Irrigated Alfalfa Management
for Mediterranean and Desert Zones

Alfalfa Diseases and Management

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Chapter 10

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Diseases can cause major yield reduction in alfalfa and reduce the feeding value of the forage. Leaves, stems, roots, and crown can be affected (Table 10.1). Often the influence of diseases goes unrecognized, particularly root diseases, as symptoms can be subtle or mistaken for something other than disease, and pathogens can be hard to detect. Pathogens that cause alfalfa diseases include fungi, bacteria, viruses, and nematodes. Abiotic diseases, which are not caused by infectious pathogens but instead by environmental factors such as extreme temperatures or mineral deficiencies, are mentioned at the end of this chapter. Nematodes are discussed in detail in Chapter 11, "Parasitic Nematodes in Alfalfa." Refer to the UC IPM Guidelines online (http://ipm.ucdavis.edu) for the latest information on disease control for alfalfa.

For a plant disease to develop, the variety must be susceptible to the pathogen, the pathogen must be present, and environmental conditions must favor disease development. Temperature and moisture are the environmental factors that most frequently determine if a disease will occur once the susceptible host and the pathogen are present.

TABLE 10.1

Common diseases of alfalfa

Symptom	Disease	Pathogen	Environmental Conditions Favoring Disease	Comments
Seedlings fail to emerge, die after emergence, or are very weak	Pre- or post-emergence damping-off	Several species of fungi, including species of *Pythium, Rhizoctonia,* and *Phytophthora*	Cold temperatures that slow down seedling growth; excess soil moisture	Fungicide seed treatments reduce risk
Brown leaf spots	common leaf spot	*Pseudopeziza medicaginis*	Moderate temperatures (60º–75ºF [15º–24ºC]); dew or rain	Look for apothecia in leaf spot
Mottled yellow blotches on leaf	downy mildew	*Peronospora trifoliorum*	Humidity at or near 100%; temperatures in the 60sºF, 15–21ºC	Look for fungal growth on the underside of leaves in the morning
Small black to brown spots on stems, petioles, and leaves	spring blackstem	*Phoma medicaginis*	Favored by moderate temperatures (mid 60s–70sºF, 15–21ºC) and moisture	
Leaf spot with diffuse brown border	Stagonospora leaf spot	*Stagonospora meliloti*	Cool and moist; fall–spring	Look for pycnidia in the center of the leaf spot; can also infect crowns and roots
Leaf spot with definite dark border and tan center	Stemphylium leaf spot	*Stemphylium botryosum*	Cool temperatures (60º–70ºF [15º–21ºC]) and moisture	
Reddish brown leaf spots	rust	*Uromyces striatus* var. *medicaginis*	Cool and moist; spring	Uncommon; leaf spots filled with reddish brown spores
Scattered dead, light-colored stems	Anthracnose	*Colletotrichum trifolii*	Warm	Mostly found in late spring and summer; can also infect crowns and roots
Plants wilting; tan to black lesions where lateral roots emerge; main tap root rotted	Phytophthora root and crown rot	*Phytophthora megasperma*	Saturated soil; more common under moderate temperatures but occasionally under high temperatures	Can be confused with scald when occurs with high temperatures
Plants wilting; white mycelium at base of plant	Sclerotinia stem and crown rot	*Sclerotinia* spp.	High humidity; foggy; cool	Look for sclerotia
Low vigor or dying plants; cracked bark on crowns or roots; red flecks in diseased tissue	Stagonospora crown and root rot	*Stagonospora meliloti*	Can be found year-round	Red flecking in diseased tissue is characteristic
Tan elliptical lesions in tap root where lateral roots emerge	Rhizoctonia root canker, crown and stem rot	*Rhizoctonia solani*	High soil temperatures; high soil moisture	Found mainly in Palo Verde, Coachella, and Imperial Valleys; in winter the root lesions are black and inactive
Yellow-green foliage; stunted growth	bacterial wilt	*Clavibacter michiganensis* subsp. *insidiosum*		Uncommon due to resistant varieties; cross section of infected root has yellowish tan center; brown pockets inside bark are sometimes evident
Wilting shoots; bleached color leaves and stems	Fusarium wilt	*Fusarium oxysporum* (f.) sp. *medicaginis*	High soil temperatures	Reddish streaks in inner portion of root
Yellow leaf tips, often in V-shaped pattern; stem with petioles but leaves have fallen, stem remains stiff and green until all leaves dead	Verticillium wilt	*Verticillium albo-atrum*		Has been found in Mojave Desert and a few coastal areas; use resistant varieties in areas where disease occurs
Low vigor, dying plants, crown with dry rot and dark black internally at the base of stems	Anthracnose crown rot	*Colletotrichum trifolii*	Warm weather and moisture by rain or irrigation	Also infects stems resulting in dead bleached stems in the crop canopy

Control of Alfalfa Diseases

Few fungicides are registered on alfalfa in the United States. The economics of pesticide registration and alfalfa production has not been conducive to the use of pesticides for disease control in alfalfa, with the exception of seed treatments. Variety tolerance or resistance is the primary tool for managing many alfalfa diseases, making variety selection a very important component for successful alfalfa production. The National Alfalfa Alliance produces an annual publication that is available under "Variety Leaflet" online at http://www.alfalfa.org. It lists commercial varieties and their resistance level for bacterial, Fusarium, and Verticillium wilts; anthracnose; and Phytophthora root rot. For many "minor" diseases, differences in varietal susceptibility exist, but they are not well documented and the information is not readily available. For a discussion on alfalfa resistance to pests, refer to Chapter 5, "Choosing an Alfalfa Variety."

In addition to variety selection, the integration of other strategies, such as irrigation management, planting methods, promotion of crop vigor, manipulation of cutting schedules, canopy management, and crop rotation, also plays an important role in disease management. Each of these techniques will be discussed in relationship to specific diseases.

Seedling Diseases or Damping-off

Causal Organisms and Symptoms

Seedling death, before or soon after emergence, is referred to as damping-off. Several soilborne fungi, including *Pythium* spp., *Rhizoctonia* spp., and *Phytophthora* spp., cause damping-off of alfalfa wherever alfalfa is grown. Excessive soil moisture, compacted or poorly drained soils, and temperatures unfavorable for seedling growth favor damping-off. The end result is a poor stand of plants that are low in vigor. Damping-off can be devastating to the long-term productivity of a new alfalfa seeding.

Seeds destroyed before germination are discolored and soft. After germination, symptoms include brown necrotic lesions along any point on the young seedling, including lesions that girdle the root or stem, leading to plant death (Color Plate 10.1 at the end of this chapter). Some infected plants escape death but are nevertheless weakened as a result of being partially girdled or having a reduced root system. These plants may be stunted and chlorotic to varying degrees. As seedlings grow older, pathogenic fungi can destroy only the outer layer of cells around the stem. A dark, constricted area near the soil surface identifies this type of injury. The magnitude of the discolored area is dependent upon the age of the seedling, as well as the duration of environmental conditions favorable for disease development. As alfalfa seedlings continue to grow, root-tip necrosis may continue to develop, but the risk of plant death from post-emergence damping-off decreases rapidly.

