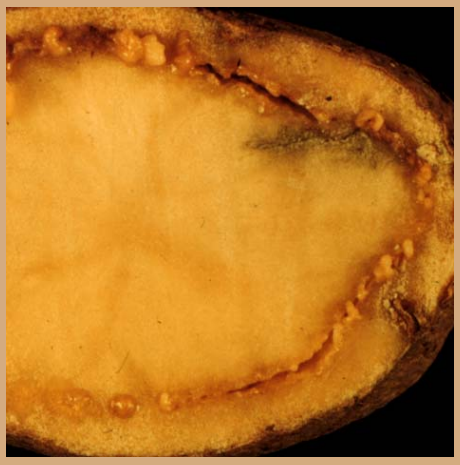
I D E N T I F Y I N G

POTATO DISEASES

IN PENNSYLVANIA



PENNSTATE

1855

College of Agricultural Sciences

Contents

Late Blight

Causal Organism
Phytophthora infestans (Mont.) De Bary (fungus)

Affects
foliage and tubers

Symptoms

Foliage

Symptoms of late blight appear as small light- to dark-green water-soaked spots, often with a chlorotic halo (Fig. 1). Lesions enlarge rapidly and turn brown or purplish black. The lesions are not limited by veins, and they coalesce as new infections occur, blighting and killing the entire leaf within a few days. If the lesions dry out, the leaf becomes very brittle (Fig. 2). Lesions may occur on petioles or stems, making detection difficult because leaves still appear green and healthy (Fig. 3). Infected stems turn black with rot but are not as spongy as stems infected with blackleg or soft rot bacteria (Fig. 4).

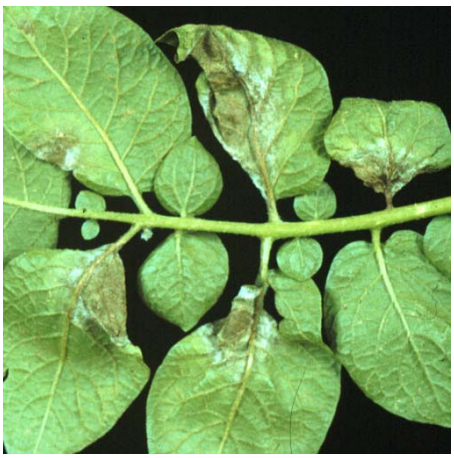
During periods of high relative humidity and leaf wetness, lesions may be bordered or totally covered by a cottonlike white moldy growth on the underside of the leaf or on the stems (Fig. 5). The white growth is the fungus sporulating, producing sporangia. Under continuously wet conditions, the fungus sporulates profusely and the disease progresses rapidly as the fungus rots the leaves and stems. High temperature and dry conditions will slow or temporarily stop disease development, but as conditions become moist and cool, the fungus resumes growth and disease development continues. Sporulation on stem lesions appears less affected by hot dry conditions because of the high relative humidity within the crop canopy.

1. Late blight lesions with chlorotic halo.

2. Late blight lesion that has dried and become brittle.

3. Late blight on stem.

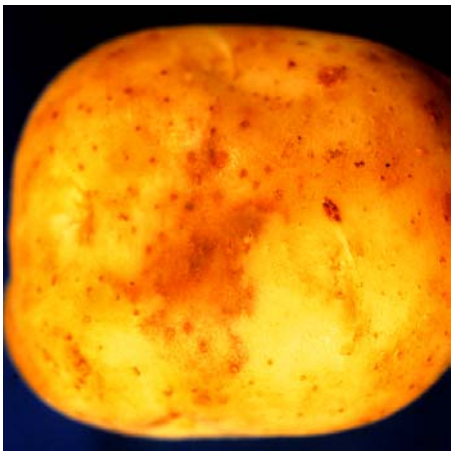
4. Late blight on stem, leaves with sporulation.



5. Late blight lesions with sporulation.

Tubers

The exteriors of infected tubers show irregular and slightly depressed areas of brown to purplish skin (Fig. 6). A coppery brown granular rot usually extends less than one-half inch into the tuber. This rot may be deeper when the infection is caused by new genotypes of late blight (Fig. 7). The boundary between diseased and healthy tissue is not clearly defined. Tubers may appear shriveled as older lesions become firm and sunken due to water loss. Invasion by secondary decay organisms is common, resulting in the complete breakdown of tubers. The cottonlike white mold may be observed on the surface of tubers when they are stored under conditions of high moisture.



