



Organic Small Fruit Disease Management Guidelines

Integrated Management of Bramble Diseases

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Introduction

Disease management strategies are very similar for both organic and conventional small fruit production systems in the Midwest. In both systems it is important to develop and use an integrated disease management program that integrates as many disease control methods as possible, the more the better. Major components of the disease management program include: **use of specific cultural practices; developing knowledge of the pathogen and disease biology, use of disease resistant cultivars, and timely application of organically approved fungicides or biological control agents or products when needed.** These guidelines have been written for caneberries (raspberry and blackberry), strawberry, blueberry and grape. Specific information is provided for each crop in its respective chapter. Most disease control methods or strategies are identical for both conventional and organic production systems. Perhaps the greatest difference between organic and conventional production systems is that organic growers are not permitted to use synthetic "conventional" fungicides. If disease control materials are required in the organic system, growers are limited to the use of "inorganic" fungicides such as sulfur (elemental sulfur and lime-sulfur) or copper fungicides (Bordeaux mixture and fixed copper products). In addition, there are several new "alternative" disease control materials and biological control products that are currently available and are cleared for use in organic production.

There are several problems associated with the use of these inorganic fungicides and "alternative" products in small fruit disease control programs. Among the most important are 1) **Phytoxicity**, which is the potential to cause damage to foliage, fruit set and fruit finish (this is a concern primarily with copper and sulfur fungicides); and 2) **their limited spectrum of fungicide activity**, which means they may not be capable of providing simultaneous control of the wide range of fungal pathogens that can cause economic damage to the crop. For example, sulfur is highly effective for controlling powdery mildew on most fruit crops, but provides little or no control of most other diseases.

In a climate like the Midwest, environmental conditions during the growing season are generally very conducive (warm and wet) to the development of several important diseases, insect pests and weeds. Limitations in relation to which pesticides may or may not be used, present the organic grower with some unique and very demanding challenges. Whereas the use of various cultural practices and disease resistance will be the "back bone" of the organic disease management program, the limited use of organically approved pesticides or biocontrol agents will probably be required at times.

Integrated Management of Bramble Diseases

An integrated disease management program for controlling raspberry and blackberry diseases integrates the use of all available control methods into one program. The use of organically approved fungicides or biological control agents for control of several important diseases can be a major part of the overall disease management program, but the use of various cultural practices is perhaps even more important in obtaining effective disease control. An effective disease management program for brambles must emphasize the integrated use of specific cultural practices, knowledge of the pathogen and disease biology, disease resistant cultivars, and timely applications of organically approved fungicides or biological control agents or products when needed.

The objective of the disease management program is to provide a commercially acceptable level of disease control on a consistent (year-to-year) basis, with minimal fungicide use.

Identifying and Understanding the Major Bramble Diseases

It is important for growers to be able to recognize the major bramble diseases. Proper disease identification is critical to making the correct disease management decisions. In addition, growers should develop a basic understanding of pathogen biology and disease cycles for the major bramble diseases. The more you know about the disease, the better equipped you will be to make sound and effective management decisions.

The following literature contains color photographs of disease symptoms on brambles as well as in-depth information on pathogen biology and disease development. These publications also contain excellent color photographs and information about insect pests as well.

Compendium of Raspberry and Blackberry Diseases and Insects

Published by the American Phytopathological Society, 3340 Pilot Knob Rd., St. Paul, MN 55121. Phone: 612-454-7250. (1-800-328-7560). This is the most comprehensive book on bramble diseases and insects available. All commercial growers should have a copy.

Bramble Production Guide

This is a comprehensive book covering most phases of bramble production. It can be purchased from: Northeast Regional Agricultural Engineering Service, 152 Riley-Robb Hall, Cooperative Extension, Ithaca, NY 14853. Phone: 607-255-7654.

Brambles: Production, Management and Marketing

Bulletin 783 of Ohio State University Extension, can be obtained from Ohio State University Extension Publications Office, 385 Kottman Hall, 2021 Coffey Rd., Columbus, OH 43210-1044. Phone 614-292-1607

The following information gives a description of symptoms and causal organisms for the most common raspberry and blackberry diseases in the Midwest.

Cane and Leaf Diseases

Anthracnose

Anthracnose is caused by the fungus *Elsinoe veneta*. One of the most common and widespread diseases of brambles in the United States, anthracnose can infect red and black raspberries, blackberries, dewberries, and loganberries. The disease is very destructive on black and purple raspberries. On red raspberries, it can be common but is usually not a serious problem. Disease losses can occur from defoliation, general stunting and a decrease in cane vigor, reduction in fruit yield and quality, and cane death. Resistance to anthracnose is not available in most varieties. The use of fungicide (lime sulfur) and cultural practices such as sanitation (removal of old and infected canes) are key control methods.

Symptoms

Anthracnose can cause symptoms on canes, leaves, fruit and stems of berry clusters. The most striking symptoms are on canes. A few days after the fungus invades the succulent tissue of young canes, minute purplish spots appear. These spots enlarge in diameter and become oval or lens-shaped. The centers become somewhat sunken and are pale-buff to an ash-gray color (Figure 27). Margins are somewhat raised and purple to purple-brown. If numerous, the lesions may merge and cover large portions of the cane. Diseased tissue extends down into the bark, partly girdling the cane. As the canes dry in late summer and early fall, diseased tissue often cracks. In the following year, fruit produced on severely diseased canes may fail to develop to normal size and may shrivel and dry, especially in a dry growing season.

Figure 27: Anthracnose lesions on black raspberry canes.



On leaves, anthracnose appears on the upper surface in early- to mid summer as irregular, yellowish-white spots about 1/16 inch in diameter (Figure 28). The spots gradually enlarge and develop a reddish-purple margin around a light-gray center. The centers of these spots may drop out, producing a "Shot hole" effect. This "Shot hole" symptom is more common on trailing blackberries and raspberries. On blackberries, leaf spots may merge together producing large grayish dead areas between the veins. Anthracnose does not usually cause much damage to leaves of erect blackberries.

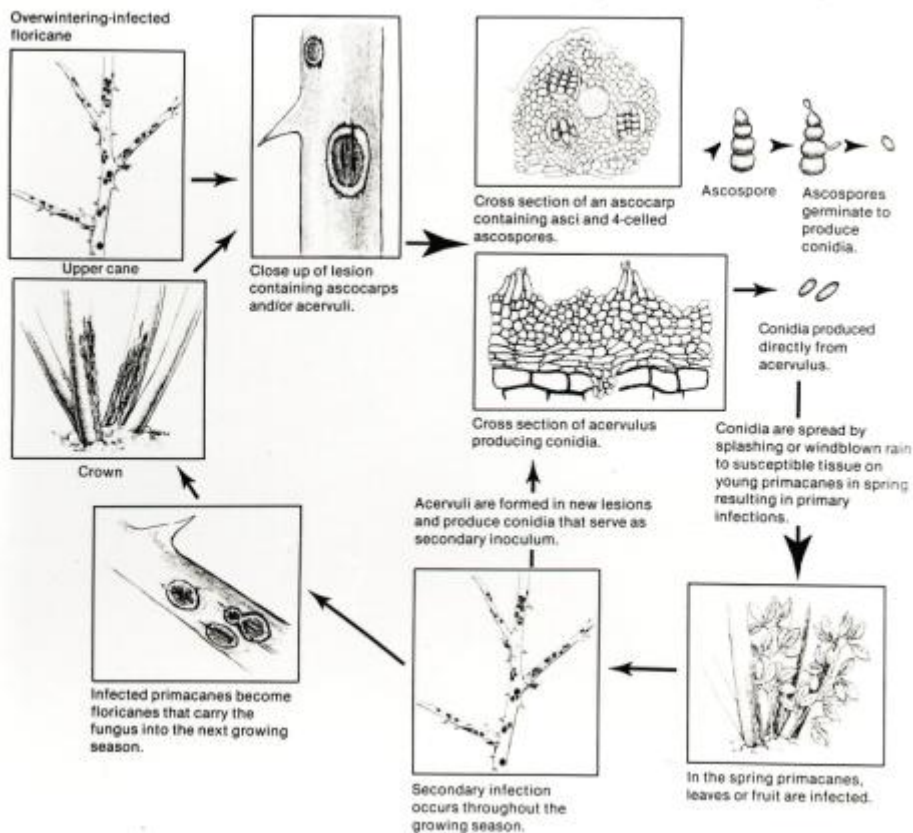
Figure 28: Anthracnose leaf symptoms on black raspberry.



Disease Development

The anthracnose fungus overwinters in the bark or within lesions on infected canes (Figure 29). In early spring the fungus produces two types of microscopic spores called conidia and ascospores. Conidia, which are produced in small fungal fruiting structures called acervuli, are the most common form of inoculum. Ascospores are comparatively rare. Production of these spores coincides with the leafing out of brambles in early spring. Spores are rain-splashed, blown, or carried by insects to young, succulent, rapidly growing plant parts that are susceptible to infection. The spores germinate in a film of water and penetrate into the plant tissue. Symptoms appear about a week later. Small pimple-like reproductive bodies are produced within lesions on infected canes and the fungus overwinters there. These bodies produce conidia for new infections the next spring, completing the disease cycle. As canes age and harden, they become much less susceptible

Figure 29: Anthracnose disease cycle. Disease cycle of Raspberry Anthracnose. Taken from the Compendium of Raspberry and Blackberry Disease and Insects of the American Phytopathological Society. Used with permission.



Cane Blight

Cane blight is caused by the fungus *Leptosphaeria coniothyrium*. Cane blight is one of the more damaging diseases of raspberries. The disease is most common on black raspberries, but also occurs on red and purple cultivars. Cane blight occasionally occurs on blackberries and dewberries. Cane blight can result in wilt and death of lateral shoots, a general weakening of the cane, and reduced yield. It is usually most severe during wet seasons. The fungus often invades the cane through wounds. Any practice that reduces wounding on canes is beneficial for control. Key control methods are the same as for anthracnose.

Symptoms

Dark brown to purplish cankers form on new canes near the end of the season where pruning, insect, and other wounds are present. The cankers enlarge and extend down the cane or encircle it, causing lateral shoots to wilt and eventually die (Figure 30). On second-year canes, the side branches may suddenly wilt and die, usually between blossoming and fruit ripening. On close examination, dark brown or purplish cankers can be observed on the main cane or branches below the wilted area. Infected canes commonly become cracked and brittle and break easily. Tiny black specks (pycnidia), which are reproductive bodies of the cane blight fungus, develop in the brown cankered bark. In wet weather, large numbers of microscopic spores (conidia) ooze out of the pycnidia. This ooze gives the bark a dark-gray, smudgy appearance.

