and oil sprays may be even longer; always consult the fungicide label for any special precautions. *Also, oils should never be applied when temperatures are above 90°F or to drought-stressed plants.* Of the horticultural oils, JMS Stylet Oil is the most highly refined and therefore the least likely to damage plants, but it may be more difficult to obtain than the others. Horticultural oils and neem oil are registered on a wide variety of crops whereas jojoba oil is only registered for use on grapes and ornamentals.

Sulfur. Sulfur products have been used to manage powdery mildew for centuries but are only effective when applied before disease symptoms appear. The best sulfur products to use for powdery mildew control in gardens are wetttable sulfurs that are specially formulated with surfactants similar to those in dishwashing detergent (e.g., Safer Garden Fungicide). *To avoid injury to the plant or tree, sulfurs should not be applied within 2 weeks of an oil spray, used on any plant when the temperature is near or over 90°F (80°F for caneberries and*

strawberry), and never applied at any temperature to apricot trees. Other sulfur products, such as liquid lime sulfur or sulfur dust, are much more difficult to use, irritating to skin and eyes, and limited in terms of the plants they can safely be used on.

Bicarbonates. A potassium bicarbonate fungicide (Kaligreen) is also available for powdery mildew control. It is registered for a wide variety of crops including most fruits and berries and is primarily a protectant material, but has some eradicant activity. A simple fungicide can be made at home by combining 2½ tablespoons of horticultural oil (Sunspray Ultra-Fine, Saf-T-Side, etc.) in a gallon of water and adding 4 teaspoons baking soda. This solution is sprayed on plants to prevent powdery mildew infections. Sprays of both potassium bicarbonate and baking soda can injure the plant, so use these materials with caution. Also, baking soda sprays can have deleterious effects on soil structure and should be used sparingly.

Biological Fungicides. Biological fungicides (AQ10 and Serenade) are commercially available beneficial microorganisms formulated into a product that, when sprayed on the plant, destroy fungal pathogens. AQ10 is a parasitic fungus, *Ampelomyces quisqualis*, that actively attacks and destroys the powdery mildew fungus. The active ingredient in Serenade is a bacterium, *Bacillus subtilis*, that helps prevent the powdery mildew from infecting the plant. While both products function to kill the powdery mildew organism and are nontoxic to people, pets, and beneficial insects, they have not proven to be as effective as the oils or sulfur in controlling this disease.

How to Use. Apply protectant fungicides to susceptible plants before or in the earliest stages of disease develop-

ment. Once mildew growth is mild to moderate, it is generally too late for effective control with protectant fungicides. The protectant fungicides are only effective on contact, so applications must provide thorough coverage of all susceptible plant parts. As plants grow and produce new tissue, additional applications may be necessary at 7- to 10-day intervals as long as conditions are conducive to disease growth. On highly susceptible plants, a good strategy is to use sulfur early in the season when temperatures are below 90 °F and to switch to other materials as the season progresses.

If mild to moderate powdery mildew symptoms are present, the horticultural oils and plant-based oils such as neem oil and jojoba oil can be used.

Caneberries. Dormant or delayed dormant sulfur sprays can be used as a preventive measure before canes begin to grow in spring. To protect new growth, treat when the disease first appears and reapply every 10 to 14 days to renew spray deposits that are washed off by rain or irrigation. Materials registered for use on caneberries include wettable sulfur, neem oil, potassium bicarbonate, and AQ10. Don't apply sulfur when temperatures exceed 80°F.

Strawberry. Treat as soon as symptoms appear. Be sure to spray both upper and lower leaf surfaces. It may help to remove and destroy affected leaves before treating the rest of the planting. Materials registered to control powdery mildew include sulfur, horticultural oils, neem oil, potassium bicarbonate, and AQ10. The sulfur treatments also reduce mite populations, but don't apply sulfur when temperatures exceed 80°F because it damages foliage and fruit.

Apple and Stone Fruit. Sprays are not necessary in many backyard situations.

However, if you have had serious powdery mildew damage in past years, treat at 2-week intervals, beginning when buds just start to open (green tip stage), until small, green fruit are present. (**Caution:** Do not use sulfur on apricot trees.) Sulfur, horticultural oils, neem oil, potassium bicarbonate, AQ10, and Serenade are all registered for powdery mildew in these crops.

Grapevines. Powdery mildew is a perennial problem in grapevines. Begin applying treatments when all buds have pushed. Thereafter, repeat at 10-day intervals until the sugar content of the grapes is 12 to 15%, which is when they begin to soften and approach ripeness and are no longer susceptible to infection. You can measure the sugar content with a refractometer, if you have access to one, or you can see if sample berries sink in a 15% sucrose solution. (Prepare the sucrose solution by dissolving 8½ teaspoons of table sugar in a half cup of warm water, then mixing in enough cold water to make the total volume 1 cup.) Sulfur, horticultural oils, neem oil, jojoba oil, potassium bicarbonate, AQ10, and Serenade are registered for controlling powdery mildew in grapes.

REFERENCES

- Flint, M. L. 1998. *Pests of the Garden and Small Farm: A Grower's Guide to Using Less Pesticide*. 2nd ed. Oakland: Univ. Calif. Agric. Nat. Res. Publ. 3332.
- Gubler, W. D., and D. J. Hirschfeld. 1992. Powdery Mildew. In *Grape Pest Management*. Oakland: Univ. Calif. Agric. Nat. Resources Publ. 3343. pp 57-63.
- McCain, A. H. 1994. *Powdery Mildew*. HortScript #3. Univ. Calif. Coop. Ext. Marin County.

For more information contact the University of California Cooperative Extension or agricultural commissioner's office in your county. See your phone book for addresses and phone numbers.

CONTRIBUTORS: B. L. Teviotdale, W. D. Gubler, and S. T. Koike
 EDITOR: B. Ohlendorf
 TECHNICAL EDITOR: M. L. Flint
 DESIGN AND PRODUCTION: M. Brush
 ILLUSTRATIONS: Illustrations: Fig. 1 Christine M. Dewees; Fig. 2 adapted from *Grape Pest Management*. Oakland: Univ. Calif. Agric. Nat. Res. Publ. 3343.

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Confine chemicals to the property being treated. Avoid drift onto neighboring properties, especially gardens containing fruits or vegetables ready to be picked.

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