



Figure 29. Anthracnose lesion on strawberry fruit.

Midwest when abnormally high temperatures and rainfall occur during fruit set and harvest. Spores are dispersed primarily by water splash. Once the disease is established in the field, the fungus can overwinter on infected plant debris, primarily old-infected, mummified fruit.

Plant Parasitic Nematodes

Plant parasitic nematodes are microscopic round worms and are common in soils throughout the Midwest. Lesion and root-knot nematodes are probably the most destructive kinds in Midwestern plantings. These organisms restrict root growth by feeding directly on roots. This makes plants less efficient at taking up water and minerals from the soil. Nematodes can also cause strawberry roots to be more susceptible to root-rotting fungi. Strawberry plantings in nematode infested soils are not long-lived. Production will decline rapidly after one or two seasons. Nematode damage is most common and most severe in replant situations, because preceding crops increase nematode numbers, and high populations of these parasites may be present when the young plants are set. Under these conditions, strawberries never develop strong root systems.

Symptoms

Strawberry plants infested with nematodes are stunted and show symptoms of mineral deficiencies and water stress, particularly as the berries form. Because nematodes are unevenly distributed in the field, damaged plants tend to occur in patches. Heavily infested plantings decline rapidly.

Root-knot nematodes cause the formation of knots or galls on fine roots. Heavy galling may cause abundant adventitious root formation and lead to a “whiskery root” condition. Other types do not form such distinct root symptoms. Infested roots are not well developed. Lateral roots may be few. Roots attacked by lesion nematodes are dark in color.

Causal Organisms

The lesion nematode (*Pratylenchus penetrans*) and the northern root-knot nematode (*Meloidogyne hapla*) are common in the Midwest. The dagger nematode (*Xiphinema americanum*) is frequently found. The dagger nematode is the vector of tomato ring-spot virus, which it can acquire from common weed hosts, such as dandelion. Ring nematodes (*Criconebella* spp.) and lance nematodes (*Hoplolaimus* spp.) are also found in soils in the Midwest. Their effect on strawberries is not known.

Use of Disease-Resistant Cultivars

In the integrated disease management program, the use of cultivars with disease resistance must be emphasized. Many commercial cultivars have resistance and/or tolerance to leaf spot, leaf scorch, red stele, verticillium wilt, and powdery mildew. The more disease resistance within the program, the better. Table 2-1 (on page 27) lists ratings for disease resistance in several of the more commonly grown cultivars. This type of information is available from a number of sources. Most nurseries should be able to provide information on disease resistance for the cultivars they sell.

Cultural Practices for Disease Control in Strawberry

The use of any practice that provides an environment within the planting that is less conducive to disease development and spread should be used. The practices described here should be carefully considered and implemented in the disease-management program.

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Table 2-1. Disease Resistance of Several Strawberry Cultivars Commonly Grown in the Midwest.

Cultivar	Season	Disease Resistance ^a				Comments
		Verticillium Wilt	Red Stele	Leaf Diseases ^b	Powdery Mildew	
June Bearing						
Earliglow	Early	R	R	R	PR	Standard for early cultivars; berry size medium. Excellent flavor, but only moderately productive.
Veestar	Early	T	S	T	PR	Early, productive. Has performed well in southeastern Pa., with medium bright berries. Fruit shows some <i>Botrytis</i> resistance.
Annapolis	Early	I	R	S	S	Fruit medium-large, firm, and glossy with good flavor. Plants runner freely. Fairly susceptible to <i>Botrytis</i> .
Noreaster	Early	R	R	I	S	Very large, early, and firm fruit with aromatic flavor and aroma. King berries slightly rough. Well adapted to heavy soils.
Mohawk	Early	R	R	PR	T	Medium-sized fruit, comparable to Earliglow. Good flavor. Tolerant of <i>Botrytis</i> . Has been very variable, as two lines of plant material exist. Plant only small quantities.
Avalon	Early	R	R	T	R	Large berry with good color and flavor; average productivity and vigor. Has performed well in southeastern Pa. For trial only.
Sable	Early	U	R	PR	S	Veestar x Cavendish cross. Productive, well suited to U-pick operations. Available in small quantities. For trial only. Produces dense beds; <i>Botrytis</i> control may require more effort than usual.
Evangeline	Early	U	S	U	R	Medium yields of conical, firm berries. Flavor good if fully ripe. Berries produced on stiff, upright stalks. May not runner well. For trial only. Limited quantities available.
Honeoye	Early-mid	S	S	PR	T	Large fruit, productive; has performed well in Pa., but lack of red stele resistance is a concern. Tends to become soft in hot weather. Flavor distinctive, “perfumy.”
Cavendish	Early-mid	I	R	PR	S	Very large firm fruit with good flavor. Very productive (yields 85% of Kent) and moderately vigorous. Tends to ripen unevenly in certain years.