6. Late blight rot on tuber.

7. Late blight rot in tuber.

Disease Cycle

The fungus survives between potato crops primarily in infected tubers (as seed, culls, volunteers). When infected tubers sprout the following spring, the pathogen can grow from the tubers into the newly formed plants. Under cool, moist conditions, the fungus can sporulate on the foliage of these plants. If the spores become airborne, they can be carried to neighboring plants or nearby fields. As long as spores continue to form on diseased foliage, infections will occur throughout the growing season.

When spores are washed off the foliage by rainfall, tubers can become infected. Tubers also may become infected at harvest through contact with spores on infected vines. Tubers inadequately covered by soil are more likely to be infected than those that are properly hilled. If the fungus sporulates on tubers in storage, any movement of those tubers can cause the sporangia to be disseminated and allow infections to occur on other tubers.

Conditions That Promote Disease

Ideal conditions for late blight are cool nights (50 to 60°F) and warm days (60 to 70°F) accompanied by fog, rain, or long periods of leaf wetness. Conditions must remain moist for 7 to 10 hours for spore production to occur.

Disease Look-alikes

Foliage

early blight, botrytis

Stem

soft rot, blackleg

Tubers

pink rot, early blight

Management/Control

- Use high-quality disease-free seed.
- Use resistant cultivars where possible; Kennebec, Sebago, and Elba are moderately resistant.
- Destroy cull piles and volunteers.
- Do not overfertilize with nitrogen.
- Make sure plants are adequately hilled.
- Apply fungicides.
- Scout suspect areas such as low-lying areas, areas near woods, and areas that tend to dry out more slowly.
- Vine kill and continue to apply protectant fungicides until plants are completely dead.
- Harvest only when vines are dead.
- Avoid harvesting under wet conditions.
- Maintain good air circulation in storage.

Early Blight

Causal Organism
Alternaria solani Sorauer (fungus)

Affects
foliage and tubers

Symptoms

Foliage

Foliar symptoms first appear as small circular dark spots on lower, older leaves (Fig. 8). Lesions are dark brown to black and have concentric rings, resulting in a targetlike appearance within the dead tissue. As lesions coalesce, they become restricted by large leaf veins and take on an angular shape (Fig. 9). Lesions may be surrounded by a chlorotic border. Infection also may occur on stems, resulting in small dark lesions that do not cause significant injury.

Tubers

Tuber lesions are dark, sunken, and often surrounded by a raised margin (Fig. 10). The underlying tissues are leathery to corky in texture, dry, and usually reddish to dark brown. Infected tubers become shriveled after prolonged storage.

Disease Cycle

The fungus overwinters in soil, plant debris, infected tubers, or other solanaceous hosts. The disease usually occurs along fields adjacent to potato fields from the previous season. Early blight usually occurs late in the season, with the first appearance in mid-July. Spores are produced on the older lesions and are dispersed to other plants by wind, rain, irrigation water, or mechanical means throughout the later part of the growing season. The disease therefore increases more rapidly after the plants flower. Tuber infection occurs during harvesting and is most severe when the tubers are bruised or wounded.

Conditions That Promote Disease

The temperature range for disease development is 68 to 86°F with an optimum range between 70 and 75°F. Alternating wet and dry conditions with long periods of high relative humidity and leaf wetness promote disease development. The disease is more severe on potatoes that are stressed from poor nutrition, insect damage, drought, or other stresses. Disease development increases as senescence begins.

Disease Look-alikes

Foliage

late blight, botrytis

Tubers

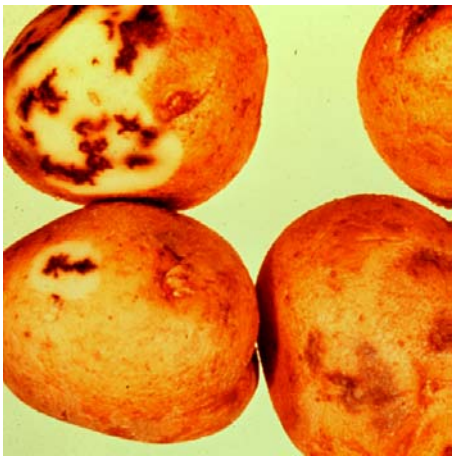
late blight, fusarium rot

Management/Control

- Rotate away from the previous year's potato fields.
- Plant cultivars with some degree of resistance, since early-maturing cultivars are more susceptible than late-maturing cultivars. Katahdin, Kennebec, Sebago, Elba, and Atlantic are moderately resistant.
- Apply protectant fungicides beginning after bloom or at the first sight of early blight symptoms.
- Use cultural practices that promote tuber skin set.
- Use harvesting methods that minimize skinning and bruising.