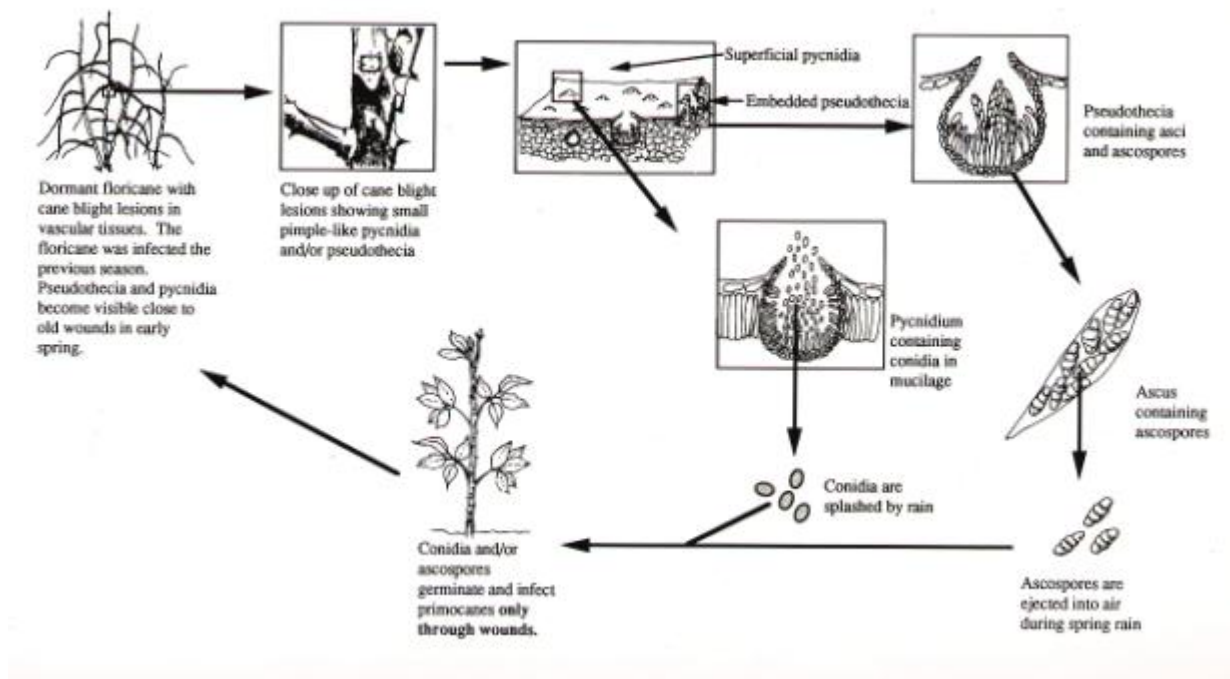
Figure 30: Cane blight lesion on thornless blackberry.



Disease Development

The pathogen survives over winter on infected or dead canes (Figure 31). The following spring, conidia, formed in the pycnidia, ooze from them during wet periods, and are blown, splashed by rain, and carried by insects to nearby canes. Under moist conditions, the spores germinate and penetrate into the plant through pruning wounds, insect punctures, fruit stem breaks, and other wounds. After entry, the fungus rapidly invades and kills bark and other cane tissues. Pycnidia are formed in older cankers and complete the disease cycle. Dead canes can continue to produce conidia and remain a source of infection for several years.

Figure 31: Cane blight disease cycle. Taken from the Compendium of Raspberry and Blackberry Diseases and Insects of the American Phytopathological Society. Used with permission.



Spur Blight of Red Raspberries

Spur blight is caused by the fungus *Didymella applanata*. Spur blight occurs only on red and purple raspberries. Spur blight has been considered to be a serious disease of red raspberry; however, recent studies in Scotland suggest that spur blight actually does little damage to the cane. The extent of damage caused by spur blight in the United States is not clearly understood. Key control methods are the same as for anthracnose and cane blight.

Symptoms

Symptoms first appear on young canes in late spring or early summer. Purple to brown areas (cankers) appear just below the leaf or bud, usually on the lower portion of the stem (Figure 32). These cankers expand, sometimes covering all of the area between two leaves. In late summer or early fall, bark in the cankered cane area splits lengthwise and fungal fruiting bodies, appearing as small black specks, develop in the cankers. They are followed shortly by the formation of many slightly larger, black, erupting spots, another form of fungal fruiting body. Leaflets sometimes become infected and show brown, wedge-shaped diseased areas, with the widest portion of the wedge at the top of the leaf. Infected leaves may fall off, leaving only petioles without leaf blades attached to the cane (Figure 33).

Figure 32: Typical symptoms of spur blight on red raspberry canes.



Figure 33: Symptoms of spur blight on red raspberry leaves. The "V-shaped" lesions are characteristic.

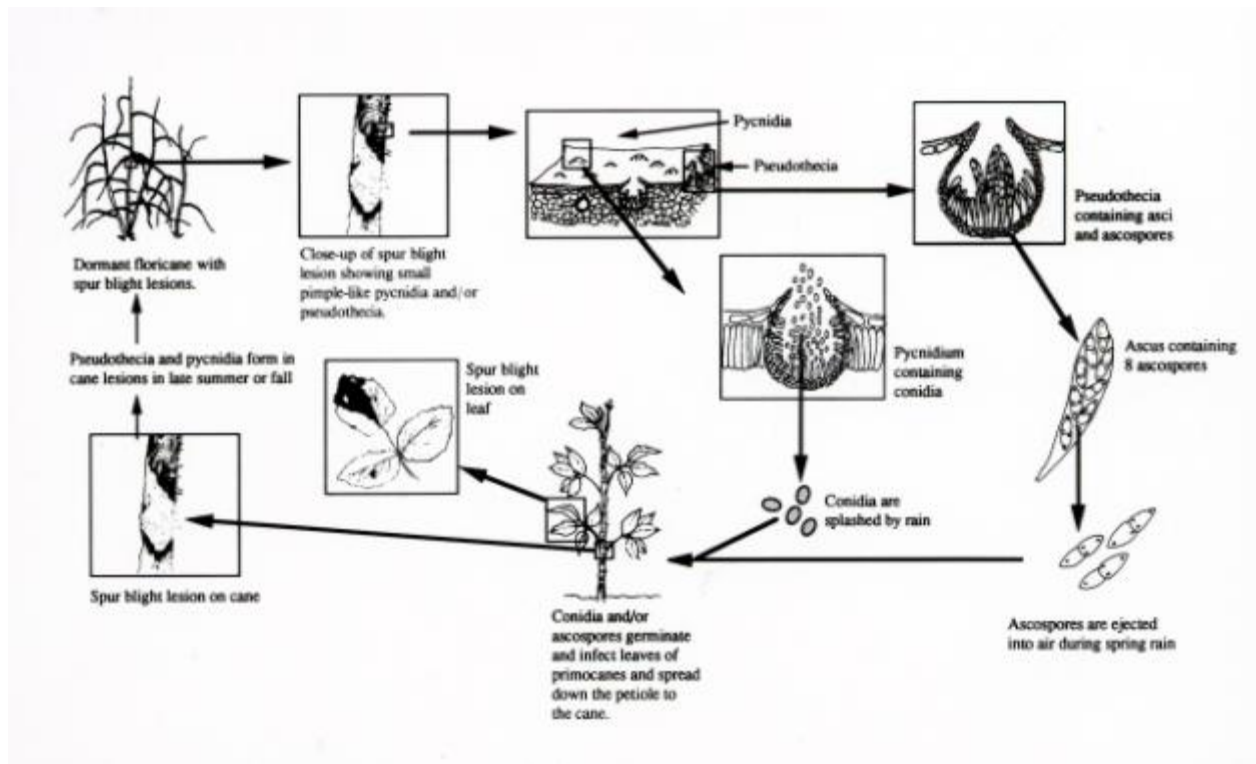


As diseased primocanes become fruiting canes (floricanes) during the next season, the side branches growing from diseased buds are often weak and withered and produce less fruit.

Disease Development

The fungus survives the winter in diseased canes (Figure 34). The following spring and summer, during wet and rainy periods, spores are released and carried by splashing rain and wind to nearby new growth. There they germinate and produce new infections, where the fungus will again overwinter.

Figure 34: Spur blight disease cycle. Taken from the Compendium of raspberry and Blackberry Diseases and Insects of the American Phytopathological Society. Used with permission.



Septoria Leaf and Cane Spot

Septoria leaf and cane spot is caused by the fungus *Septoria rubi*. The disease is common and can be quite severe in the southern portions of the Midwest on erect and trailing blackberries and black raspberries. Leaves and canes of severely infected plants become badly spotted. The disease can cause premature defoliation which will produce weak plants that are more susceptible to winter injury.

Symptoms

On leaves, Septoria leaf spot lesions have a whitish to gray center surrounded by a brown to purple border (Figure 35). The spots are circular and are about 1/8 inch in diameter. Tiny black pycnidia (fungal fruiting bodies) form in the center of the spots. The pycnidia are small; therefore, it may be necessary to use a magnifying glass (10X hand lens) to see them. Leaf spots caused by Septoria are similar to those of anthracnose. Spots on canes and petioles are similar to those on leaves but are generally more elongated.

Figure 35: Septoria leaf spot on blackberry leaflet.



Disease Development

The fungus overwinters as mycelium and pycnidia (fungal fruiting bodies) in dead plant debris (leaves and stems) and on infected canes. Pycnidia on infected canes from a nursery can be an effective means for moving the fungus into new fields. In the spring, spores (conidia) are produced inside the pycnidia. They are released in high numbers and carried to young susceptible leaves and canes by splashing or wind-driven rain. The fungus spores germinate in a film of moisture and penetrate the leaf or cane tissue. As leaf and cane spots form and age, new pycnidia form in the centers. These also produce and release spores that can cause secondary infections throughout the growing season. Although the environmental conditions required for infection are not clearly understood, periods of rainfall are highly conducive to disease development. After overwintering in infected canes or debris, the fungus produces spores for new infections the following spring, completing the disease cycle.

Rosette

Rosette, or double blossom, is caused by the fungus *Cercospora rubi*. Rosette is a serious disease of many varieties of erect and trailing blackberries, particularly in the humid southern United States and the southern regions of the Midwest. The disease is not present in the more northern regions of the Midwest. Rosette also occurs on red and black raspberry but is seldom serious. Rosette infected blossoms do not form berries and non-infected parts of the same cane may produce poor quality fruit. The disease seriously

reduces fruit quality and yield. Once the disease is established in organic plantings, little can be done to control it.

Symptoms

Symptoms of rosette disease are striking and may completely change the plants' appearance due to a proliferation of shoots. This proliferation of shoots is referred to as a witches' broom. Buds on new canes of erect and trailing blackberries are infected in early summer. Generally, no symptoms will develop until the following spring, although a few "Witches' brooms" may develop during warm spells in late fall. In the spring, numerous leafy sprouts develop from infected buds (Figure 36). These shoots are generally smaller than normal and have pale green foliage that later turns a bronze color. Several of these witches' brooms may be formed on one cane. Unopened infected flower buds are abnormally large and coarse and frequently somewhat redder. Sepals enlarge and occasionally change into leaves. Flower petals may become green and leaflike. As flower buds open, petals are usually pinkish in color, wrinkled and twisted. Pistils are usually larger and longer than normal and occasionally become abnormally shaped. The fungus produces a whitish spore mass that can cover the surface of the infected pistils and stamens. Berries do not develop from infected blossoms. Non-infected parts of the same cane often produce small, poor quality fruit. In some varieties the witches' brooms symptoms may not be apparent; however, the fruit set in infected blossoms is always impaired.