^a I = intermediate, PR = partially resistant, R = resistant, S = susceptible, T = tolerant, U = unknown.

^b Includes leafscorch and leaf spot.



Table 2-1 (continued). Disease Resistance of Several Strawberry Cultivars Commonly Grown in the Midwest.

Cultivar	Season	Disease Resistance ^a				Comments
		Verticillium Wilt	Red Stele	Leaf Diseases ^b	Powdery Mildew	
June Bearing (continued)						
Brunswick	Early-mid	U	R	U	U	Good size and flavor. May perform better in cooler locations. Susceptible to Phytophthora crown rot. For trial.
Raritan	Mid	S	S	S	S	Widely planted cultivar in spite of disease susceptibility; first fruits are large, but size decreases more rapidly than most cultivars. Very flavorful.
Guardian	Mid	R	R	R	S	Very productive, firm, large fruit, sometimes rough (uneven) looking. <i>Botrytis</i> is generally more prevalent. Tends to get a “long neck,” which breaks down and allows easy entry for slugs and sap beetles. Susceptible to Sinbar injury.
Redchief	Mid	PR	R	R	R	Productive, with good color and size. Flavor average. Excellent disease resistance.
Lester	Mid	S	R	R	U	Productive, good-sized berry. Flavor is good, though size tends to “run down” quickly. Fruit is fairly susceptible to <i>Botrytis</i> .
Kent	Mid	S	S	S	T	Extremely productive berry with large firm fruit. Tends to yield fruit in middle of rows, resulting in high rot, so keep rows narrow. Flavor average. Susceptible to Sinbar injury.
Settler	Mid	T	U	T	S	Large, attractive, moderately firm fruit. Very susceptible to Sinbar injury. In Pa., for trial only.
DelMarvel	Mid	R	R	R	U	Very vigorous plants, with high production; large, firm, aromatic fruit. In Pa., for trial only.
Primetime	Mid	R	R	R	U	Medium-firm berry with mild, lightly aromatic flavor. Good <i>Botrytis</i> resistance. In Pa., for trial only.
Mira	Mid	U	R	S	R	Glossy, medium-red, tart berries. High yielding in areas north of Pa. Good winter hardiness. Vigorous plants. In Pa., for trial only.
Eros	Mid	S	R	U	U	‘Allstar’ hybrid from England, with darker fruit color than ‘Allstar.’ Large fruit, well-balanced flavor. Available in small quantities. For trial only.



Table 2-1 (continued). Disease Resistance of Several Strawberry Cultivars Commonly Grown in the Midwest.

Cultivar	Season	Disease Resistance ^a				Comments
		Verticillium Wilt	Red Stele	Leaf Diseases ^b	Powdery Mildew	
June Bearing (continued)						
Darselect	Mid	U	U	T	U	Attractive fruit with good color and quality. Vigorous. Available in small quantities for trial.
Jewel	Mid-late	S	S	PR	R	Large soft fruit; can be very dark. Tends to soften in hot weather. Very productive, though dense foliage can encourage <i>Botrytis</i> .
Allstar	Mid-late	R-T	R	T	T	Productive, elongated, flavorful berries. Lighter color than most berries. Good fruit size. Has become the standard mid-season berry in Pa., in spite of light color. Has potential for the annual system on plastic mulch. Susceptible to angular leaf spot.
Seneca	Mid-late	S	S	U	U	Round, large, medium-red, exceptionally firm fruit with firm skin. Plant is vigorous. Flavor mediocre, but firmness of fruit may be useful for shipping market. Has potential for the annual system on plastic mulch.
Lateglow	Mid-late	R	R	T	T	Productive; good size and flavor. First berries extremely large, though size “runs down” over season. Extremely vigorous plant and needs to be controlled.
Latestar	Mid-late	R	R	R	U	Mild flavor, but variable yields and small fruit size. Vigorous plants. Flowers and ripens a few days later than ‘Allstar.’ In Pa., for trial only. Susceptible to gray mold.
Winona	Mid-late	T	R	R	U	Large, firm conical fruit with bright red-orange color and good flavor. Released from Minnesota. May be marginal quality when warm. In Pa., for trial only.
Mesabi	Mid-late	R	R	R	R	Large, dark-red fruit with good flavor. Winter hardy. Skin tends to become weak in warm weather.
Cabot	Mid-late	U	R	T	U	Huge berries, averaging 20 to 30 g over season. Berries rough-looking with firm flesh and tender skin. Available in small quantities. Greatest value may be as a novelty berry. Doesn't runner well. For trial only.