8. Early blight lesions on leaves.

9. Early blight lesions on leaves and stem.



10. Early blight rot in tubers.

Verticillium Wilt (Early Dying)

Causal Organism
Verticillium dahliae Kleb and *Verticillium albo-atrum* Reinke and Berth (fungi)

Affects
foliage and tubers

Symptoms

Foliage

Verticillium wilt causes early senescence of plants (Fig. 11). Symptoms often are difficult to distinguish from normal senescence, since they are expressed typically during the later part of the season. Foliar symptoms appear as uneven chlorosis and wilting of lower leaves (Fig. 12). Either top leaves, single stems, or leaves on one side of the stem may begin to wilt first (Fig. 13); however, the stem remains erect as the leaves wilt, turn yellow, and eventually die. A diagnostic symptom is wilted leaflets on one side of a petiole. Tan discoloration of the vascular tissues usually can be seen when the stem is cut in cross section or in a longitudinal section near its base (Fig. 14).

Tubers

Some tubers from infected plants may develop a light brown discoloration in the vascular tissue at the stem end, which usually does not extend through the tuber (Fig. 15). Other disorders also can cause this type of discoloration.

Disease Cycle

The fungus survives in the soil, on the seed piece, or in infected plant debris, and can persist in the soil for many years. Because Verticillium has a wide host range, it can survive at low levels on many symptomless crop and weed species. Infection occurs through root hairs, wounds, or sprouts, and then continues into the vascular system (water-conducting tissues). As infected plants die, the fungus grows through all of the dying tissues and forms infective propagules that are released into the soil.

Potato early dying is a syndrome consisting of premature vine death and declining yields in areas where potatoes have been in production for several years. Although Verticillium is the primary pathogen, other organisms have been associated with this syndrome. Root-lesion nematodes most frequently coinfect with Verticillium. Other pathogens have been reported to increase Verticillium wilt and have been implicated in the early dying syndrome.

11. Verticillium wilt, advanced senescence.

12. Verticillium wilt with wilting on lower leaves and uneven chlorosis.

Conditions That Promote Disease

Elevated temperature and moisture during the early part of the growing season, followed by drought, promote Verticillium. Continuous potato cropping and planting susceptible cultivars (Kennebec and Superior) increase the pathogen population.

Disease Look-alikes

Foliage
blackleg, black dot

Tubers
ring rot

Management/Control

- Do not plant susceptible cultivars.
- Rotate potatoes with cereals, grasses, or legumes.
- Avoid rotation with highly susceptible solanaceous crops such as eggplant or tomato.
- Plant resistant cultivars such as Elba or moderately resistant cultivars such as Katahdin, Norchip, and Atlantic. Avoid susceptible cultivars such as Kennebec and Superior.
- Control weeds.
- Control nematode populations.
- Avoid overirrigation.
- Use green manure crops such as corn, oats, peas, rape, rye, and sudangrass to reduce the pathogen population.

13. Verticillium wilt with chlorosis of one side of plant.

14. Verticillium wilt with discoloration of vascular tissue.

15. Verticillium wilt with discoloration of tuber vascular tissue.

Rhizoctonia Canker (Black Scurf)

Causal Organism
Rhizoctonia solani Kuhn (fungus)

Affects
stems, stolons, and tubers

Symptoms

Stems and stolons

Characteristic symptoms of Rhizoctonia are brownish black sunken lesions on underground stems and stolons (Fig. 16). The disease may cause nonuniform stands of weak, spindly-looking plants. Early-season infections often result in the pruning of young stolons where lesions girdle them completely. Dark stem lesions occurring below the soil line may girdle the main stem, resulting in yellowish or purplish leaves that curl upwards. On relatively healthy-looking plants, aerial tubers may form (Fig. 17). During midseason, the fungus may develop a white powdery mold growth on the stems that extends just above the soil line (Fig. 18). This often is associated with stem lesions below the ground.