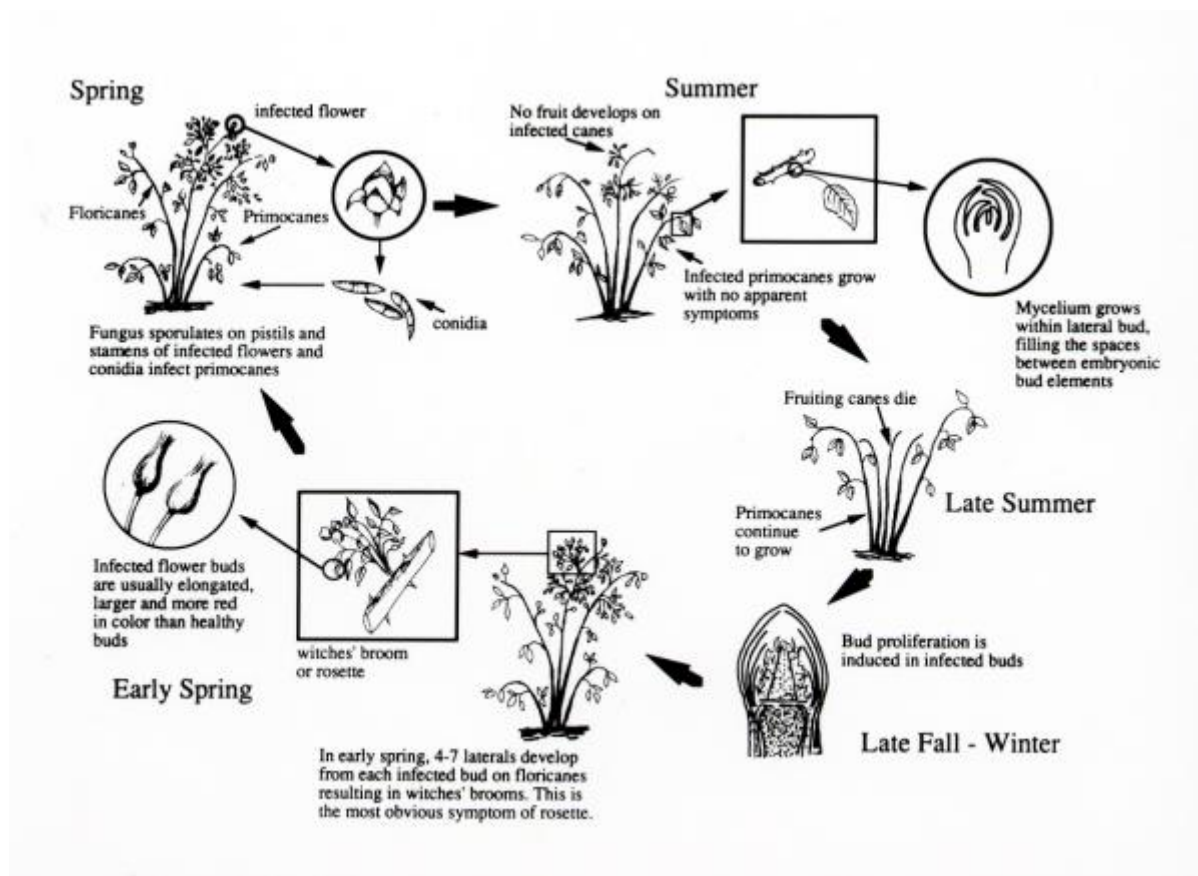
Figure 36: Symptoms of rosette disease on blackberry.



Disease Development

Young buds on vegetative canes are infected in early spring (Figure 37). The double blossom fungus grows between the bud scales and surrounds the embryonic tissues within the bud. As secondary buds develop beside an infected bud, they are also invaded. After the bud is colonized by the fungus, very little happens. Infected buds usually remain symptomless until the next spring. A few infected buds are sometimes forced out in an unusually warm late fall. The fungus overwinters in infected buds. During the winter the fungus continues to grow within the bud. Bud proliferation is induced. When infected buds break dormancy in spring, they develop a large number of short, abnormal and off-colored shoots (the witches' broom effect). Infected flower buds usually produce abnormal blossoms upon which the fungus produces its spores. These spores are carried by wind or insects to the newly formed vegetative buds, which are only susceptible to infection in early spring. The fungus infects these buds and overwinters in them to cause new symptoms the next spring, thus completing the disease cycle.

Figure 37: Disease cycle of rosette. Taken from the Compendium of Raspberry and Blackberry Diseases and Insects of the American Phytopathological Society Used with Permission.



Powdery Mildew

Powdery mildew is caused by the fungus *Sphaerotheca macularis*. Powdery mildew affects susceptible cultivars of red, black, and purple raspberries. Blackberries and their hybrids are usually not affected. The disease can be severe (varying from year to year) on highly susceptible cultivars, and these plants may be stunted and less productive. The infection of flower buds reduces fruit quantity. Infected fruit may be lower in quality or unmarketable as a result of the unsightly covering of mycelial growth. The key control method is to avoid susceptible varieties. Sulfur will provide good control on susceptible varieties.

Symptoms

Infected leaves develop light green blotches on the upper surface. Generally, the lower surface of the leaf directly beneath these spots becomes covered by white, mycelial growth of the powdery mildew fungus. The leaf spots may appear water-soaked. Infected leaves are often mottled, and if surface growth of the fungus is sparse, they often appear to be infected by a mosaic virus. Infected shoot tips may also become covered with mycelial growth (Figure 38). When severely infected, the shoots become long and spindly (rat-tailed), with dwarfed leaves that are often curled upward at the margins (Figure 39). Infected fruit may also become covered with a white mycelial mat. When the disease is severe, the entire plant may be stunted.

Figure 38: Powdery mildew on blackberry leaves. Note the leaves are covered with the white growth of the fungus.



Figure 39: Powdery mildew on blackberry. Note the distortion of leaves.



Disease Development

The fungus overwinters as mycelium in buds on shoot tips in Minnesota, but in California it has been reported to overwinter only as cleistothecia (fungal fruiting structures), producing ascospores as primary inoculum in the spring. Conidia are generally abundantly produced on the surface of infected tissue, and these serve as secondary inoculum for repeated cycles of infection throughout the growing season. They are airborne and probably remain viable for no more than 21 days. The development of this disease, like most other powdery mildew diseases, is favored by warm, dry weather.

Orange Rust

Orange rust is the most important of several rust diseases that attack brambles. All varieties of black and purple raspberries and most varieties of erect blackberries and trailing blackberries are very susceptible. Orange rust does not affect red raspberries. Orange rust is caused by two fungi that are almost identical, except for a few differences in their life cycles. *Arthuriomyces peckianus* occurs primarily in the northeastern quarter of the United States and is the causal agent for the disease in the Midwest. *Gymnoconia nitens* is a microcyclic (lacks certain spores) stage of *A. peckianus*. *G. nitens* is the more common rust pathogen on erect and trailing blackberries in the Southeast.

Unlike all other fungi that infect brambles, the orange rust fungus grows "Systemically" throughout the roots, crown and shoots of an infected plant, and is perennial inside the

below-ground plant parts. Once a plant is infected by orange rust, it is infected for life. Orange rust does not normally kill plants, but causes them to be so stunted and weakened that they produce little or no fruit. Key control methods are cultural practices such as removing infected plants early in the spring and eradication of wild hosts (brambles) near the planting. Organic fungicides are not effective for control. In severely infested areas, black raspberries or blackberries should probably not be planted. Red raspberries are not susceptible.

Symptoms

Orange rust-infected plants can be easily identified shortly after new growth appears in the spring. Newly formed shoots are weak and spindly (Figure 40). The new leaves on such canes are stunted or misshapen and pale green to yellowish (Figure 41). This is important to remember when one considers control, because infected plants can be easily identified and removed at this time. Within a few weeks, the lower surface of infected leaves are covered with blister-like pustules that are waxy at first but soon turn powdery and bright orange (Figure 42, 43). This bright orange, rusty appearance is what gives the disease its name. Rusted leaves wither and drop in late spring or early summer. Later in the season, the tips of infected young canes appear to have outgrown the fungus and may appear normal. At this point, infected plants are often difficult to identify. In reality, the plants are systemically infected, and in the following years, infected canes will be bushy and spindly, and will bear little or no fruit.

Figure 40: Black raspberry plants showing early season symptoms of orange rust. Note the "Spindly" elongated shoots. Orange pustules will develop on the underside of infected leaves.

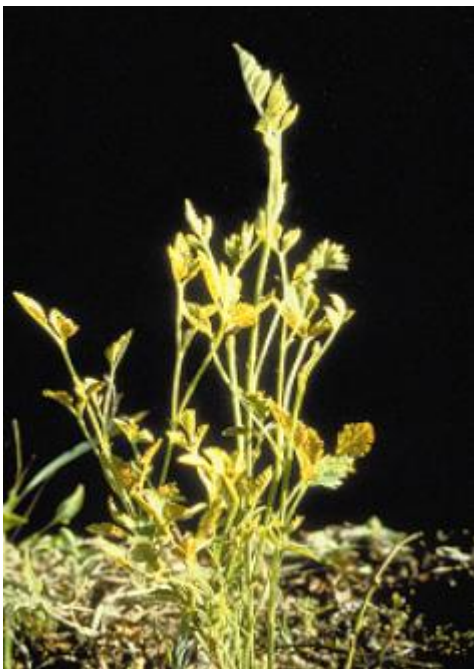


Figure 41: Leaves on infected plants are usually yellow (chlorotic) and smaller than leaves on healthy plants.



Figure 42: Orange rust symptoms on the underside of a black raspberry leaf.



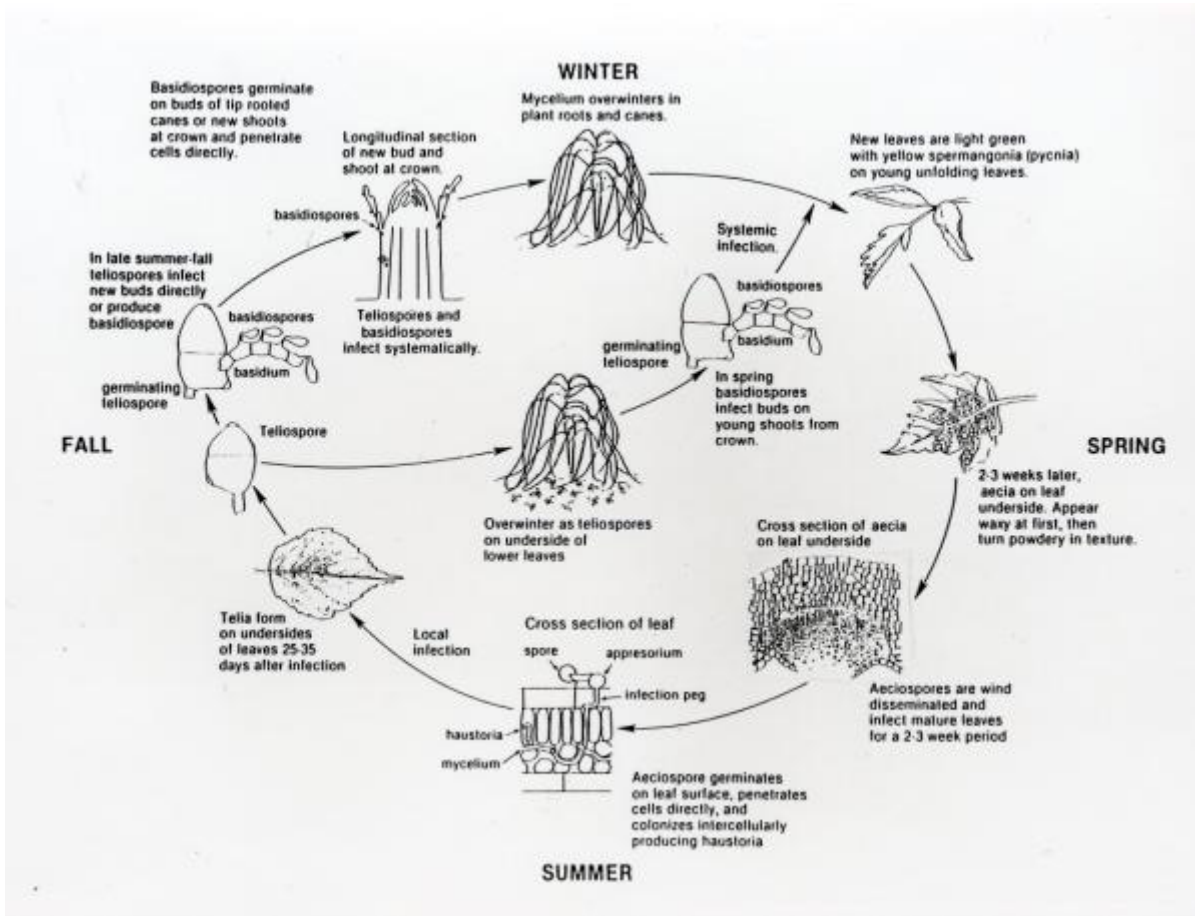
Figure 43: Close-up blister like pustules on the underside of an infected black raspberry leaf. Pustules contain bright orange masses of fungus spores.