Pythium ultimum (Trow) and *P. irregulare* (Buisman) cause both pre- and post-emergence damping-off of alfalfa in California. *Pythium violae* (Chester & Hickman) incites root-tip necrosis and inhibition of lateral root formation. *Rhizoctonia solani* (Kuhn) may kill seedlings prior to emergence but usually causes post-emergence necrosis of the stem at or near the soil surface, with a distinct margin between infected and healthy tissue. *Phytophthora megasperma* (f.) sp. *medicaginis* (Kuan & Erwin), another common soilborne pathogen, can be particularly devastating in poorly drained soils (see "Phytophthora Root and Crown Rot").

Pythium spp. survive in soil as sporangia, hyphal swellings, and thick-walled oospores (see "Glossary" for definition of plant pathology terms). These structures are stimulated to germinate by nutrients that occur in seed and root exudates. In some species, secondary infections may occur from zoospores released from sporangia. Zoospores are motile and swim short distances in water films in soil or move greater distances in surface water. Damping-off caused by *Pythium* spp. usually occurs in fields with poor drainage under cool soil temperatures; however, *P. aphanerdamatum* ([Edson] Fitzp.)

is more likely to infect plants under warm soil conditions.

Rhizoctonia solani survives between crops as sclerotia in soil and as mycelia in infested plant debris. It infects host cells directly or through natural openings and wounds. Damage by *R. solani* is often related to the amount of organic matter that remains in the soil from the previous crop, with damage increasing as the level of organic matter increases.

Managing Seedling Diseases

Pythium spp. and *Rhizoctonia* spp. are common in agricultural soils. Both are transported by water, contaminated soil on equipment, and movement of infected plant materials. Both have wide host ranges.

Seedlings are most susceptible to damping-off following seed germination and shortly after emergence. Therefore, disease is more likely when this extremely susceptible period is extended, which may be the result of unfavorable temperatures, excessive moisture, low light, incorrect planting depth, or improper fertilization.

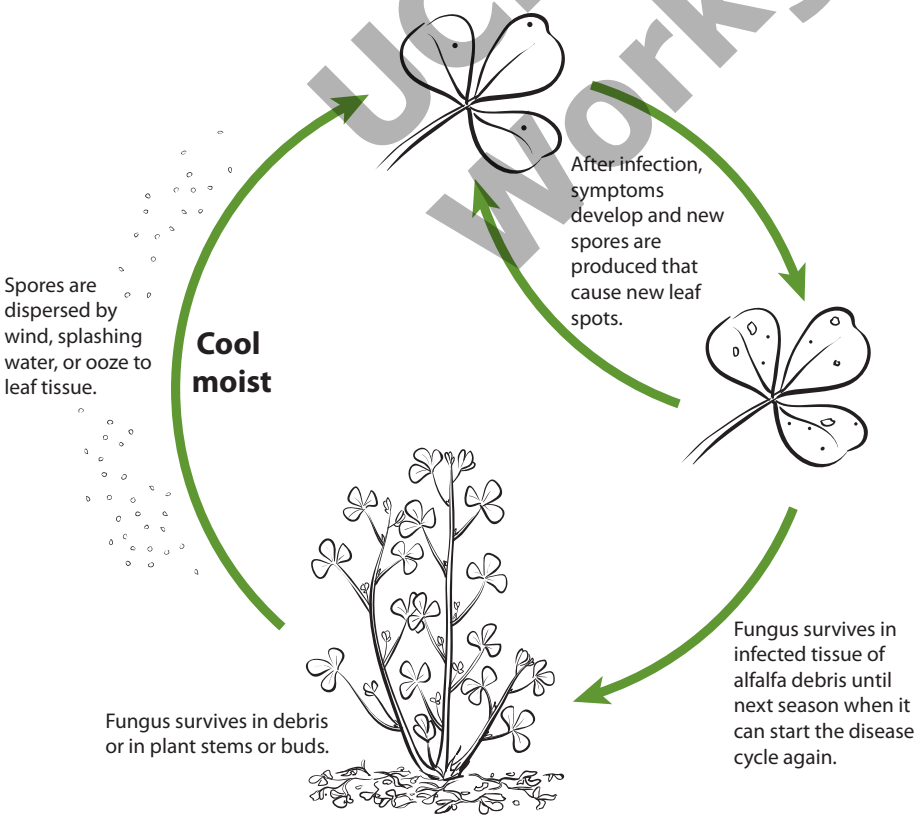
Cultural and chemical measures are generally effective means of controlling damping-off. Planting high-quality seed under environmental conditions favoring rapid germination and seedling growth reduces the chance of infection. Excessive irrigation, compaction, and poor drainage of soils should be avoided. Fungicide seed treatments that are effective against *Rhizoctonia* and *Pythium* are available. Although crop rotations do not eliminate these pathogens because of their wide host ranges, rotations with crops like small grains may help to reduce inoculum levels.

Foliar Diseases

Diseases that cause foliar symptoms can reduce yield and quality by reducing photosynthesis and defoliating plants. Defoliation decreases both yield and quality. Most foliar diseases are favored by leaf wetness and therefore are less of a problem in the relatively dry climates of Mediterranean and desert areas than in climates with high summer humidity and rainfall (Fig. 10.1). However, even in these drier climates, leaf spots occur in spring, winter, and fall following rain, long periods of dew formation, or foggy weather. Irrigation, either by flood or sprinkler, may also favor diseases if not managed properly. Usually only one cutting, or two at most, are affected, but a few leaf spot-causing fungi are capable of invading and killing crowns, resulting in stand loss over time.

FIGURE 10.1

Generalized disease cycle for most leaf spot diseases.



Common Leaf Spot

Common leaf spot, caused by the fungus *Pseudopeziza medicaginis* ([Lib.] Sacc.), usually occurs from winter through early spring. Symptoms include small (1/8 in. [0.3 cm] in diameter), circular, brown to black spots on the upper surface of leaves (Color Plate 10.2). Margins of spots are characteristically toothed or uneven. As the disease progresses, infected leaves turn yellow and drop. In cool, moist weather, the fungus produces circular, raised, brown fruiting bodies, called "apothecia," within the spots. These structures are visible through a hand lens. During cool, moist periods, spores are forcibly discharged into the air from apothecia. Spores that land on alfalfa leaves initiate infection if favorable environmental conditions are present. The fungus survives in undecomposed leaves and leaf debris on the soil surface.

In irrigated fields in California, common leaf spot can cause more leaf loss during curing, raking, and baling than before cutting.