Tubers

The fungus forms sclerotia (survival structures) on the tubers (Fig. 19). The sclerotia vary from netted or scurfy residues to individual black masses on the tuber surface. Tubers may be misshapen, cracked, or may develop a russetlike skin (Fig. 20).

16. Rhizoctonia cankers girdling the stem.

17. Rhizoctonia aerial tubers.

18. Rhizoctonia mycelium growth on lower stem.

Disease Cycle

The fungus survives in soil with decomposing plant residue. Sclerotia can survive on infected tubers and persist in the soil for many years. Sclerotia germinate and invade stems or sprouts. Roots and stolons are invaded as they develop throughout the growing season. Sclerotia can form on new tubers at any time, but maximum development occurs as tubers remain in the soil after the death of the vines.

Conditions That Promote Disease

Ideal conditions for Rhizoctonia are cool (55 to 60°F), moist soils. The pathogen population increases with continuous potato cropping.

Disease Look-alikes

Tubers

powdery scab, common scab

Management/Control

- Use disease-free seed.
- Use seed treatments of registered fungicides to reduce some infections, especially from an infected seed piece.
- Warm the seed prior to planting.
- Plant in warm (60°F) soil.
- Any practice that promotes rapid emergence will reduce attack by Rhizoctonia.
- Use proper crop rotation, preferably grasses or cereals.

19. Rhizoctonia sclerotia on tubers.

20. Rhizoctonia cracks and russetlike skin.

Fusarium Dry Rot and Seed Piece Decay

Causal Organism
Fusarium spp. (fungus)

Affects
tubers

Symptoms

Externally, tubers may have sunken or wrinkled areas and an occasional white or pink fungal growth. Internally, tubers develop a crumbly dry decay ranging from dark brown (chocolate colored) to black (Fig. 21). In addition, cavities often develop in the rotted tissue that contains the white or pink fungal growth. A moist rot may occur if tubers are invaded by a secondary infection with soft rot bacteria.

21. Fusarium dry rot in tuber.

Disease Cycle

The fungus can be seed- or soilborne. It enters tubers through wounds or bruises incurred during harvesting or handling. The disease can spread quickly if potatoes are improperly cured. Infected seed tubers result in low-quality seed that causes poor crop stands. The fungus can survive as resistant spores or mycelium in decayed plant debris in the soil.

Conditions That Promote Disease

Conditions that promote dry rot in storage include storage temperatures above 50°F, too much soil piled with the tubers, bruising or wounding of tubers during harvest or handling, and improper suberization of tubers or seed pieces.

Disease Look-alikes

Tubers
early blight

Management/Control

- Minimize bruising and wounding of tubers during harvest and handling.
- Avoid harvesting when tuber pulp temperatures are cold.
- Harvest when vines are dead.
- Remove excess dirt and clods from tubers before storing.
- Promote proper wound healing. (Temperatures from 55 to 60°F with 90 to 95 percent relative humidity encourage wound healing.)
- Reduce the storage temperature gradually when curing is complete.
- Apply the fungicide thiabendazole to harvested tubers going into storage.

Silver Scurf

Causal Organism
Helminthosporium solani Dur. and Mont. (fungus)

Affects
tubers

Symptoms

Symptoms of silver scurf include light brown circular spots with indistinct borders. These may cover a considerable portion of the tuber (Fig. 22). The affected areas have a distinct silvery sheen, especially if wet. Tubers may shrivel in storage due to moisture loss. Red-skinned varieties may lose their color.

22. Silver scurf.

Disease Cycle

The main source of inoculum is infected seed. The fungus sporulates on the surface of the seed piece, and then the spores wash onto new tubers. Infection takes place through lenticels. Symptoms may be visible at harvest, but sometimes are not visible until potatoes are in storage.

Conditions That Promote Disease

The longer the mature tubers remain in the ground, the more severe the problem becomes. Fluctuations in storage temperatures at high relative humidity (>90%) can result in condensation on tuber surfaces, allowing the fungus to sporulate and colonize new tissue.

Disease Look-alikes

Tubers
black dot

Management/Control

- Use disease-free seed.
- Treat seed with fungicides before planting.
- Follow good crop rotation practices.
- Harvest tubers as soon as they are mature.
- Disinfect the storage space and equipment.
- Minimize the amount of soil going into storage with the tubers.
- Provide good ventilation in storage.