Disease Development

In late May to early June, wind and perhaps rain-splash spreads the bright orange aeciospores from the pustules on infected leaves to healthy susceptible leaves where they infect only localized areas of individual mature leaves (Figure 44). When environmental conditions favorable for infection occur, the spores germinate and penetrate the leaf. About 21-40 days after infection, small, brownish black telia develop on the underside of infected leaflets. The teliospores borne in these telia germinate to produce a basidium, which in turn produces basidiospores. In blackberries these spores then infect buds on cane tips as they root. They also may infect buds or new shoots being formed at the crowns of healthy plants in the summer. The fungus becomes systemic in these young plants, growing into the crown at the base of the infected shoot, and into newly formed roots. As a result, a few canes from the crown will show rust the following year. The fungus overwinters as systemic, perennial mycelium within the host.

Figure 44: Orange rust disease cycle. Taken from the Compendium of Raspberry and Blackberry Diseases and Insects of the American Phytopathological Society. Used with Permission.



Orange rust is favored by low temperatures and high humidity. Temperatures ranging from 43 to 72 F favor penetration and development of the fungus, but higher temperatures decrease the percentage of spore germination. At 77 F, aeciospores germinate very slowly, and disease development is greatly retarded. Spore germination and plant penetration have not been observed at 86 F. Aeciospores require long periods of leaf wetness before they germinate, penetrate, and infect plants.

Late Leaf Rust

Late leaf rust, caused by the fungus *Pucciniastrum americanum*, can cause serious damage to susceptible red raspberry cultivars. Economic losses occur from fruit infection and premature defoliation. Because it usually appears late in the season and only occasionally in a severe form, some consider it to be a minor disease. The wild red raspberry, *Rubus strigosus*, in the eastern United States is very susceptible to this rust. A number of cultivars originating from this species also are highly susceptible. While late leaf rust occurs throughout the northern half of the United States and southern Canada, it is more common east of the Mississippi River. In recent years, its occurrence has increased in the northern areas of the Midwest and it has caused significant losses. The rust does not occur on black raspberries or blackberries. Organic fungicides are not effective for control. Once established in the planting, little can be done to control it.

Symptoms

On mature leaves, late leaf rust causes small chlorotic or yellow spots to form on the upper leaf surface (Figure 45). These spots may turn brown before leaves die in the fall. Unless the disease is severe, foliar infections can be rather inconspicuous. Small pustules filled with powdery spores (not waxy like orange rust spores) are formed on the undersides of infected leaves (Figure 46). These spore masses may also occur on leaf petioles, canes, and even on the fruit. Infected fruit are worthless; thus, yield of marketable fruit is reduced (Figure 47). Badly infected leaves may drop prematurely, and in years when the disease is severe, canes may be defoliated by September.

Figure 45: Symptoms of late leaf rust on the upper surface of red raspberry leaves. Note the chlorotic spots.



Figure 46: Symptoms of late leaf rust on the lower surface of red raspberry leaves. Note the masses of powdery yellow spores.



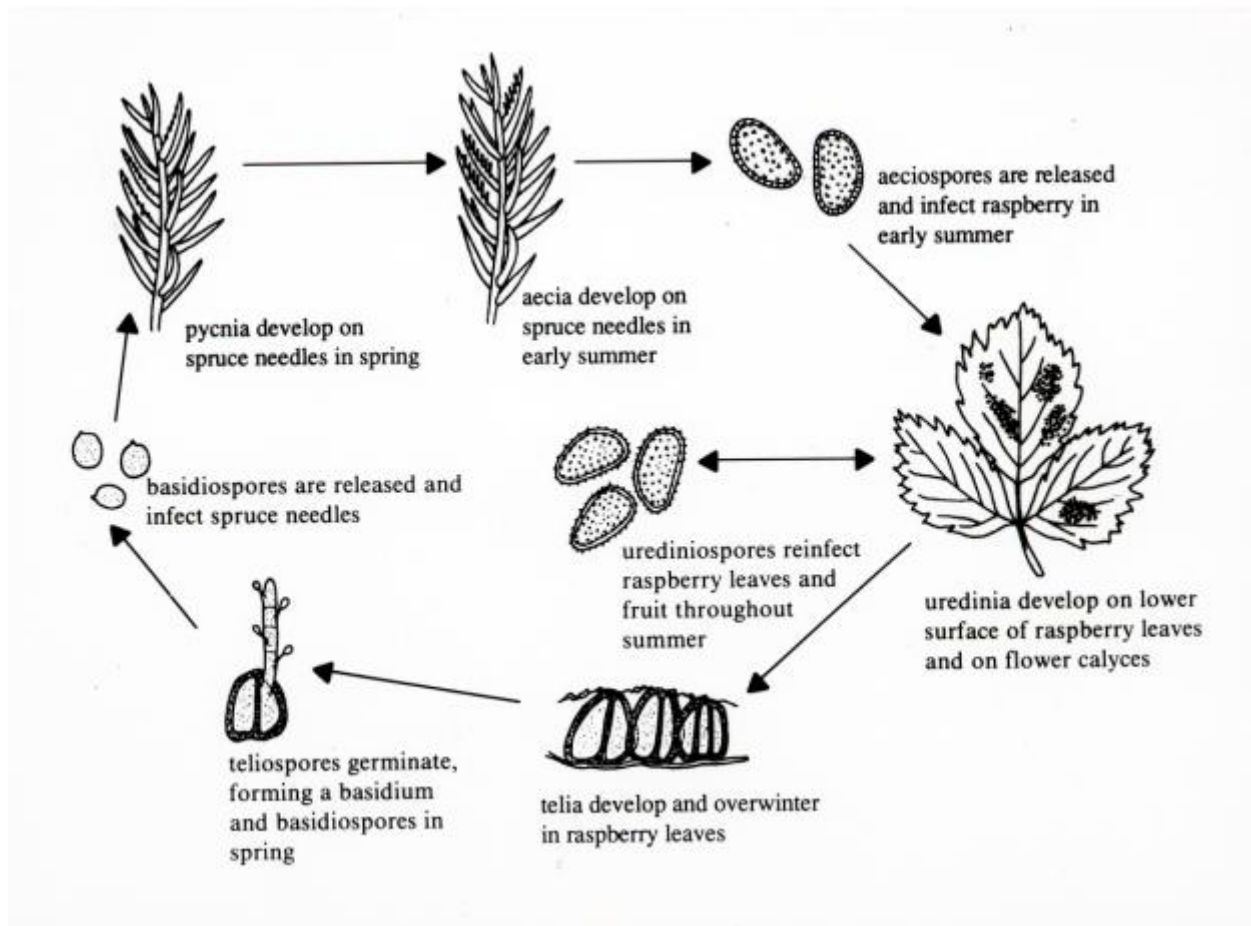
Figure 47: Late leaf rust symptoms on red raspberry fruit. Note the pustules on individual drupelets.



Disease Development

Unlike the orange rust fungus, the late leaf rust fungus is not systemic. The rust fungus produces two types of spores (urediniospores and teliospores) only on raspberries (Figure 48). The alternate host for the rust is white spruce (*Picea canadensis*), on which another type of spore (aeciospore) is produced. The rust apparently does not need the aeciospores stage to survive on raspberries, because the disease is found year after year in regions remote from any spruce trees. The fungus probably overwinters on raspberry canes and, in the following season, produces urediniospores that serve as the source of primary inoculum for new infections.

Figure 48: Late leaf rust disease cycle. Taken from the Compendium of Raspberry Diseases and Insects of the American Phytopathological Society. Used with Permission.



The small, numerous, light-yellow spots seen on the undersurfaces of the leaves are the uredinial pustules that contain the urediniospores of the fungus. These spores are capable of causing new infections throughout the growing season. Black, one-celled teliospores may be found later in the season intermingled with the uredinial pustules. They are capable of infecting the alternate host (spruce) through the production of yet another type of spore (basidiospore), but probably play little part in the life cycle of the rust on *Rubus*.

Bramble Fruit Rots

Figure 49: Botrytis fruit rot (gray mold) on raspberry fruit.



Disease Development

The gray mold fungus is capable of infecting a great number of different plants. It overwinters as minute, black fungus bodies (sclerotia) on infected plant debris including dead raspberry leaves and canes. In early spring, these fungal bodies produce large numbers of microscopic spores (conidia). Spores are spread by wind where they are deposited on blossoms and fruits. They germinate when moisture is present and infection occurs within a few hours. The fungus usually enters the fruit through flower parts, where it remains inactive (latent) within the tissues of infected green fruits. As the fruit matures, the fungus becomes active and rots the fruit. Thus, while infection actually occurs during bloom, symptoms are usually not observed until harvest. This is important to remember when one considers control. Temperatures between 70 and 80°F and moisture on the foliage from rain, dew, fog, or irrigation create ideal conditions for disease development. The disease can develop at lower temperatures if foliage remains wet for long periods.

Vast numbers of conidia are produced on the surface of infected plant parts, especially fruit. One infected fruit may be covered by millions of spores, which are carried by wind to cause additional infections on flowers and ripe fruit.

Bramble Root Diseases

Phytophthora Root Rot

Phytophthora root rot is caused by several related species of soilborne fungi belonging to the genus *Phytophthora*. To date, *P. megasperma*, *P. cryptogea*, *P. citriicola*, *P. cactorum*, and at least two additional unidentified *Phytophthora* species have been implicated in this disease. The disease occurs on red, black, and purple raspberries, although in the northeastern United States it has been documented most commonly on red raspberries. The disease has reported to occur in blackberries in Kentucky. *Phytophthora* root rot can be an extremely destructive disease on susceptible cultivars where conditions favor its development. Infected plants become weak and stunted and are particularly susceptible to winter injury; seriously infected plants commonly collapse and die. Key methods of control include site selection or improvement to avoid saturated soils and the selection of more resistant red raspberry varieties.

Symptoms

The disease is most commonly associated with heavy soils or portions of the planting that are the slowest to drain (lower ends of rows, dips in the field, etc.). In fact, most declining plants that are considered suffering from "Wet feet" probably are suffering from *Phytophthora* root rot. Symptoms include a general lack of vigor and a sparse plant stand. Apparently healthy canes may suddenly decline and collapse during the late spring or summer (Figure 50). In such cases, leaves may initially take on a yellow, red, or orange color or appear scorched along the edges. As the disease progresses, affected canes wilt and die. Infected plants frequently occur in patches, which may spread along the row if conditions remain favorable for disease development.

Figure 50: Above ground symptoms of Phytophthora root rot on primocanes of 'Heritage' red raspberry.



Because wilting and collapsing may be caused by other factors (winter injury, cane borers, etc.), it is necessary to examine the root system of infected plants to diagnose the disease. Suspect plants should be dug up and the epidermis (outer surface) scraped off the main roots and crown. On healthy plants, the tissue just beneath the epidermis should be white; on plants with Phytophthora root rot, this tissue will be a characteristic brick red (eventually turning dark brown as the tissue decays) (Figure 51). Sometimes a distinct line can be seen between infected and healthy tissue, especially on the below-ground portion of the crown.