Infected alfalfa should be cut in a timely manner because the severity of the disease increases as the plant continues to grow. Although the disease does not kill plants, defoliation reduces vigor, hay quality, and yield. In irrigated fields in California, common leaf spot can cause more leaf loss during curing, raking, and baling than before cutting. Most growers just live with this disease because information on which varieties are less susceptible is not widely available.

Downy Mildew

Downy mildew, caused by the pathogen *Peronospora trifoliorum* (de Bary), occurs when temperatures are cool and humidity is near 100 percent. Because this fungus requires moisture to form spores and for spores to germinate, this disease occurs only during extended wet periods in California. Little disease occurs when temperatures exceed 65°F (18°C) and humidity is low. The upper surface of infected leaves turns light green, in some cases almost a mottled yellow (Color Plate 10.3a). On the underside of the affected area, bluish gray areas of mycelia, spores (sporangia), and branched, spore-bearing structures (sporangiophores) can be seen through a hand lens (Color Plate 10.3b). These are more often found in the morning when humidity in the canopy is high. Sometimes entire buds and leaves become infected, resulting in systemic infection causing distortion and general yellowing of leaves (Color Plate 10.3c). Spring-planted fields are most likely to be affected because plants are in the seedling stage when weather tends to be most favorable for the disease. Infected leaves may drop from the plant, reducing yield and quality. Mycellium in systemically infected crown buds and shoots and resistant resting spores (oospores) in debris is how the fungus survives summer conditions. This disease rarely results in plant death, and stand survival is usually not affected.

Spring Blackstem

Spring blackstem is caused by the fungus *Phoma medicaginis* (Malbr. & Roum.). Symptoms include small, black to dark brown spots on lower leaves, petioles, and stems that range from irregular to triangular in shape (Color Plate 10.4). As they increase in size, lesions coalesce and become light brown. Affected leaves turn yellow and often wither before falling. Lesions on stems and petioles enlarge and may girdle and blacken large areas near the base of the plant. Young shoots are often killed. Most damage occurs before the first cutting. The fungus also causes crown and root rot.

The pathogen produces brown to black fruiting bodies (pycnidia) on overwintered stem lesions and on fallen leaves. In early spring, spores released from pycnidia are splashed onto foliage and stems by rain or overhead irrigation. In addition, new shoots are infected as they grow through infested crop residue or stubble. The fungus also may be seed-borne.

Control measures include early cutting to reduce leaf loss and planting pathogen-free seed.

Stagonospora Leaf Spot

Spots on leaves and stems caused by the fungus *Stagonospora meliloti* ([Lasch] Petr.) are most commonly found in spring when conditions are moist and cool. Spots are characterized by a brown, diffuse border with a light tan center (Color Plate 10.5). Small, dark fruiting bodies (pycnidia) that appear as black dots develop in the center of the lesion. Leaves with multiple infections often defoliate after pycnidia form. Spores from pycnidia moved by rain or irrigation water germinate and can infect leaves, stems, or crowns. The crown and root rot phase of the disease is discussed under "Root, Stem, and Crown Diseases" in this chapter.

Stemphylium Leaf Spot

A tan center and a dark border around an irregularly shaped lesion (Color Plates 10.6) distinguish this leaf spot disease caused by the fungus *Stemphylium botryosum* (Wallr.). Once the border is formed, the spot does not increase in size. Spores form in the center of the lesion. Cool temperatures (60°–70°F [15.5°–21°C]) and moist weather favor infection and spread. The disease is usually found in first and second cuttings. Because defoliation occurs only under heavy disease pressure, Stemphylium leaf spot is not considered as serious as some other leaf-spot diseases.

A different strain of the fungus that is more active under warm temperatures exists in the midwestern and eastern United States. Spots will not have a dark border and will continue expanding, affecting large portions of leaves.

There are no known control measures available. Early cutting may reduce the incidence of the disease and forestall significant leaf loss in years when the disease is particularly severe. Although there may be some resistant varieties, this is not commonly tested or reported by seed companies.

Rust

Rust, caused by *Uromyces striatus* (Schröt. var. *medicaginis* [Pass.] Arth.), is easily distinguished from other foliar diseases by the masses of reddish brown spores produced from pustules located on both sides of leaves, and on petioles and stems. Heavily infected leaves drop prematurely, reducing yield and quality. The disease is rather rare in Mediterranean and desert climates, and no control measures are used.

Root, Stem, and Crown Diseases

Diseases affecting crowns and roots may lead to plant death, resulting in stand and yield reductions, and therefore in the long run can be more important than leaf diseases, although at times less obvious.

Anthracnose

Anthracnose (also called southern anthracnose), caused by the fungus *Colletotrichum trifolii* (Bain. & Essary), is a common problem in older alfalfa stands. The disease affects leaves, stems, and crowns, but crown rot is the most important phase of the disease. The most obvious symptom of anthracnose in the crown is a dry, bluish black, V-shaped rot (Color Plate 10.7). As the decay spreads down into the root, the color turns tan to brick red. Dead stems associated with such crowns are sometimes bleached white. Because stems die suddenly, dead leaves remain attached to the stem (Color Plate 10.8).

On stems, Anthracnose is identified by small, irregularly shaped blackened areas that become large, oval or diamond-shaped, straw-colored lesions with black borders (Color Plate 10.9). Tiny fruiting bodies (acervuli) containing salmon-colored spores develop in the lesions. As lesions enlarge, they may coalesce, girdling and killing affected stems. In summer and fall, dead, white shoots are scattered throughout the field. The tip of the affected stem is often curled over like a shepherd's crook.

The fungus persists in alfalfa debris and crowns. The disease reaches maximum severity during late summer and early fall, coincident with warm, humid weather. During the growing season, spores on stem lesions are a source of inoculum. Splashing rain and irrigation water disperse spores onto growing stems and petioles. Spores may also be spread by seed contaminated during the threshing process.

Control of anthracnose primarily involves the use of resistant cultivars. In infested fields, alfalfa can be harvested before losses become too severe. Rotation with crops other than clover and alfalfa for 2 years will eliminate sources of inoculum in the field.

Phytophthora Root and Crown Rot

This is one of the most common diseases in alfalfa. Phytophthora root and crown rot commonly occurs in poorly drained or overwatered soils throughout alfalfa growing regions. Primary symptoms include tan to brown lesions on taproots, especially where a lateral root emerges (Color Plate 10.10). Lesions eventually turn black, while the center of the root turns yellow. In the root interior, orange to reddish streaks spread several centimeters from the rotted ends of the roots toward the crown. Occasionally, the disease may spread to the crown from the taproot. If the crown becomes infected, the plant will probably die. Often the lower part of the taproot is completely rotted, and lateral roots become larger than normal. Although these plants may survive, the lateral roots will never grow very deep, limiting the plant's ability to take up water from lower in the soil profile. If infection is limited, the plant may continue growing at a reduced rate but will be more susceptible to other pests and diseases. Root and crown rot can be injurious to seedling stands but is more common in established fields.