Table 2-1 (continued). Disease Resistance of Several Strawberry Cultivars Commonly Grown in the Midwest.

Cultivar	Season	Disease Resistance ^a				Comments
		Verticillium Wilt	Red Stele	Leaf Diseases ^b	Powdery Mildew	
June Bearing (continued)						
Delite	Late	R	R	R	U	Large berries, very resistant to disease, average flavor.
Sparkle	Late	S	R	S	S	Flavorful, high-quality, attractive but soft fruit. Tends to grow very thickly. Size decreases rapidly during harvest season.
Day Neutral						
Tribute		PR	R	T	R	Slightly later than 'Tristar,' with larger fruit. Flavor not as strong, and plants are more vigorous.
Tristar		R	R	T	R	Bears an early crop; smaller than 'Tribute;' flavor is excellent. Flesh and skin firm. Moderate vigor. Size reduced when weather is too hot.
Everest		U	U	U	U	An alternative for growers who wish to try a day-neutral other than 'Tribute' or 'Tristar.' Recommended for small quantity trials only.
Plasticulture System						
Sweet Charlie	Early	U	U	U	U	Good flavor and size. Yields lower than for 'Chandler' but produces crop for early market. Tends to break dormancy and flower during warm spells in late winter and early spring.
Chandler	Mid	U	S	S	S	Standard berry for this production system. Large, firm berries. Flavor is sweet if allowed to ripen fully and not over-fertilized with nitrogen.
Camarosa	Mid	U	U	S	S	Large, firm berries. Productive and vigorous in warmer climates. Flavor fair. Cool fall temperatures may negatively affect flower bud initiation.
Marmolada	Mid	R	U	U	U	Requires high nitrogen rates for high yields. Large, glossy, bright red fruit with red flesh. Flavor fair. In Pa., for trial only.
^a I = intermediate, PR = partially resistant, R = resistant, S = susceptible, T = tolerant, U = unknown. ^b Includes leafscorch and leaf spot.						
Used with permission from the <i>Commercial Berry Production and Pest Management Guide, 2002-2004</i> , The Pennsylvania State University.						



Use Disease-Free Planting Stock

Always start the planting with healthy, virus-indexed plants obtained from a reputable nursery. Remember that disease-free plants are not necessarily disease resistant — cultivar selection determines disease resistance.

Select the Site Carefully

Soil Drainage (*Extremely Important*)

Select a planting site with good water drainage. Avoid low, poorly-drained wet areas. Good water drainage (both surface and internal drainage) is especially important for control of leather rot and red stele. Both of these diseases require free water (saturated soil) in order to develop. If there are low areas in the field that have a tendency to remain wet, this is the first place that red stele will develop. Under Midwestern growing conditions, any time there is standing water in the field, plants are subject to leather rot infection. Any site in which water tends to remain standing is, at best, only marginally suited for strawberry production and should be avoided.

Any practice, such as tiling, ditching, or planting on ridges or raised beds, that aids in removing excessive water from the root zone will be beneficial to the disease-management program.

Previous Cropping History

Select a site that does not have a history of Verticillium wilt in any crop. Select a site that does not have a history of red stele or black root rot. To minimize the risk of black root rot, do not replant strawberries immediately after removing an old strawberry planting. In general, it is also not a good practice (due primarily to *Verticillium*) to plant strawberries immediately after solanaceous or other *Verticillium*-susceptible crops. These include tomatoes, potatoes, peppers, eggplant, melons, okra, mint, brambles, chrysanthemums, roses, or related crops. If possible, select sites that have not been planted to any of these crops for at least three to five years. There should be no herbicide residual in the soil from previous crops.

Site Exposure

A site with good air circulation that is fully exposed to direct sunlight should be selected. Avoid shaded areas. Good air movement and sunlight exposure are

important to aid in drying fruit and foliage after a rain or irrigation. Any practice that promotes faster drying of fruit or foliage will aid in the control of many different diseases.

Crop Rotation

First Planting of Strawberry — If the land has no recent (five years or less) history of strawberry production or Verticillium diseases in other crops, soil-borne diseases such as red stele or Verticillium wilt should not be a problem.