Figure 51: Below ground symptoms of Phytophthora root and crown rot on red raspberry. Note the sharp line of demarcation between healthy, white tissue and infected reddish-brown tissue. This reddish-brown or brick-red discoloration on roots is typical of Phytophthora root rot.



Disease Development

The fungi persist primarily as mycelium in infected roots or as dormant resting spores in the soil. When the soil is moist, reproductive structures (sporangia) are formed upon the infected tissue or by germinating resting spores (oospores) in the soil. Within each of these structures a number of individual spores called zoospores are formed. These zoospores are expelled into the soil during periods when the soil is saturated with water. The zoospores have 'Tails' (flagella), which allow them to swim through the water-filled soil pores to reach new plant parts. Upon reaching a plant root or crown, the zoospores become attached and infect. As water remains standing and oxygen is depleted from the root zone, the plant is progressively less capable of resisting the fungus and infection becomes more likely and severe. Each new infection site is a potential source of additional resting spores and zoospores, allowing for epidemic disease development in sites which are subjected to repeated periods of standing water. Although the optimum season for infection is not known for certain, it is likely that spring and fall are particularly favorable periods. However, it is assumed that infection can occur throughout the growing season if soil moisture conditions are favorable.

Verticillium Wilt

Verticillium wilt is caused by the soilborne fungus *Verticillium dahliae* and is one of the most serious diseases of raspberries. This disease reduces raspberry yields by wilting, stunting, and eventually killing the fruiting cane or the entire plant. The disease is usually more severe in black and purple than in red raspberries. Blackberries are also susceptible to the disease, but seldom suffer severe losses.

Verticillium wilt is usually a cool-weather disease and is most severe in poorly drained soils and following cold, wet springs. The appearance of symptoms on new canes frequently coincides with drought stress during hot, dry, midsummer weather. Key methods for control are site selection and proper crop rotation to avoid planting in infested soils.

Symptoms

Symptoms usually appear on black raspberries in June to early July, and on red raspberries about a month later. The lower leaves of diseased plants may at first appear to have a dull green cast as compared to the bright green of normal leaves. Starting at the base of the cane and progressing upward, leaves wilt, turn yellow, and drop. Eventually, the cane may be completely defoliated except for a few leaves at the top (Figure 52). Black raspberry and blackberry canes may exhibit a blue or purple streak from the soil line extending up the cane to varying heights (Figure 53). This streak is often not present or is difficult to detect on red raspberries. In the spring following infection, many of the diseased canes are dead. Others are poorly developed and have shriveled buds. The new

leaves are usually yellow and stunted. Infected canes may die before fruit matures, resulting in withered, small, and tasteless berries.

Figure 52: Verticillium wilt symptoms on black raspberry plant.



Figure 53: Blueish streaks can often be observed on black raspberry canes affected by verticillium wilt.



Disease Development

Verticillium is a common soilborne fungus. It causes disease on more than 160 different kinds of plants, including strawberries, eggplant, tomatoes, potatoes, stone fruits and peppers. The fungus overwinters in the soil and plant debris as dormant mycelium or tiny black specks called microsclerotia. The fungus can survive in the soil for many years. When conditions are favorable, microsclerotia germinate and produce threadlike fungal filaments (hyphae). These hyphae can penetrate the root directly, but invasion is aided by breaks or wounds in the roots. Once inside the root, the fungus grows into the water-conducting tissue (xylem). The destruction of water-conducting tissue prevents the movement of water from the roots to the rest of the plant. Thus, the plant eventually wilts and dies.

Bacterial Crown Gall and Cane Gall

Crown gall is caused by the bacterium *Agrobacterium tumefaciens*. Cane gall is caused by a very similar bacterium, *Agrobacterium rubi*. Crown gall is a widespread disease of all brambles. Cane gall affects black and purple raspberries more frequently than red raspberries or blackberries. These diseases are particularly serious in nursery fields where freedom from the disease is essential. The bacteria induce galls or tumors on the roots, crowns, or canes of infected plants. Galls interfere with water and nutrient flow in the plants. Seriously infected plants may become weakened, stunted, and unproductive. Key methods of control include starting the planting with disease free plants and crop rotation. A biocontrol agent (Galltrol) is currently available as a preplant treatment.

Symptoms

Young galls (tumorlike swellings) are rough, spongy, and wart-like (Figure 54). Galls can be formed each season and vary in size from a pinhead to several inches in diameter. They develop near the soil line or underground in the spring. Cane galls occur almost exclusively on fruiting canes and usually appear in late spring or early summer. Both crown and cane galls become hard, brown to black, woody knots as they age. Some disintegrate with time and others may remain for the life of the plant. The tops of infected plants may show no symptoms, but plants with numerous galls may be stunted; produce dry, poorly-developed berries; break easily and fall over; or show various deficiency symptoms due to impaired uptake and transport of nutrients and water.

Figure 54: Gall on the root of a crown gall infected red raspberry plant.



Disease Development

Crown gall bacteria enter the plant only through natural openings or wounds in the epidermis or bark of the plant. The bacteria survive in infested soil for years and can invade the roots and crowns of susceptible plants through natural growth cracks, tissue damaged by winter injury, or damage caused by soil insects. Man-made wounds that occur during pruning and cultivation are important points of entry. After the bacteria enter plant tissues, an incubation period of 11 to 28 days, or more if the host is dormant, may be required before the bacteria induce cell proliferation, enlargement, and disorganized growth, resulting in the production of galls. Bacteria, abundant in the outer portions of galls, are continually sloughed off into the soil. The bacteria overwinter in soil and in diseased galls. The following spring, these bacteria are spread by splashing rain, water, cultivation (any practice that moves soil), pruning tools and insect feeding. When they contact wounded tissue of a susceptible host, they enter and induce gall formation, completing the disease cycle.

Virus Diseases of Raspberries

Red and black raspberries are susceptible to numerous viruses. Raspberries probably suffer greater infection and more serious damage from viruses than any other fruit crop in the United States. Virus infection in raspberries can reduce fruit yields 70 percent or more. There are four main virus-induced diseases of raspberries: mosaic, leaf curl, streak, and tomato ringspot. Key control methods include starting the planting with disease free (virus indexed) plants and eradication of wild hosts as well as infected plants within the planting.

Other disorders of raspberries can cause symptoms similar to viruses. Late-spring frosts, mineral deficiencies (such as iron and nitrogen), powdery mildew, pesticide injury, and feeding by leafhoppers, aphids and mites can all cause symptoms similar to those caused by various viruses. Positive identification of a bramble virus or virus complex cannot be

based on foliar symptoms alone. Greenhouse and laboratory tests using specific scientific techniques are required for positive identification of viruses.

Mosaic

This disease is caused by a virus complex (more than one virus involved). Viruses of the mosaic complex (Rubus yellow net, black raspberry necrosis, raspberry leaf mottle and raspberry leaf spot virus) cause the greatest reduction in growth, vigor, fruit yield, and quality of any of the bramble viruses. No raspberry plants are immune, but black and purple cultivars are damaged more severely than red cultivars. The symptoms of mosaic vary considerably, depending upon the cultivar grown, which virus or viruses of the complex are involved, and time of year. Symptoms are most evident on new canes during cooler weather of spring and fall. Symptoms may disappear in the summer when temperatures are high. This is an important point to remember when considering control of virus diseases. Even though symptoms may disappear temporarily, plants remain infected for life. Infected canes are usually short and less vigorous than healthy canes. Leaves are mottled with yellowish or light green spots on a darker green background (Figure 55). On more susceptible cultivars, leaves become puckered with large, dark-green blisters surrounded by yellowish or yellowish-green tissue. Leaves that develop in hot weather may be symptomless or show only faint mosaic pattern with yellow flecks in the normal green color. Leaves formed in late summer show a fine, yellowish, speckled mottling.

Figure 55: Mosaic virus symptoms on raspberry leaves. Note the mottled areas of dark green and light green or yellow.



Mosaic-infected plants are often progressively more stunted each year. In addition to leaf symptoms, the fruit yield is reduced and may be dry, seedy (often crumbly), and lack flavor. On black and purple raspberries, the tops of newly-infected canes often curl downward, turn black, and die.

The raspberry mosaic virus complex is spread almost exclusively by one species of insect, the large raspberry aphid (*Amophorophora agathonica*). The aphid is widespread and feeds on the undersides of leaves near the tip of the canes. The aphids become contaminated with the viruses and can spread the viruses to healthy plants up to a quarter of a mile or more away. The mosaic virus can also be spread by commercial propagation from infected plants and movement of the diseased nursery plants.

Leaf Curl

Leaf curl is less common than the mosaic complex, but it is considerably more destructive. Infected plants are worthless and should be destroyed immediately. The yield of infected raspberries can be reduced up to 70 percent. Infected black raspberry plants may degenerate and die after two or three years.

Leaf curl symptoms are easily recognized. Leaves on infected plants are uniformly small, dark green, crinkled, and tightly curled downward and inward. When diseased shoots first appear, they are pale yellowish-green, but they soon turn dark green, become stiff and brittle, and usually do not branch. Each year the plant loses more vigor and is progressively more dwarfed. Fruiting laterals are shorter and more upright than normal ones. Berries on infected plants may ripen prematurely and are small, dry, seedy, and crumbly.

The raspberry leaf curl virus, the causal agent of raspberry leaf curl disease, is spread exclusively by the small raspberry aphid (*Aphis rubicola*). Heavy populations of this aphid can cause severe inrolling of leaves even in the absence of the leaf curl virus. Winged forms of the aphid can transmit the virus to healthy raspberries from nearby infected brambles. Windborne aphids may spread the disease several miles.

Raspberry Streak

Raspberry streak, caused by tobacco streak virus, is generally a minor, but widespread disease. It is presently limited to northern Ohio, western Pennsylvania, and western New York. Streak affects only black raspberries.

The most obvious symptom of the disease is numerous purplish streaks that appear on the lower parts of infected canes. Usually, the streaks are less than an inch long. Terminal leaves on infected canes are often hooked or recurved, twisted or rolled, and darker green than normal. Leaves on the lower positions of the cane may show yellowing along veins and mottling. Fruits on infected canes are smaller than normal, dull, seedy, and crumbly and lack flavor. The individual drupelets often ripen unevenly, giving the fruit a blotched appearance.

Tomato Ringspot Virus

This virus disease occurs only in red raspberries and is widespread in the major red raspberry-producing areas of the Pacific Coast and northeastern United States. Infected plants may appear normal, but they are usually somewhat less vigorous than healthy plants. The most obvious symptom of the disease is the production of small, crumbly berries that fall apart when touched. The crumbly berry is caused by the failure of some of the tiny fruitlets (druplets), which make up the fruit, to develop.

The tomato ringspot virus can affect many other species of woody and herbaceous plants. This virus is transmitted through the soil by the dagger nematode (*Xiphinema americanum*).

Control of Virus Diseases

Always start new plantings with the highest-quality plants available. Use only certified, disease-free, virus-indexed stock. Avoid obtaining uninspected plants from friends or neighbors. Select a planting site that is sunny and fertile and has good air and water drainage. Destroy all wild and neglected raspberries and other brambles located within 500 to 1,000 feet of your planting site.

Do not plant black or purple raspberries near red raspberries, even though the red raspberries appear to be healthy. Red raspberries may have latent infections. This means that they can be infected, but do not show symptoms. Even though infected plants are symptomless, the virus can still be transmitted from them to healthy plants. If black and red raspberries are planted together, separate them as far apart as possible. If possible, plant black raspberries upwind from reds. The reason for this is the aphids that transmit viruses are generally blown or carried by wind rather than by active flight. Therefore, you do not want aphids to be blown from your red raspberries to your more susceptible black raspberries.