Phytophthora root and crown rot is favored by waterlogged soil conditions and is associated with poorly drained fields or parts of fields. The disease commonly occurs at the tail end of flood-irrigated fields where water collects. This disease is typically associated with moderate temperatures (75°–81°F [24°–27°C] for optimum growth), but a high temperature isolate has been reported in the Low Desert production areas of California that has a temperature optimum of 81°–91°F (27°–33°C).

The causal organism *P. megasperma* (f.) sp. *medicaginis* survives in soil as thick-walled oospores or as mycelia in infected plant tissue. It produces thin-walled sporangia that release motile zoospores in the presence of free water. Pre-plant land preparation is critical in controlling this disease—any soil preparation that enables good drainage and prevents standing water will reduce disease occurrence. Appropriate slope and deep tillage to minimize soil compaction will reduce the likelihood that Phytophthora root and crown rot will occur. Reducing the length of flood irrigation runs, shortening irrigation time, leveling land, installing a tailwater ditch to remove excess water, and planting on beds will further reduce the chances of disease occurrence. Installation and maintenance of tile drains may be necessary in some cases. Return water should be used with caution because spores of the pathogen can be carried in recirculated irrigation water.

Appropriate slope and deep tillage to minimize soil compaction will reduce the likelihood that Phytophthora root and crown rot will occur.

Fortunately, there are many cultivars resistant to Phytophthora root rot. They are listed in the National Alfalfa Alliance publication or on their Web site: (http://www.alfalfa.org). Resistant varieties should be used along with sound cultural practices in fields known to have problems with Phytophthora.

Rhizoctonia Root Canker, Crown and Stem Rot

Rhizoctonia root canker and crown rot occur during periods of high temperatures and high soil moisture. The causal fungus, *R. solani*, occurs worldwide. It can cause serious seedling

damping-off; however, in California, most new stands are planted when temperatures are less than ideal for its development. Only certain strains of the fungus can cause the root canker form of the disease. In California, the disease is found mainly in the Palo Verde, Imperial, and Coachella Valleys. Tan, elliptical lesions on the taproot in the areas where lateral roots emerge are distinctive symptoms. In winter, when the fungus is inactive, these sunken lesions will turn black and at that stage appear to be inactive (Color Plate 10.11). If roots are girdled during summer, the plant will die. If disease severity is low to moderate, new roots emerge when temperatures are too cool for the fungus to be active. New infections occur the following summer when conditions are once again favorable. The fungus can also infect the crown at the location where new buds emerge and move into the crown, killing tissue. During cool weather the infection stops, but if significant portions of the crown have been killed, fewer stems will emerge.

No control measures are known. There are currently no resistant varieties for Rhizoctonia root and crown disease of alfalfa.

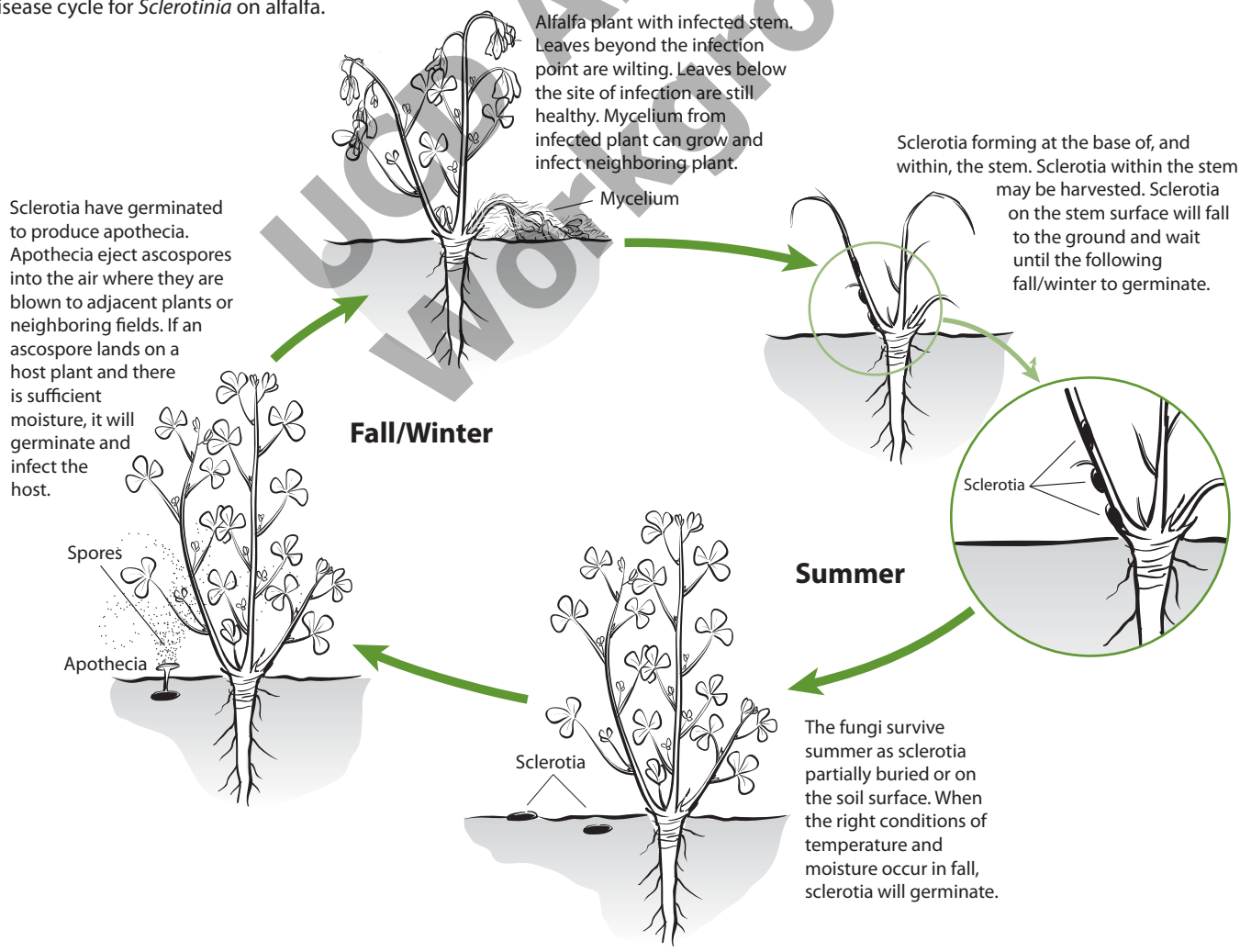
Sclerotinia Stem and Crown Rot

Sclerotinia stem and crown rot, caused by *Sclerotinia trifoliorum* (Eriks.) or *S. sclerotiorum* ([Lib.] de Bary), can cause substantial damage to alfalfa under wet, cool conditions that are common during foggy Central Valley winters. It is not common during dry winters or in desert regions.