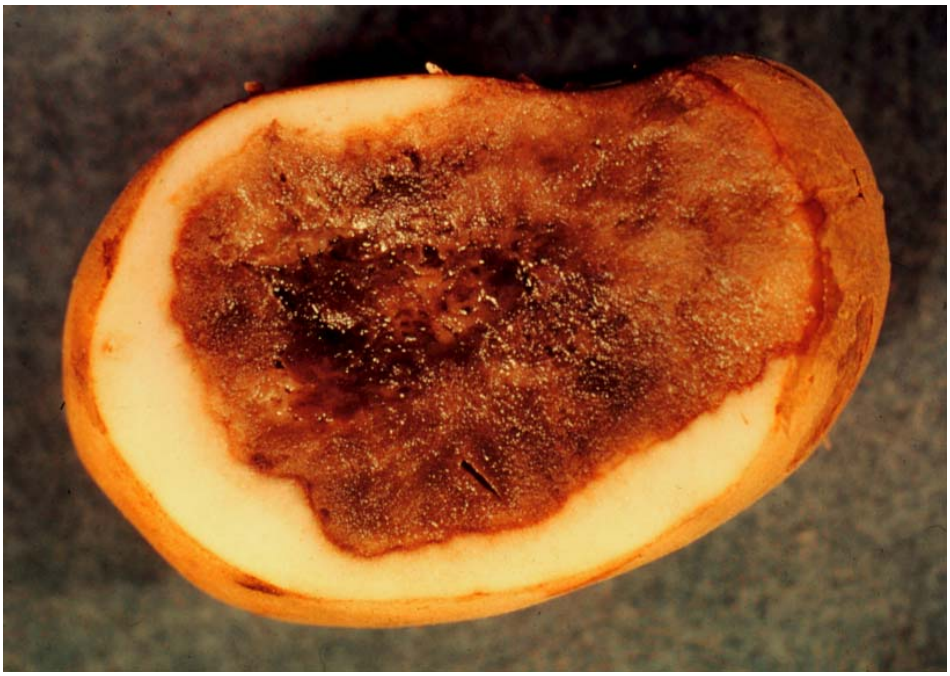
Pythium Leak

Causal Organism
Pythium ultimum Trow. and other *Pythium* spp. (fungus)

Affects
tubers

Symptoms

The rot starts as discolored water-soaked areas that appear around a bruise or wound. Diseased tissue is clearly demarcated from healthy tissue by a dark boundary line. Rotted tissue is spongy and extremely watery, and ranges in color from gray to brown to black (Fig. 23). When a diseased tuber is squeezed, a clear, watery fluid is exuded. Pure Pythium leak is not a slimy rot, but rather gives the tuber the texture of a cooked potato. Invasion by secondary organisms is common, however, and this may alter the texture of the rotted area.



23. Pythium leak.

Disease Cycle

Because the fungus is soilborne and enters the tubers only through wounds, infection usually occurs only at harvesting or grading.

Conditions That Promote Disease

Soil temperature above 70°F at harvest promotes the incidence of leak. Extremely wet conditions followed by a short period of dryness during tuber maturation increase the incidence of leak. Relatively high temperature and poor ventilation in storage promote the rot.

Disease Look-alikes

Tubers
pink rot

Management/Control

- Rotate fields out of potatoes for 3 to 4 years.
- The fungicide metalaxyl, applied at flowering and 2 to 3 weeks later, has controlled leak in some production areas.
- Avoid bruising and injury during harvest.
- Avoid harvesting in extremely warm conditions.
- If rotting begins in storage, increase air movement to cool and dry the tubers as quickly as possible.

Pink Rot

Causal Organism
Phytophthora erythroseptica Pethybr. (fungus)

Affects
tubers and foliage

Symptoms

Symptoms include brown to blackened roots or stolons. In severe cases, leaves are chlorotic, stunted, and wilted. The disease usually is identified by the tuber rot. The advancing margin of tuber decay is delimited by a dark line, which is sometimes visible through the skin (Fig. 24). The eyes of infected tubers are often dark brown. Rotted tissues remain intact but spongy with the consistency of a cooked potato. A clear liquid is exuded if a cut tuber is squeezed. The internal tissues of a cut tuber turn salmon pink after exposure to air for 15 to 20 minutes, then turn brownish black and eventually completely black (Figs. 25 and 26).