Go through the raspberry planting at least twice a year and remove all plants showing any virus symptoms. This should be done once about mid-June and again in August or September. Before removing infected plants, kill all aphids on them by spraying infected plants with an insecticide a day or two before removal. Dig out the diseased plants, including roots, and dispose of them away from the planting site. In established plantings, where more than 5 to 10 percent of the plants show visible virus symptoms, removal of infected plants probably will not pay. In this case, maintain the planting until fruit yield becomes unprofitable, then destroy it. It is unwise to establish new plantings next to old, infected ones. Maintain strict aphid control at all times, especially in late spring and early summer when aphid populations are highest.

If the virus is transmitted by nematodes, the nematodes must be controlled in order to control the disease. Have the soil tested for plant parasitic nematodes before planting. Samples should be taken in July of the year preceding planting. Spring samples, taken when soils are cold, are not accurate and do not give the grower sufficient time to apply a preplant nematicide. Information on collecting soil samples and submitting them for analysis is available from your Extension service.

Use of Disease-Resistant Cultivars

In an organic disease management program where emphasis is placed on reducing overall fungicide use, it is essential to identify any available disease resistance and use it. Unfortunately, resistance to most of the major diseases is not available in most commercially grown raspberry and blackberry cultivars in the Midwest. Thus, the disease management program must rely mainly on the use of cultural practices and efficient fungicide use. Whereas resistant cultivars are not generally available for most diseases, cultivars do vary greatly in their level of susceptibility to certain diseases. If resistance is not available, those cultivars that are highly susceptible to important diseases should at least be avoided.

Disease resistance varieties

Phytophthora Root Rot

Phytophthora root rot is most serious on red raspberries and some of the hybrids. The black raspberry varieties 'Cumberland' and 'Munger' are reported to be susceptible. The cultivars 'Bristol', 'Dundee' and 'Jewel' appear to be moderately to highly resistant. Among red raspberry cultivars, none are immune to the disease, but cultivars do differ greatly in their level of susceptibility. Among varieties grown in the Midwest and Northeast, 'Titan' and 'Hilton' are extremely susceptible, with 'Festival', 'Heritage', 'Reveille', and 'Taylor' moderately to highly susceptible. 'Newburgh' is somewhat resistant, and 'Ratham', 'Boyne', 'Killarney', and 'Nordic' are considered to be fairly resistant.

Verticillium Wilt

Red raspberries are more tolerant than black raspberries. 'Cuthbert' and 'Syracuse' appear to be resistant under field conditions. Black raspberries are highly susceptible. Blackberries are susceptible, but the disease is seldom a serious problem.

Orange Rust

Red raspberries are immune. Other brambles are susceptible. Of blackberries, 'Eldorado', 'Raven', 'Snyder', and 'Ebony King' are reported to be resistant. The Arkansas erect types (Arkansas Indian series) are reported to be resistant to orange rust.

Virus Diseases

Mosaic Virus

Blackberries are resistant. Black and purple raspberries are more severely affected than red raspberries. Of the purple or black raspberries, 'New Logan', 'Bristol', and 'Black Hawk' are tolerant and 'Cumberland' is susceptible. The red raspberries 'Milton', 'September', 'Canby', and 'Indian Summer' are resistant because the aphid vectors of the virus avoid them.

Leaf Curl Virus

Blackberries are symptomless. All raspberries are susceptible.

Tomato Ringspot Virus

Red raspberries and blackberries are susceptible.

Raspberry Streak

Black and purple raspberries are susceptible.

Cultural Practices for Disease Control in Brambles

The use of any practice that reduces or eliminates pathogen populations or creates an environment within the planting that is less conducive to disease development must be used. Cultural practices are the major means of control for several important bramble diseases. The following practices should be carefully considered and implemented whenever possible in the disease management program.

Use Virus-Indexed Planting Stock

Always start the planting with "Healthy" virus-indexed nursery stock from a reputable nursery. The importance of establishing plantings with virus-indexed nursery stock

cannot be overemphasized, since the selection of planting stock and planting site are the only actions a grower can take to prevent or delay the introduction of most virus diseases. Plants obtained from an unknown source or neighbor may be contaminated with a number of pathogens that experienced nurserymen work hard to control.

Site Selection

Proper site selection is critical to developing a successful disease management program. Establishing a planting on a site that is conducive to disease development is a critical error. Such plantings may be doomed to failure, regardless of the amount of pesticide a grower uses. The following considerations should play a major role in the disease management program.

Soil drainage - Soil drainage (both surface and internal drainage) is an *extremely important* consideration when selecting a planting site. Planting brambles on poorly or even marginally drained sites is a poor management decision. For example, poorly drained soils that are frequently saturated with water are highly conducive to the development of Phytophthora root rot, *especially in red raspberries*. Even in the absence of plant disease, wet soils are not conducive to good plant growth and productivity.

Any practice such as tiling, ditching, or planting on ridges that aids in removing excessive water from the root zone will increase the efficacy of the disease management program. Once the planting is established, it is difficult, if not impossible to improve soil drainage.

Site Exposure (Air Circulation and Sunlight Exposure) - Avoid sites that do not have full exposure to sunlight, such as shaded areas near woods or buildings. In addition, sites with poor air circulation that tend to accumulate still, damp air should be avoided. Planting rows in the direction of the prevailing winds will help promote good air circulation and rapid plant drying.

The primary reason for the above considerations is to *promote faster drying of canes, foliage, and fruit*. Most plant pathogenic fungi and bacteria require water on plant surfaces in order to penetrate and infect the plant. Any practice that reduces wetness duration (speeds drying time) of susceptible plant parts is beneficial to the disease management program.

Previous Cropping History - Avoid establishing plantings on sites that have a previous history of problems with Verticillium wilt, either in previous plantings of brambles or other susceptible crops. In general, it is not a good practice to plant brambles immediately after solanaceous or other Verticillium-susceptible crops, such as tomatoes, potatoes, peppers, eggplant, melons, strawberries and other related crops. Certain common weeds, such as black nightshade, redroot pigweed, lamb's-quarters, and horsenettle will also support growth of the Verticillium fungus, and fields with a high population of these weeds should also be avoided. This is particularly important if Verticillium wilt is known to have been a problem on the site in the past. The fungus that causes Verticillium wilt

can survive in soil for very long periods of time (at least 14 years in California). If a site is known to have had a problem with Verticillium wilt within the last 5 to 10 years it should probably not be used for establishing plantings of Verticillium-susceptible bramble cultivars unless the soil is fumigated before planting.

Most brambles are susceptible to Verticillium wilt and when the disease becomes established within the planting, it can be devastating. Resistance to Verticillium wilt in the cultivars currently grown in the Midwest is not available. In general, black raspberries are significantly more susceptible than red raspberries, and (in general) blackberries are the least susceptible.

If the site has a previous history of Phytophthora root rot, either in previous bramble plantings or other perennial fruit crops, it should probably be avoided. Phytophthora spp. (like Verticillium) can also survive in soil for extended periods of time. It is important to remember that Phytophthora root rot is usually associated with poorly drained (wet) sites and improving soil drainage is one of the principal means of control.

If nematodes have been a problem in previous crops or they are suspected to be a problem on the site, a soil analysis to determine the presence of harmful nematodes should be conducted. Nematodes are most likely to be a problem on the lighter (sandy) soils. Nematode sampling kits and instructions on taking samples can be obtained through your Extension office. Infested sites may be treated with an approved nematicide before planting if sampling indicates a need to do so.

Proximity (closeness) to established bramble plantings and wild bramble plants -

Ideally, a new planting should be isolated as far as possible from old established plantings or wild bramble plants that serve as reservoirs for diseases and other pests. The benefits of using virus-indexed plants to establish a new field are greatly reduced if the fence row around the planting or a woods directly adjacent to the planting contains wild, virus-infected or orange rust-infected plants. The same is true if a new planting is established next to an old planting that has disease problems.

Currently no information is available on exactly how far away from an established planting or weeded area is "Far enough". The distance of 600 to 1000 feet is used commonly in Extension literature; similarly, the New York State virus certification program requires that nurseries in the program use a minimum distance of 1,000 ft. It is probably safe to say "The farther the better".

Crop Rotation (Replanting Brambles)

When replanting brambles on the same site, the practice of crop rotation must be considered. Due to the build up and persistence of soilborne plant pathogens, replanting brambles on the same site is not recommended without the use of crop rotation. Soil fumigation is not an option in organic production systems.

At present, data describing how long a rotation is required before replanting brambles on the same site is not available. In fact, this requirement is probably different for every different planting site. Once again, the safest recommendation is probably "the longer, the better", particularly if the site has a history of soilborne diseases.

All soilborne diseases, however, are not the same. For instance, Verticillium wilt generally becomes a problem only after populations of the Verticillium fungus slowly build up to high levels. Thus, if no brambles or other susceptible crops are grown for a suitable period (probably at least 5 years), the fungus population declines and brambles can be reintroduced and grown for a number of years before the population builds back up to damaging levels. This same principle is true for many harmful nematodes, but it is not true for Phytophthora root rot. The Phytophthora fungi reproduce very rapidly under proper environmental conditions, so even a low population can rebuild to damaging levels within one or two seasons.

Crop rotation will not eliminate all problems associated with soilborne diseases. It should always be integrated with other control measures, such as the choice of resistant or partially-resistant cultivars, improvements in drainage, etc. Where other control measures cannot be used (for instance, the site cannot be adequately drained), it is not advisable to replant brambles.

Avoid Excessive Fertilization

Fertility should be based on soil and foliar analysis. The use of excessive fertilizer, especially nitrogen, should be avoided. Sufficient fertility is essential for producing a crop, but excessive nitrogen can result in dense foliage that increases drying time in the plant canopy, i.e., it stays wet longer. Research has shown that excessive use of nitrogen can result in increased levels of Botrytis fruit rot (gray mold).

Control Weeds In and Around the Planting

Good weed control within and between the rows is essential. From a disease-control standpoint, weeds in the planting prevent air circulation and result in fruit and foliage staying wet for longer periods. For this reason, most diseases caused by fungi are generally more serious in plantings with poor weed control than in those with good weed control. Furthermore, some disease-causing organisms (Verticillium wilt fungus, crumbly berry virus) can build up on certain broadleaf weeds in the planting. Any practice that opens up the canopy in order to increase air circulation and reduce drying time of fruit, foliage and young canes is generally beneficial to disease control. Controlling wild brambles (which are weeds) near the planting is also important because they can serve as a reservoir for several important diseases and insect pests.

Sanitation (Removal of Overwintering Inoculum)

The fungi that cause anthracnose, cane blight, spur blight, Botrytis fruit rot, cane and leaf rust and several other important diseases overwinter within the planting on canes infected

during the previous year. Pruning out all **old fruited** canes and any diseased new canes (primocanes) immediately after harvest and removing them from the planting breaks the disease cycle and greatly reduces the inoculum. All infected pruning waste should be removed from the field and destroyed. If you are attempting to minimize fungicide use, good sanitation (removing old fruited canes) is critical. If old fruited canes cannot be removed before winter, they should *definitely* be removed before new growth starts in the spring.

For fall bearing raspberries, such as Heritage, all canes are cut off each year. Removing all cut canes from the planting will aid the disease management program. If it is impossible to remove pruned canes from the field, they should be chopped in place as quickly as possible with a flail mower to speed decomposition before new canes emerge.