This disease is characterized by the presence of white, cottony fungal strands (mycelia) on crowns or stems and by the presence of

FIGURE 10.2

Disease cycle for *Sclerotinia* on alfalfa.



black, hard structures (sclerotia) at the base of crowns and stems, or inside the stems. Sclerotia are round or irregularly shaped (0.1–0.3 in. [2–8 mm] in diameter) (Color Plate 10.12a). When broken open, the interior is white. The disease cycle of both fungal species that cause Sclerotinia stem and root rot of alfalfa is similar (Fig. 10.2). The fungi survive summer as sclerotia partially buried or on the soil surface. In late fall or early winter, once temperatures cool and soils become wet from rain or irrigation, sclerotia germinate and form small (0.25 inch [5 mm] in diameter or less), orange, yellow, or tan mushroom-like structures (apothecia) on the soil surface (Color Plate 10.12b). Apothecia produce millions of spores that are carried by air currents to surrounding plants or fields (Fig 10.3). If conditions are wet and temperatures are low (50°–68°F [10°–20° C]), spores that fall on susceptible alfalfa tissue germinate and infect the plant. If conditions continue to be favorable for disease development, white, cottony mycelial growth will form on stems and around the crown and spread to nearby plants (Color Plate 10.12c).

This disease causes stem death and, if the crown is infected, the plant might die. If plants are young, weakened by other factors, or if conditions are extremely favorable for disease development over a prolonged period, substantial stand loss may occur. However, in established, healthy alfalfa, plants often survive even when all stems of a plant are killed. Healthy stems will be produced the following spring.

There is no effective genetic-based resistance incorporated into nondormant commercial varieties at this time. For established fields, the best strategy is to remove as much foliage before winter as possible by mowing or grazing. This, along with good weed control, opens the canopy, allowing air movement and sunshine around the bases of plants, thereby reducing the humidity and moisture required by the fungus to initiate and maintain infections.

In wet or foggy winters, this disease can be serious on seedling stands planted the previous September or October. By December, there is dense growth that promotes humidity in and around plants. Weeds such as chickweed

FIGURE 10.3

Ascospores being discharged from apothecia of Sclerotinia sclerotiorum.

(*Stellaria media* [L.] Vill.) further increase the chances of disease development by adding to the humidity within the canopy.

Research has shown that burning back seedling growth with herbicides, especially once the disease has started, is not very effective in reducing Sclerotinia disease. Deep plowing of fields before planting will prevent germination of most sclerotia that may be present in the field. However, neighboring alfalfa fields or weed hosts can be the source of new infections. Fungicide trials show promising results, but no fungicides have been registered for use on alfalfa in California.

Although plantings in early February in the San Joaquin Valley are likely to escape this disease, there are other disadvantages of planting at that time of the year, such as increased risk of damping-off, slow early growth, and reduced yields in the first year. Growers who plant in September and October find that the benefit of early planting usually outweighs the

risk of Sclerotinia and they continue that practice despite potential damage to seedling fields from this disease.

Stagonospora Crown and Root Rot

Crown and root rot caused by the fungus *S. meliloti* is widespread in the Mediterranean and desert zones of California and is one of the primary reasons for early stand decline. Plant vigor decreases because of the slow death of the crown tissue that is caused by this disease. Symptoms include rough and cracked bark tissue on infected roots and crowns. The presence of red flecks in diseased root tissue is a distinctive diagnostic symptom (Color Plate 10.13). Fine, red streaks also occur in the xylem (the water-conducting tissue) in the center of the root, below rotted portions of the crown. Affected crown tissue is generally firm and dry, unless secondary organisms invade the tissue. Foliar symptoms caused by this pathogen when it infects stems and leaves are discussed under "Foliar Diseases."

Spores of *S. meliloti* form in very small, dark brown, round or pear-shaped structures (pycnidia) and are spread by water that splashes from infected leaves, stems, or plant debris. The fungus enters the crown through stems and grows slowly downward into the taproot. Although infection can take 6 months to 2 years to kill a plant, and aboveground symptoms may be overlooked, the disease reduces plant vigor and yield. Crown infections can occur throughout the year but the disease is most damaging when alfalfa is not actively growing.

To minimize the effects of Stagonospora crown and root rot, it is important to provide optimum growing conditions for the alfalfa crop.

To minimize the effects of Stagonospora crown and root rot, it is important to provide optimum growing conditions for the alfalfa crop. Rotating out of alfalfa for 2 years eliminates sources of inoculum within a field.

Wilt Diseases

Wilt diseases are characterized by the pathogen invading the vascular system (water- and sugar-conducting tissues) of plants, leading to the plant wilting and usually dying. Often, the surface of the root displays no obvious disease symptoms.

Bacterial Wilt

Bacterial wilt, caused by the bacterium *Clavibacter michiganensis* subsp. *insidiosus* ([McCulloch] Davis et al.), occurs in most areas of California but is rarely seen today due to the development of wilt-resistant cultivars. Bacterial wilt was the first disease for which resistant cultivars were developed, and few alfalfa varieties are released today without at least some level of bacterial wilt resistance.

Disease symptoms rarely appear before the second or third year of a stand, which may be another reason why this disease is not considered to be that serious in the southern San Joaquin Valley and desert valleys, where stands usually are removed after 3 to 4 years. Aboveground symptoms include yellow-green foliage and stunted growth (Color Plate 10.14). Leaflets may be mottled and slightly cupped or curled upward. Stems on affected plants may be thin and weak. Disease symptoms are most evident in regrowth after harvest. A cross section of an infected taproot reveals a yellowish tan color in the center. Brown pockets on the inside of bark tissue are sometimes evident. Once infected, plants do not usually recover. Within 5 to 8 months after showing symptoms, plants frequently die. Infected plants are prone to winter kill if a freeze occurs.

The bacterium survives in plant residue in soil and enters plants through wounds in the roots and crown or through the cut ends of freshly mowed stems. Disease severity and incidence increase when root-knot nematodes are present in soil (see Chapter 11, "Parasitic Nematodes in Alfalfa"). The bacterium can survive in dry plant tissue or seed for up to 10 years and can be disseminated over long distances in seed and dry hay. However, the population of the organism in soil declines

quickly when infected plant residue decomposes. The bacterium can be spread by surface water, tillage, and harvesting equipment. The greatest incidence of the disease occurs in poorly drained areas of fields, and large areas can be infected during periods of continuously wet weather.

Resistant cultivars generally keep this disease under control. If bacterial wilt is discovered in a field, that field should be mowed last to prevent the spread of inoculum by the mower to younger stands. Within a field, infested areas should be mowed last and never mowed when the foliage is wet.