Replanting Strawberries, Crop Rotation, and Soil Fumigation — If strawberries are to be replanted in the same field, crop rotation must be used or the field should be fumigated. Fumigation is currently not an option in organic production systems. With rotation, the site should be plowed, worked down, and planted to a crop that is not susceptible to Verticillium wilt for a minimum of two years. Many soil-borne pathogens form specialized survival structures and are capable of surviving for several years in soil, even when strawberries are not present. The longer the site can be rotated away from strawberries prior to replanting, the better.

The combination of crop rotation plus soil fumigation is a sound approach that is used by many conventional growers. However, for organic growers (who cannot use soil fumigation), crop rotation alone often provides acceptable control for most soil-borne diseases, if the rotation is sufficiently long.

Neither crop rotation nor soil fumigation will reliably provide adequate control of red stele. With red stele, disease-resistant cultivars and improved soil drainage must be emphasized. Cultivars with resistance to red stele and Verticillium wilt should always be used.

Fertility

Fertility should be based on soil and foliar analysis. Soil should be analyzed and nutrient levels adjusted before planting. The use of excess fertilizer, especially nitrogen, should be avoided. Sufficient fertility is essential to produce a crop, but excess nitrogen results in dense foliage that increases drying time in the planting (stays wet longer) and also results in softer berries that are more susceptible to fruit rots. Avoid the application of nitrogen in the spring prior to harvest on medium to heavy soils. Excessive use of nitrogen has been shown to increase the level of Botrytis fruit rot (gray mold).



Weed Control

Good weed control is essential to successful strawberry production. From the disease control standpoint, weeds in the planting prevent air circulation and result in fruit and foliage staying wet for longer periods. Gray mold, in particular, is a much more serious problem in plantings with poor weed control compared to plantings with good weed control.

In addition, weeds will reduce production through direct competition for light, nutrients, and moisture with strawberry plants and will make the planting less attractive to pick-your-own customers, especially if you have thistles!

Mulch

Research and grower experience has shown that a good layer of straw mulch is very beneficial for controlling fruit rots, especially leather rot. Bare soil between the rows should be avoided and a good layer of straw mulch is highly recommended. The mulch keeps berries from contacting the soil where the leather rot fungus overwinters. In addition, it also aids in preventing infested soil from splashing onto the berries. Recent research has shown that plastic mulch (a layer of plastic) under the plants and/or between the rows increases splash dispersal of the pathogens that cause anthracnose and leather rot.

Sanitation

Any practice that removes old leaves and other plant debris from the planting is beneficial in reducing the amount of *Botrytis inoculum*. Leaf removal at renovation is highly recommended.

Irrigation Practices

The application of supplemental water should be timed so that the foliage and fruit will dry as rapidly as possible. For example, irrigating early in the day is better than in the evening. If diseases, such as gray mold, leather rot, anthracnose, or bacterial blight, become established in the planting, overhead irrigation should be minimized or avoided.

Control Movement of People and Machinery

Movement of people (pickers) and machinery from a field or area that is infested to a clean or uninfested

field should be avoided. Diseases of primary concern are anthracnose, leather rot, and angular leaf spot (bacterial blight). Diseases such as these are usually spread over relatively short distances by splash dispersal (rain or irrigation). Movement from one field to another field through the air (wind-blown spores) is generally not a problem with these diseases. However, pickers moving from a field where the disease is present to a non-infested field can transport fungal spores or bacteria very efficiently on shoes, hands, and clothing. If people or machinery are used in fields where these diseases are a problem, they should complete work in non-infested fields before moving to infested fields.

In addition, any machinery that moves soil from one field to another can introduce soil-borne diseases, such as red stele, *Verticillium* wilt, leather rot, and nematodes, from infested into non-infested fields.

Harvesting Procedures

- Pick fruit frequently and early in the day before the heat of the afternoon (preferably as soon as plants are dry). Picking berries as soon as they are ripe is critical. Overripe berries will cause nothing but problems during and after harvest.
- Handle berries with care during harvest to avoid bruising. Bruised and damaged berries are extremely susceptible to rot.
- Train pickers to recognize and avoid berries that have disease symptoms of gray mold and leather rot. If at all possible, have pickers put these berries in a separate container and remove them from the field.

Post-Harvest Handling

- Always handle fruit with care during movement from the field to market to avoid any form of damage.
- Get the berries out of the sun as soon as possible.
- Refrigerate berries immediately to 35 to 40°F in order to slow the development of gray mold (*Botrytis*) and other fruit rots.
- Market the berries as fast as possible. Encourage your customers to handle, refrigerate, and consume or process the fruit immediately. Remember that even under the best conditions, strawberries are very perishable.