Plant population and canopy management

Any practice that alters the density of the plant canopy and increases air circulation and exposure to sunlight is generally beneficial to disease control. Optimizing between-row and within-row spacings and maintaining interplant spacings through judicious cane thinning throughout the life of the planting is desirable. Ideally, rows for red raspberries should not be over 2 feet wide and should contain about 3 or 4 canes per square foot. Control of plant vigor, particularly through avoidance of high levels of nitrogen and careful use of cane vigor control techniques, can greatly aid in improving the canopy density. Specialized trellis designs for various *Rubus* spp. can further improve air circulation and increase exposure to sunlight, as well as increase harvest efficiency. Trickle irrigation, as opposed to overhead sprinkler irrigation, greatly reduces the wetting of foliage and fruit and the risk of splash dispersal of several important fungal pathogens.

Removing young fruiting shoots (before they exceed 4 inches in length) from the lower portions of canes (approximately the lower 20 inches) will remove fruit that might become soiled. This practice also removes shoots that disproportionately contribute to shading and poor air circulation in the canopy.

For information on methods for cane vigor control, trellis designs and optimum spacing requirements, the following book is very useful: *Bramble Production Guide*, edited by Marvin Pritts and David Handley. It can be purchased from: Northeast Regional Agricultural Engineering Service, 152 Riley-Robb Hall, Cooperative Extension, Ithaca, NY 14853. Phone: 607-255-7654.

Inspect the Planting Frequently and Rogue Out (Remove) Diseased Plants

Plants showing symptoms of virus diseases, rosette, or orange rust must be removed and destroyed immediately, including the roots, whenever they are found. These plants may bear fruit, but it will be of poor quality. The longer these plants remain, the greater the chances that other plants will become infected. Viruses and the orange rust fungus are systemic and can move to adjacent plants via root grafts. Because of this possibility, use a

flag to mark the locations where diseased plants are removed so the adjacent plants can be checked frequently for new symptoms.

For **orange rust**, it is particularly important to inspect the planting early in the growing season. The planting should also be inspected on a routine basis (at least once a week) from the time growth starts in the spring through harvest. New leaves of early spring growth on orange rust infected plants are chlorotic (yellowish), shoots are bunched and spindly. They are easy to identify in the spring. It is important that infected plants be identified and removed prior to the development of the "Orange rust" pustules on the leaves. If these pustules are allowed to develop, they will produce large numbers of aeciospores which will spread the disease. If infected plants are not removed early in the spring, they become more difficult to identify later in the growing season.

Early spring is also a good time to inspect for virus diseases. Symptom expression of many viruses is more obvious during cool growing conditions. The higher temperatures of mid-to late summer often reduce virus symptoms making infected plants difficult, if not impossible, to detect.

Adjust Production Practices to Prevent Plant Injury and Infection

Many plant pathogens take advantage of wounds in order to penetrate and infect the plant. Therefore, any practice that minimizes unnecessary physical damage to the plant is beneficial to the disease management program. Cane blight and bacterial crown gall are two important pathogens of brambles that enter the plant almost exclusively through wounds. The use of sharp pruning tools will help minimize damage to canes during pruning operations. Prune only when necessary (avoid cosmetic pruning of primocanes) and avoid pruning during periods when plants are wet or immediately before wet weather is forecast. Most plant pathogens require water on the surface of plant tissues before they can penetrate the plant. Providing proper cane support through trellising or otherwise tying the canes will aid greatly in avoiding abrasions from sharp spines and wind whipping of plants during windy conditions. Proper spacing between rows and the use of the proper size equipment will also prevent plant damage.

Proper Harvest, Handling and Storage of Fruit

Proper harvesting and storage methods are critical components of the disease management program. It is of little value to produce high-quality fruit in the field if it is bruised or crushed during harvest or permitted to rot during storage. Raspberry and blackberry fruit are *very perishable*. Even under the "Best conditions" these tender fruits are extremely susceptible to physical damage and post harvest rots. The following practices need to be considered well in advance of initiating the harvest. The proper implementation of these practices will aid greatly in providing your customers with the best quality fruit possible.

a) Handle all fruit carefully throughout all phases of harvest, transport and sale. Bruised or crushed (leaky) fruit are much more susceptible to fungal infection and rot than firm, intact fruit.

b) Harvest all fruits as soon as they are ripe. During periods of warm weather, harvest may require picking intervals as short as 36 to 48 hours. Pick early in the day before the heat of the afternoon. Overripe fruit in the planting will attract a number of insect pests and provide a source for inoculum buildup of fruit rotting fungi.

c) It is highly desirable to combine harvesting and packing into one operation. This prevents unnecessary handling and additional physical injuries.

d) If possible, train pickers to remove damaged or diseased berries from the field. Some growers have programs where they pay the picker as much, or more, for damaged berries picked into separate containers, than for healthy berries. This is a good sanitation practice that reduces inoculum levels of fruit rotting-fungi in the field. Providing hand-washing facilities in the field so pickers can periodically clean their hands, should be helpful in reducing the movement of fungus spores that are encountered by touching rotten (diseased) berries.

e) Pick into shallow containers. Ideally, fruit should be no more than 3 to 4 berries deep; this greatly reduces bruising and crushing the fruit, which results in juice leakage that encourages the development of fungal fruit rots.

f) Refrigerate fruit immediately after harvest. Fruit should be cooled as close to 32°F as possible within a few hours after harvest. This temperature should be maintained throughout storage and, if possible, throughout shipment and sale. If you do not have refrigeration, fruit should be placed in the coolest place possible. Never allow the fruit to sit in the sun.

g) Avoid condensation of water on fruit after it is removed from cold storage. This is best accomplished by enclosing it in a waterproof over-wrap before it leaves the refrigerated area. The over-wrap should be kept in place until the fruit temperature has risen past the dew point.

h) Sell the fruit immediately ("Move it or lose it"). Many berries produced in the Midwest are sold to pick-your-own customers or directly at farm markets, and are not refrigerated prior to sale. Customers should be encouraged ("educated" to handle, refrigerate, and consume or process the fruit immediately in order to assure the highest quality possible. We must remember that even under the best conditions, raspberry and blackberry fruits are very perishable.

Bramble disease control strategies

Disease control considerations	Viruses ^a	Verticillium wilt	Orange rust	Cane blights ^b	Powdery mildew	Fruit rot
Good air/water drainage	-	-	-	++	+	++
500+ ft from wild brambles	++	-	-	-	-	-
Rotation	+ ^c	++ ^d	-	-	-	-
Cultivar tolerance or resistance	++ ^e	++ ^f	++ ^g	-	+	-
Avoid adjacent plantings	++ ^j	-	++	-	+	-
Eliminate wild brambles	++	-	++	-	+	-
Disease-free stock	++	++	++	++	+	-
Aphid control (vectors)	++	-	-	-	-	-
Rogue infected plants	++	-	++	-	-	-
Speed drying (weeds, pruning)		-	++	++	-	++
Prune 3 days before rain	-	-	-	++	-	-
Dispose of diseased pruned canes	-	+	+	++	-	-
Maintain plant vigor	-	-	-	++	-	-
Fungicide sprays	-	-	++	++ ^h	++ ⁱ	-
Harvest before overripe	-	-	-	-	-	++
Fruit storage conditions	-	-	-	-	-	++

Key: ++= most important controls; += helpful controls; -= no effect.

^a Viruses: Mosaic (rasp.), Leaf Curl (raspberry, with blackberry symptomless), Ringspot (red raspberry), and Streak (purple and black raspberry).

^b Cane blights: anthracnose, cane blight, spur blight, and Botrytis blight.

^c Rotation effective for ringspot virus only; 2 years of grass crop (e.g. corn) with excellent weed control before planting red raspberry should eliminate need to fumigate for *Xiphinema*, a nematode vector.

^d Rotation for *Verticillium* wilt: Avoid fields planted to susceptible crops (tomatoes, potatoes, eggplant, peppers, strawberries, raspberries, stone fruit) within the past 5 years. Avoid fields with history of *Verticillium* wilt unless soil is fumigated.

^e Virus resistance, tolerance, and immunity: Mosaic-Blackberries are not affected; black and purple raspberries are more severely affected than red raspberries. Of purple and black raspberries, "New Logan", "Bristol", and "Black Hawk" are tolerant; "Cumberland" is susceptible. Of red raspberries, "Milton",

"September", "Canby", and "Indian Summer" are Resistant because aphid vectors avoid them. Leaf Curl-Blackberries are symptomless; all raspberries are affected. Tomato Ringspot-Red raspberries are affected. Streak - Black and purple raspberries are affected.

^f Verticillium tolerance: Most blackberries are resistant; red raspberries are more tolerant than black raspberries. "Cuthbert" and "Syracuse" red raspberries appear to be resistant under field conditions.

^g Orange Rust resistance: Red raspberries are immune. Other brambles are affected. Of blackberries, "Eldorado", "Raven", "Snyder", "Ebony King", "Choctaw", "Commanche", "Cherokee", and "Cheyenne" are reported resistant.

^h Fungicide program for cane blights: The lime-sulfur spray (delayed dormant) is most important for anthracnose and cane blight.

ⁱ Fungicide program for powdery mildew: Sulfur will provide good control of powdery mildew.

^j Keep blacks and purples away from reds because mosaic virus can spread from reds and is more severe on blacks and purples; Keep all reds away from blackberries because blackberries can be a symptomless carrier of leaf curl

Fungicide use strategies for organic production

Unfortunately, there are not many options to choose from when one considers current fungicide use strategies. The current options are:

1. Do Not Use Fungicides

This is always an option, but may not be a wise decision for commercial grape plantings in the Midwest. This option should not be confused with "organic" production. Grape growers in "organic" production systems will most probably use Sulfur or Copper to some extent for disease control. Sulfur and Copper are fungicides. Growers that choose not to use fungicides must rely completely on cultural practices, disease resistance, or biological control agents or products for disease control. For strawberries, caneberries and blueberries organic fungicides are often of little value against the more common diseases such as Botrytis fruit rot (gray mold); therefore, little or no fungicide will probably be used in organic production of these crops.

2. Protectant Fungicide Program

In a protectant program, fungicides are used as a protective barrier on the plant surface. This chemical barrier prevents the fungus from entering the plant. It works much like paint on a piece of wood to keep out water. Protectant fungicides (such as sulfur and copper) are not systemic and cannot move into plant tissues. Once the fungus penetrates into the plant, protectant fungicides will not control it. As the protective barrier breaks down or new foliage is produced, additional applications are required to maintain the protective barrier.

Protectant fungicide programs have been, and still are very effective; however, they generally result in a fairly intensive use of fungicide. On grapes, protectant fungicides are usually applied on a 7-10 day schedule early in the growing season and on a 10-14 day schedule later in the season. Obviously, maintaining a protective barrier on the plant surface throughout the growing season requires several applications.

The following is a brief description of some disease control materials that are commonly or traditionally used in organic production systems. Copper fungicides, elemental sulfur and liquid lime sulfur are the old “standard” fungicides, and have been used for many years in organic production systems.

Note: Prior to using any material in the organic system, it is important that the grower consult his/her organic certification agency or program to be positive that use of the material is permitted.

Copper Fungicides

When different formulations of copper are dissolved in water, copper ions are released into solution. These copper ions are toxic to fungi and bacteria because of their ability to destroy proteins in plant tissues. However, because copper can kill all types of plant tissues, the use of copper fungicides carries the risk of injuring foliage and fruit of most crops. Factors promoting this injury include: 1) the amount of actual copper applied, and 2) cold, wet weather (slow drying conditions) that apparently increases the availability of copper ions and, thus, increases the risk of plant injury. Because of the potential to injure plants and to accumulate in soil, the use of copper fungicides in conventional production systems has largely been replaced with conventional fungicides that are generally safer to plant tissues and often more effective.