Fusarium Wilt

Wilting shoots are the first obvious symptom of Fusarium wilt, caused by the fungus *Fusarium oxysporum* (Schlechtend.:Fr. [f.] sp. *medicaginis* [Weimer] W. C. Snyder & H. N. Hans.). Bleaching of leaf and stem tissues follows, and there may be a reddish tint to the foliage. On roots, dark reddish brown streaks occur internally (Color Plate 10.15). In advanced stages, the entire inner portion of the stem may be discolored. This dark discoloration is in contrast to the yellow-brown discoloration caused by bacterial wilt. Fusarium wilt is favored by high soil temperatures, and while significant in the past, this disease occurs infrequently due to the development of resistant cultivars.

Verticillium Wilt

Verticillium wilt of alfalfa, caused by the fungus *Verticillium albo-atrum* (Reinke and Berth), can be a serious disease in susceptible varieties. Yields have been reduced up to 50 percent by the second year of production. This disease has been found in California's Mojave Desert and in Riverside and San Bernardino Counties in southern California, and in a few coastal areas. It is not known to occur in the Central Valley or the Imperial, Palo Verde, or Coachella Valleys of California. It is much more common in the Intermountain regions of the West, and in the Pacific Northwest and eastern U.S. regions. Symptoms include yellowing of leaf tips, sometimes in a V-shaped pattern. This yellowing should not be confused with that caused by *Empoasca* spp. leafhopper feeding (see Chapter 9, "Managing Insects in Alfalfa"). The edges of some apical leaflets will roll upward. As symptoms progress, leaves become desiccated (Color Plate 10.16) and sometimes develop a reddish hue. The leaves may drop, leaving behind a stiff petiole. The infected stem does not wilt and remains green until all leaves are dead. Xylem tissue in roots turns brown.

Verticillium albo-atrum can be carried internally and externally on alfalfa seed. The fungus also survives in alfalfa hay and in animal manure. It penetrates alfalfa roots directly or through wounds. Spreading within an alfalfa field can also occur through infection of cut stems when swathing. The fungus has been detected on sheep that are trucked from one region to another to graze fields in winter months.

The most practical control measure is to plant resistant varieties. In areas where the disease does not occur, care to prevent importation of infected seed or plant materials is recommended. Verticillium is not considered a serious problem in the Mediterranean or desert regions of California.

Diseases of Limited or Minor Importance

Phymatotrichum Root Rot

Phymatotrichum root rot, also called Phymatotrichopsis root rot, cotton root rot, and Texas root rot, is limited to certain areas in the deserts of Southern California (the Palo Verde Valley, and to a lesser extent, the Imperial and Coachella Valleys) and Texas and Arizona. The causal fungus, *Phymatotrichopsis omnivora* (Duggar) Hennebert (= *Phymatotrichum omnivorum* [Duggar]), has a host range of more than 1,800 plant species.

Extensive research in Arizona and Texas has shown that *P. omnivora* infestation is limited to certain soil types and that the infestation most likely was originally associated

with natural desert flora before the introduction of agriculture.

The disease develops late in spring as soil temperatures rise. The first symptom on alfalfa is a rot of the outer surfaces of the roots, followed by bronzing of leaves and sudden wilting. Plants die quickly when taproots are girdled. A sheath of soil clings to the roots with white to tan mycelial strands on the root surface. The disease appears as somewhat circular spots (fairy rings) within the field (Color Plate 10.17).

Because the causal fungus of Phymatotrichum Root Rot is virtually impossible to eradicate and could affect the value of the land, the disease diagnosis should be confirmed by an expert diagnostician.

The fungus survives many years in soil as sclerotia, as deep as 6 feet (2 m) or more. Sclerotia produce mycelial strands that grow through soil and eventually contact a root. The growth of the fungus is favored by moist soil conditions. The soil temperature range for growth is from 59° to 95°F (15° to 35°C), with an optimum of 82°F (28°C). The fungus is more prevalent in alkaline soils than in acidic soils; calcareous soils with high clay content are particularly favorable for this disease.

Because the causal fungus is virtually impossible to eradicate and could affect the value of the land, the disease diagnosis should be confirmed by an expert diagnostician. Crop rotation with nonsusceptible crops such as corn, sorghum, or onion can help prevent the increase in size of infested areas within a field, but it will not eliminate the infestation. No resistant cultivars are available.

Summer Black Stem and Leaf Spot

Cercospora medicaginis (Ell. & Ev.) is the causal agent of summer blackstem, which has been observed in the Imperial Valley. Defoliation from the base of the stem to the top is the most obvious symptom, but leaf spots usually appear first. Leaf spots are brown at first and surrounded by a wavy margin. As spores on the surface of the spot are produced, the spot appears gray or silvery. A diffuse yellow margin often surrounds the spot, and brown lesions may form on stems. High humidity and temperatures ranging from 75° to 82°F (24° to 28°C) favor disease development. Symptoms usually appear after the alfalfa has grown a dense canopy. Early harvest before extensive defoliation will minimize losses. There are no resistant cultivars.

Crown Wart and Crown Gall

Both crown wart and crown gall, two rare diseases on alfalfa in California, are caused by pathogens that produce galls or swellings on crowns and stems of alfalfa (Color Plate 10.18). Crown wart is caused by the fungus *Physoderma alfalfae* (Pat. & Lagerh.), and alfalfa is the only host. It is usually confined to fields with excessive soil moisture during early spring months. It is rare, but when it occurs it can cause damage. The fungus survives as resting spores that release zoospores under favorable conditions. Zoospores infect crown buds, causing cells to divide and enlarge, forming galls that reach full development in early summer. Resting spores of *P. alfalfae* can be easily seen by examination of tissue with a compound microscope. This differentiates it from bacteria-caused crown gall because bacteria are difficult to see with a compound microscope. Good drainage and avoiding excessive irrigation are the major control measures of crown wart. Alfalfa should not be planted after alfalfa on infested land.

Crown gall is caused by the bacterium *Agrobacterium tumefaciens* (Smith & Townsend), which is pathogenic on many plant species. It rarely occurs in alfalfa but has been found in the low desert climate of the Imperial Valley. The bacteria enter through fresh wounds less than 24 hours old. In reaction to infection, plant cells enlarge and divide to form irregularly shaped galls on crown branches at or just below the soil line. The potential for

yield loss is not fully known because the disease has occurred so rarely.

Alfalfa Dwarf

Alfalfa dwarf was first recognized as an alfalfa disease in Southern California in the 1920s. Infected plants are stunted and exhibit small, bluish green leaves and fine stems (Color Plate 10.19). The size of the taproot is normal, but when sliced the taproot tissue is abnormally yellowish with dark streaks of dead tissue scattered throughout. In newly infected plants, the yellowing is mostly in a ring beginning under the bark. Unlike bacterial wilt, there are no pockets of infection beneath the bark. Eventually, infected plants die.

Dwarf is not recognized as an economic disease of alfalfa. However, the bacterium that causes alfalfa dwarf, *Xylella fastidiosa* (Wells et al.), is the same pathogen that causes Pierce's Disease of grapes, a very important grape disease in California. The role that alfalfa plays in the epidemiology of Pierce's Disease can be important. Increased levels of Pierce's Disease in grapes located adjacent to alfalfa fields containing infected plants have been documented in the San Joaquin Valley. Before the introduction of the glassy-winged sharpshooter (*Homalodisca coagulata* [Say]), the primary vectors of Pierce's Disease in California were several species of sharpshooter leafhoppers. These sharpshooters are primarily grass feeders, found commonly in grassy weeds infesting alfalfa. It is believed that alfalfa in such fields becomes infected almost by accident, when these insects would occasionally probe the alfalfa while searching for hosts. Although glassy-winged sharpshooter is known to feed on alfalfa, it appears that when other hosts are available, alfalfa is not a favored host of this vector. Thus, it is not expected that glassy-winged sharpshooter in alfalfa will play a key role in the epidemiology of alfalfa dwarf or Pierce's Disease.

Viruses

There are no viruses in California known to be of economic importance in alfalfa production. Two viruses, Alfalfa Mosaic Virus (AMV) and Cucumber Mosaic Virus (CMV), are the most common viruses detected in this crop. Symptoms of AMV, consisting of yellow mottling or streaking on leaves (Color Plate 10.20), can be seen at times, but at other times the symptoms are masked and leaves appear normal. CMV shows no symptoms in alfalfa. These and other viruses may be transmitted by aphids that feed on alfalfa and then move to other fields. Thus, alfalfa can serve as a reservoir for viruses important in other crops. For example, AMV can cause problems in tomatoes, peppers, and potatoes. CMV is one of several viruses that cause plant death in garbanzo beans grown in the San Joaquin Valley. It is also an important pathogen of cucurbits such as squash, melons, and pumpkins. Currently, however, there is no information documenting how significant a role alfalfa plays in the epidemiology of these viruses in other crops.

Abiotic Disease-like Symptoms

Frost and Freeze Injury

In general, alfalfa tolerates the cold weather usually associated with Central Valley and desert area winters in California. However, occasional frosts can turn exposed leaves, especially those at the top of plants, brown. Some varieties are more affected than others, and tall, uncut alfalfa tends to be affected more than short alfalfa. There can be injury if newly planted alfalfa is just emerging and only a few unifoliolate (single) leaves have developed during a cold spell (less than 26°F [-3°C]). Injury results in discolored, weak plants, and death usually results. Once plants have a few trifoliolate leaves, they are more capable of tolerating low temperatures experienced in the Central Valley and desert valleys.

Scald or High Temperature Flooding Injury

Scald is a hazard in hot regions of Mediterranean and desert zones, especially when alfalfa is grown on heavy soils. It is an abiotic malady caused by the combination of high soil temperatures and water-saturated soil over an extended length of time. Death is due to lack of oxygen to roots. Scald is usually limited to hot desert valleys (Imperial and Palo Verde Valleys) when soil is saturated for long periods after irrigation or rainfall. However, scald has been observed in the San Joaquin and Sacramento Valleys during hot weather. Affected plants may die within 3 to 4 days after irrigation.

Symptoms include off-color (whitish or tan) foliage and wilting, even though the soil is wet (Color Plate 10.21). Roots may rot and have a putrid odor when removed from the soil. The water-conducting tissue (xylem) of affected roots becomes brown and necrotic. Fields that have been recently mowed are much more susceptible to scald than fields closer to harvest.

When air temperatures exceed 104°–113°F (40°–45°C), alfalfa is extremely susceptible to flooding injury. Lack of sufficient soil aeration at high temperatures is probably the main factor, with poor tailwater management being a key trigger on heavy soils.

Irrigating for relatively short periods (e.g., 4 hrs) or at night during periods of high daytime temperatures reduces the likelihood of scald.

The primary control measure is proper water management. Irrigating for relatively short periods (e.g., 4 hrs) or at night during periods of high daytime temperatures reduces the likelihood of scald. Some soils, however, remain saturated long after irrigation because of heavy clay soil, poor drainage, slope of the land, and length of the irrigation run. Irrigations should be avoided when temperatures are excessively high, over 109°F (43°C). Newly mowed plants should not be irrigated until enough regrowth occurs to prevent submersion of entire plants; thus a 3–6 day delay after cutting may be recommended.

Scald is often confused with Phytophthora root rot because both require saturated soil conditions. If temperatures (at the soil surface) have not exceeded 100°F (38°C), it is probably not scald.

Air Pollution

Air pollutants cause crop injury, such as reduced photosynthetic rates and early senescence, which adversely affect crop yield and quality. Many air pollutants (e.g., ammonia, chlorine, hydrogen chloride, hydrogen fluoride, or sulfur dioxide) are capable of causing plant damage, but only the photochemical oxidants (ozone and peroxyacetyl nitrate [PAN]) are of major concern. Both are formed by the reactions of oxygen, oxides of nitrogen, and organic molecules in the presence of sunlight. The primary source of these precursor molecules is automobile exhaust, but industrial processes and other forms of combustion contribute to air pollution.

High levels of ozone cause a bleached stippling on upper leaf surfaces and isolated necrotic spots distributed between the veins of injured leaves (Color Plate 10.22). Symptoms usually appear on middle-aged and older leaves. Affected leaves may senesce and fall. High concentrations of ozone are associated with low wind velocities and bright sunlight.

PAN injury begins with the absorption of gas through the plant stomates (pores in the leaves) and the collapse of adjacent mesophyll cells. The collapsed tissues produce air pockets between the lower epidermis and the palisade cells. Refraction of light through these air pockets is apparently responsible for the silvery or glazed appearance on the undersurface of the leaf. Symptoms on alfalfa leaves resemble those described for ozone injuries, but the lesions may be larger. In addition, a silver or copper sheen is frequently apparent on affected leaves. PAN injury is generally limited to certain urban areas where the combination of dense vehicular traffic and steep topography traps the pollutants.

Nutrient Deficiencies and Herbicide Injury

Symptoms of nutrient deficiencies, herbicide injuries, and insect feeding can sometimes be confused with diseases. General stunting, yellowing, and leaf distortion can be due to disease, nutrient deficiency (e.g., low levels of phosphorus), herbicide injury or insects. Nutrient deficiencies are described in Chapter 6, "Alfalfa Fertilization Strategies," herbicide injuries are described in Chapter 8, "Weed Management in Alfalfa," and insect feeding symptoms are discussed in Chapter 9, "Managing Insects in Alfalfa."

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Glossary of Plant Pathology Terms

Abiotic: not living, a disease that is caused by something that is not living and not infectious.

Acervulus (*pl.* acervuli): a fruiting body produced by some species of fungi and that is usually at least partially embedded in plant tissue.

Apothecium (*pl.* apothecia): a fruiting body of one group of fungi (Ascomycetes) that generally contains spores that are ejected.