Several terms are used when discussing copper as a fungicide. The original material used was copper sulfate (also known as blue vitriol or bluestone). When this material was combined with lime in the French vineyards, the combination became known as Bordeaux mixture.

Bordeaux Mixture

Bordeaux mixture is a mixture of copper sulfate and hydrated lime in water. It has long residual action and has been used for years to control many diseases, including downy mildew and powdery mildew of grape. It can be made (mixed) on site by combining copper sulfate with spray grade lime. It is also commercially available as a dry wettable powder.

Fixed Copper Fungicides

Following the discovery and use of Bordeaux mixture, several relatively insoluble copper compounds or fixed coppers were developed. Fixed copper formulations release less copper ions and are generally less injurious to plant tissues (safer to use) than Bordeaux mixture, but their use is still limited because of their potential to injure plants and lack of compatibility with other pesticides. Some of the more common commercial formulations of fixed copper include C-O-C-S, Kocide 101, Tribasic Copper sulfate, Champ, and Tenn-Copp 5E. There are several fixed copper fungicides registered for use on small fruit.

Sulfur Fungicides

Sulfur is available as liquid lime sulfur and as dry wettable powders or liquid (flowable) formulations of elemental sulfur.

Liquid Lime Sulfur

Liquid lime sulfur can be used at high concentrations as a dormant spray on raspberries and blackberries for control of cane blight, spur blight and anthracnose and on grapes for control of anthracnose. At high concentrations, it should be used only when plants are dormant. It can cause severe damage if applied after green foliage appears. Lime sulfur has a foul odor that many people dislike. It is also registered for use on grapes and caneberries as a more dilute concentration for use during the growing season.

Dry Wettable Sulfurs or Flowable Sulfurs

Sulfur for use as a fungicide is available under many trade names. The microfine wettable sulfurs or flowable sulfurs are usually much less injurious to foliage and fruit than liquid lime sulfur, but their use during hot weather (above 85°F) may result in some leaf burning and fruit damage. Sulfur fungicides are very effective for control of powdery mildew on most fruit crops, but are not highly effective for control of most other fruit crop diseases. Sulfur is very toxic to foliage of certain grape varieties (mainly American grapes) including Concord, Chancellor, DeChaunac and Foch. Sulfur is relatively safe on most other varieties see Table 6, page 68. Applications after the fruit begins to ripen may pose problems during fermentation if the grapes are intended for wine making.

Growers should note that sulfur is lethal to some beneficial insects, spiders and mites. These beneficial insects are natural predators of harmful insects and mites that affect fruit crops. Killing these beneficial insects may increase certain pest problems, especially mites.

Specific comments on fungicide use will be made in the text for each crop where applicable.

“New Alternative” Disease Control Materials for Small Fruit

Many products are currently available or currently being introduced as “biological control agents” or “biopesticides”. These include living microorganisms, “natural chemicals such as plant extracts, and “plant activators” that induce resistance in plants to disease. For most of these products, independent evaluations are currently being conducted; however, their effectiveness under moderate to high disease pressure is uncertain. Although many of these new products have great potential for use within organic production systems, their effectiveness needs to be determined in field tests. It is important to remember that registration of these materials for control of a specific disease on a crop is no guarantee that they will provide effective control under moderate to heavy disease pressure. In addition, many products may be effective for only one or a few diseases and most have very limited residual activity (they have to be applied often). It is also important to remember that these are registered pesticides and growers need to be certain that their use is permitted within their organic certification program.

The biological control committee of the American Phytopathological Society has developed a web page for “**Commercial Biocontrol Products Available for Use Against Plant Diseases**”. The web page address is: www.oardc.ohiostate.edu/apsbcc/. This web page lists all the products currently available along with information such as registered crops and diseases controlled. It also lists the name of the company that manufactures or distributes the product along with phone numbers and web site addresses. This site is updated regularly and is a valuable resource for growers interested in these products.

The following are a few of the most common “alternative disease control products currently registered for use on small fruit.

- **AC10** (*Ampelomyces quisqualis*) is a biofungicide registered for control of powdery mildew in grapes, strawberries, blueberries, raspberries, currants, and gooseberries. *A. quisqualis* is a fungus, that parasitizes powdery mildew fungi. Preliminary results in grapes in Michigan show moderate disease control. Adding an adjuvant such as Nufilm (0.02% v/v) enhances its efficacy. Application should start as soon as susceptible tissue becomes available and continue on a 7 to 14 day schedule. A minimum of 2 sequential applications if needed to maintain the population of *A. quisqualis*. The following chemicals cannot be tank-mixed with AQ10: sulfur and potassium salts of fatty acids.
- **Armcarb 100** (potassium bicarbonate=baking powder) is a reduced-risk, protectant (contact) fungicide. Armcarb 100 is registered for control of powdery mildew and other diseases in grapes, blueberries, strawberries, and brambles. Preliminary results in grapes in Michigan indicate moderate control of powdery mildew. Start applications at the first sign of disease and continue on a 7-14 day schedule. The preharvest interval (PHI) on all crops is 0 days.
- **Galltrol** (*Agrobacterium radiobacter* strain 84) is a biological control product for control of crown gall, caused by *Agrobacterium tumefaciens* on several tree fruit and nut crops. The active ingredient is the bacterium, *Agrobacterium radiobacter*

- strain 84. On small fruits it is effective for control of crown gall on raspberry and blueberry. It is not effective for controlling crown gall on grapes. It is purchased as a pure culture grown on agar in petri plates. The bacterial mass from one plate is diluted into one gallon of non-chlorinated water and plants are treated with a pre-plant dip in the solution or as a soil drench.
- **Kaligreen** (potassium bicarbonate = baking powder) is a reduced-risk protectant (contact) fungicide. Kaligreen is registered for control of powdery mildew on grapes, strawberry, brambles (raspberry and blackberry) and blueberry. It provides good control of powdery mildew when applied on a frequent-protectant program of 7 to 10-day intervals. It has little or no efficacy against most other fungal diseases on small fruit. It is formulated as a micro-encapsulated powder that is mixed in water and sprayed directly on the crop. Kaligreen has a preharvest interval (PHI) of 1 day on all small fruit crops.
 - **Messenger** (harpin) is a reduced risk product registered for use on grapes, blueberries, cranberries, strawberries, brambles, and currants. The active ingredient is derived from a protein produced by certain bacteria. This protein stimulates natural plant defenses. Messenger has no direct effect on pathogens. The efficacy of this material for disease control or suppression has not been sufficiently confirmed. Messenger has a 0 day PHI.
 - **Mycostop** (*Streptomyces griseoviridis* strain K61) is a biocontrol product registered for use on all fruit crops for control of several important pathogenic fungi that cause seed, root, and stem rot and wilt diseases. The active ingredient is the bacterium, *Streptomyces griseoviridis* strain K61. It is sold as a powder formulation that is mixed with water and applied as a spray or a drench.
 - **Oxidate** (hydrogen dioxide) is a broad-spectrum bactericide/fungicide registered for use in grapes, blueberries, cranberries, strawberries, and brambles. It is a rather corrosive material and works by oxidizing fungal and bacterial cells. The efficacy of the material for disease control has not been sufficiently confirmed on several diseases. In one Ohio fungicide evaluation, it provided no control of grape black rot.
 - **Serenade** (*Bacillus subtilis*) is a biocontrol product registered for control of powdery mildew, Botrytis bunch rot and sour rot in grapes. Serenade is also reported to provide some suppression of downy mildew. This product needs further evaluation, but preliminary results show a moderate level of control of Botrytis bunch rot and powdery mildew. Serenade did not control grape black rot in Ohio. Good coverage is important for control. Applications are recommended on a 7-10 day schedule. Serenade has no maximum seasonal application rate and has a 0 day PHI.
 - **Trichodex** (*Trichoderma harzianum*) is a biofungicide registered for use on all small fruit crops for control of a wide range of diseases, but primarily for control of Botrytis fruit rot. It is sold as a wettable powder formulation that is mixed with water and sprayed directly onto the plants.
 - **Trilogy** (Clarified Hydrophobic Extract of Neem Oil). The label states that Trilogy is a broad spectrum fungicide of certain diseases and controls mites in citrus, deciduous fruits and nuts, vegetable crop, cereal grains and other miscellaneous crops. The label does not state what diseases are controlled on

specific crops. Trilogy is registered for use on grapes, strawberry, brambles (raspberry and blackberry), and blueberry. Trilogy is a liquid that is applied for diseases as a 1% solution in sufficient water to achieve complete coverage of the foliage.

As the efficacy of these new materials is tested and validated, they will be included in these guidelines where appropriate.

Efficacy of Disease Control Materials

for Powdery Mildew

Powdery mildew is different from most other plant diseases caused by fungi, because the fungus that causes it lives almost entirely on the surface of infected plant parts. The fungus may penetrate only one cell layer deep into the plant. Thus, it is exposed to eradication following topical treatment with a range of products that do not affect many other pathogenic fungi that colonize deeper into infected plant tissues. Research in New York and other locations has demonstrated that many new and “alternative materials can provide effective control of powdery mildew if applied often enough (7 day schedule) through the growing season. These

materials burn out the fungus growing on the surface, but do not provide protection against new infections; thus, repeated applications are important. These materials include: Nutrol (manopotassium phosphate); Kaligreen and Armicarb (potassium bicarbonate-baking soda); oils such as Stylet Oil and Trilogy; and dilute solutions of hydrogen peroxide (Oxidate).

Unfortunately, these materials have little or no effect on many other small fruit diseases. In addition, organic growers need to consult with their certification agency or program to be sure that any material they use is “certified” or acceptable as organic.

Organic Fungicides for Bramble Disease Control

Liquid Lime Sulfur

Lime sulfur is recommended for use on brambles as a delayed-dormant application in early spring (when buds show 1/4 inch green). It is used at the rate of 10-20 gal per acre. If applied at this rate later in the season (after 1/4 inch green) it can cause severe damage to leaves and young canes. Lime sulfur is recommended for control of the cane infecting fungi (anthracnose, cane blight and spur blight). The delayed dormant application in spring is intended to eliminate or reduce the overwintering inoculum for these diseases on canes. Where cane diseases are a problem, this spray is very important. Where good sanitation is used, (old fruited and

infected canes are removed from the field) and cane diseases are not a problem, the need for this spray may not be necessary, or at least it would probably be safe to use the lower rate, especially on red raspberries.

Lime sulfur has a bad smell (rotten eggs) so there can be a problem spraying it around your neighbors. Some growers have received complaints from neighbors after applying lime sulfur. In addition, lime sulfur is very caustic. It is harmful to machine parts, paint (especially on cars) and sprayers. Special care should be taken to avoid drift to nontarget objects and proper protective clothing should be worn by the applicator.

Copper Fungicides

If a dormant application of fungicide is required, and lime sulfur cannot be used, Bordeaux mixture or a fixed copper fungicide can be used in its place. Although lime sulfur is the proven material, dormant sprays of copper should provide some level of control. The use of copper in the growing season (after leaves are present), could result in significant plant damage.

Sulfur

Sulfur is available as a wettable powder or in flowable formulations. Sulfur is registered for control of powdery mildew. Sulfur has little or no activity against the other bramble diseases caused by fungi. Because powdery mildew is generally not a serious problem in the Midwest, sulfur is of little importance within the bramble disease management program.

There are several biocontrol products available for control of Botrytis fruit rot. Their efficacy under moderate to severe disease pressure needs to be determined.