Fruiting body: in fungi, a structure in which or on which spores are produced. Examples are apothecia and pycnidia.

Hypha (*pl.* hyphae): microscopic, threadlike vegetative growth of fungi.

Inoculum: the pathogen or part of the pathogen that infects a plant. For most fungus-caused diseases, spores are the inoculum.

Mycelium (*pl.* mycelia): refers to numerous hypae growing close together, usually visible to the unaided eye.

Oospore (*pl.* oospores): a thick-walled, microscopic, resting/survival spore produced by the Oomycete group of organisms.

Pycnidium (*pl.* pycnidia): a type of dark, fungal fruiting body that is embedded in leaves or stems and which can also act as a survival structure. Spores from pycnidia usually need free water to allow for them to ooze out of the fruiting body.

Sclerotium (*pl.* sclerotia): a resting or survival structure produced by some fungi species that is usually dark and often visible with the unaided eye.

Sporangium (*pl.* sporangia): microscopic spores that may germinate directly or contain more spores within them, produced by some fungus species.

Survival structure: a form of a pathogen that can withstand environmental conditions that are unfavorable for the pathogen's survival. They can be composed of special vegetative structures, fruiting bodies, or spores, depending on the species of fungus. Examples are sclerotia, pycnidia, and oospores.

Zoospore (*pl.* zoospores): a type of spore produced by some fungus species that has one or more flagella and therefore can actively move through water. Mostly found in Oomycetes, such as some *Pythium* and *Phythophthora* species.

Color Plates

PLATE 10.1

Damping-off. The seedling on the far left is healthy while those in the center show various stages of damping-off. Note lesions on roots of the seedling second from the left and the pruned root system of the seedling third from the left. The seedling on the far right has recovered from root pruning caused by damping-off organisms.

PLATE 10.2

Common leaf spot. Infected leaves with small circular black or brown spots of common leaf spot. Note the raised fruiting bodies in the center of the lesions. Severely infected leaves usually fall from the plant.

PLATES 10.3

Downy mildew. (A) Leaves infected with downy mildew show a blotchy yellow pattern on the upper surface. (B) On the lower surface the fungus appears as a gray, furry mass. (C) Systemic infection by the downy mildew fungus results in distortion of all leaves from the infected growing point.

PLATE 10.4

Spring blackstem. Black lesions on leaf and petiole due to spring black stem. Note that there are no raised fruiting bodies in the center of these lesions unlike those associated with common leaf spot.

PLATE 10.5

Stagonospora leaf lesions. Leaf lesions of Stagonospora leaf spot are easily visible symptoms of this disease. The lesions are generally associated with the leaf margin and are irregular in shape.

PLATES 10.6

Stemphylium leaf spot. (A) Leaves infected with Stemphylium leaf spot exhibit irregular shaped brown or tan spots on the upper surface of the leaves. (B) Upon close inspection, mature lesions are tan in color with a dark border. They can be distinguished from common leaf spot by their irregular shape and lack of fruiting bodies and from spring black stem by their color and shape.

PLATE 10.7

Anthracnose crown rot. Alfalfa crown with Anthracnose crown rot showing the dark v-shaped rotted area.

PLATE 10.8

Anthracnose crown and stem rot. Flagged stem due to infection with anthracnose caused by *Colletotrichum trifolii*.

PLATE 10.9

Anthracnose stem lesion. Anthracnose lesion on stem with dark border. Fresh lesions contain spores in a salmon-colored matrix.

PLATE 10.10

Phytophthora root rot. Lesions of Phytophthora root rot on alfalfa roots. Note the dark discolorations and the large lateral roots which are compensating for the lost taproot.

PLATE 10.11

Rhizoctonia root rot. Rhizoctonia root lesions are yellow to tan during the growing season but turn black in winter.

PLATES 10.12

Sclerotinia stem and crown rot. (A) Black, pebble-like sclerotium which formed inside an infected stem. Sclerotia also form externally at the base of infected stems. (B) Apothecium of *Sclerotinia* sp., growing from buried sclerotium, usually found after soil temperatures have cooled and rain or irrigation have occurred. (C) Mycelium of Sclerotinia.

PLATE 10.13

Stagonospora crown rot. Red and orange speckles scattered through a longitudinal section of the crown are the most distinctive symptom of Stagonospora crown and root rot.

PLATE 10.14

Bacterial wilt. The small, yellowish plant on the right is infected with bacterial wilt. This disease is seldom seen today thanks to resistant varieties.

PLATE 10.15

Fusarium wilt. A root infected with Fusarium wilt shows a brownish to reddish discoloration in the center.

PLATE 10.16

Verticillium wilt. Foliar symptoms of verticillium wilt are similar to those caused by gopher feeding. However, the stems of plants infected with the disease do not wilt and usually retain their green color. Near the top of shoots, the stems between the leaves (internodes) are short, and the plant cannot be pulled out of the ground easily.

PLATE 10.17

Phymatotrichum root rot. This disease, which is limited to certain desert soil types of the southwestern U.S., usually starts as somewhat circular spots in which plants have suddenly wilted and died. Diagnosis should be confirmed by an expert.

PLATE 10.18

Crown wart. Distinctive symptom of crown wart is growth of galls on crown.

PLATE 10.19

Alfalfa dwarf. The small, stunted plant on the right is infected with alfalfa dwarf caused by the bacterium, *Xylella fastidiosa*, which is transmitted by sharp-shooter leafhoppers.

PLATE 10.20

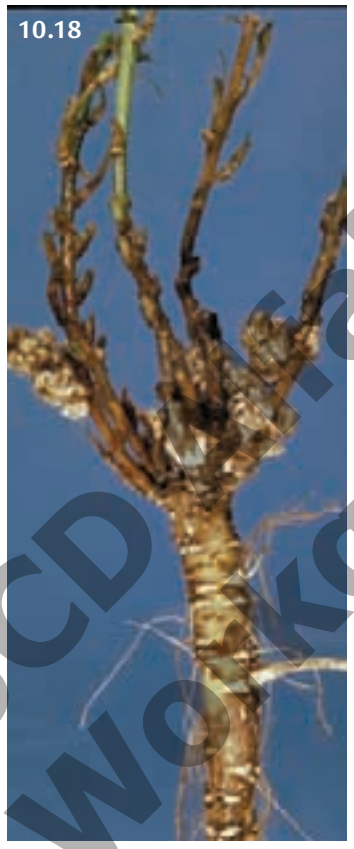
Alfalfa mosaic. Alfalfa mosaic virus shows a bright yellow mottling on the leaves and is transmitted by several species of aphids.

PLATE 10.21

Scald and flooding injury. Alfalfa in the foreground has been killed by a combination of high temperatures and water logged soil due to flooding. Note that plants on the levees, above the flooding, have survived.

PLATE 10.22

Ozone injury. Alfalfa leaves damaged by ozone show bleached areas between the veins. PAN damage is similar.



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