Disease Cycle

The fungus is soilborne and can infect roots, stolons, and underground stems. Tubers usually become infected through diseased stolons, but infection can occur through buds or lenticels. Tubers usually are infected in the field, but the disease can spread in storage.

Conditions That Promote Disease

Plants that are subjected to water saturation in fields, especially late in the season, will have a higher incidence of pink rot.

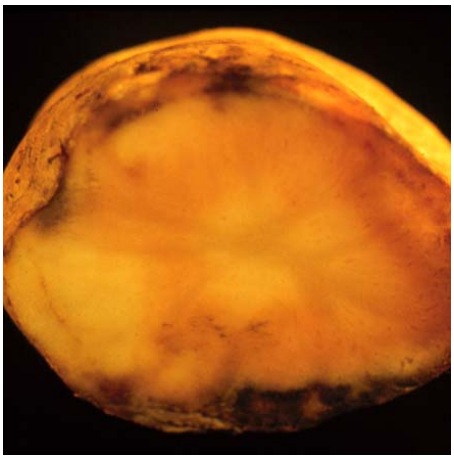
Disease Look-alikes

Tubers
late blight, pythium

Management/Control

- Plant seed in soils with good drainage.
- Avoid excessive irrigation late in the season.
- Grade and discard infected tubers.
- Provide adequate air flow through the pile if the disease is detected in storage.
- The fungicide metalaxyl, applied at flowering and 2 to 3 weeks later, has controlled pink rot in some production areas.

24. Pink rot symptoms on outside of tuber.



25. Pink rot in tuber.

26. Pink rot after pink color has changed to black.

Black Dot

Causal Organism
Colletotrichum coccodes (Wallr.) S. J. Hughs (fungus)

Affects
foliage and tubers

Symptoms

Foliage

Foliage yellows and wilts in mid- to late summer. Symptoms often go unrecognized because of the similarity of black dot to Verticillium wilt. White to tan lesions often can be found on the stem, if wounding occurred there to allow the fungus to infect the plant (Fig. 27). Numerous black dots (sclerotia, which are dormant fungal masses) may appear on the infected stems, stolons, roots, and tubers. The infected stems also have a purplish discoloration within the vascular tissue. Small brown lesions (similar to Rhizoctonia) may appear on the stolons. Roots may be discolored (brown to black) and stunted.

Tubers

A brownish to gray discoloration, similar to that caused by silver scurf, occurs on the tubers, often covering a large portion of their surface (Fig. 28). Unlike silver scurf, black dot will produce sclerotia within the discolored area; these can be seen easily with a hand lens.

Disease Cycle

Sclerotia survive on the surface of infected tubers, and once introduced into new fields, can live on infected plant residue in the soil for a long time. When conditions are favorable, the fungus invades underground stem tissue and moves upward in the plant. Airborne spores can infect the foliage, especially when it has been injured by windblown sand or debris. More sclerotia are produced in late stages of the disease's development. In addition, the fungus can invade tomatoes and weed species.

Conditions That Promote Disease

Ideal conditions that promote black dot include poor soil drainage and aeration, high soil temperature, and low soil moisture. Low plant fertility also increases black dot incidence.

Disease Look-alikes

Foliage

verticillium wilt

Tubers

silver scurf

Management/Control

- Plant certified seed.
- Rotate crops with grains, preferably waiting five years before replanting potatoes or tomatoes.
- Keep soil adequately fertilized.
- Irrigate, but avoid excessive watering.
- Avoid skinning or bruising tubers.
- Control weeds.

27. Black dot lesion on stem.

28. Black dot lesion on tuber.

Powdery Scab

Causal organism:
Spongospora subterranea f. sp. *subterranea* Toml. (fungus)

Affects
tubers, roots, and stolons

Symptoms

Powdery scab infections start in the roots and then proceed to the tuber. Lesions similar to those caused by other root-invading organisms may be observed on the roots and stolons. Galls usually will form on the roots (Fig. 29). The initial infections on tubers are purplish-brown pinhead lesions that develop into a raised pimple-like area (Figs. 30 and 31). When the pustules are mature, a powdery spore mass is easily visible within the raised area (Fig. 32). Craterlike symptoms, with raised skin at the borders of the pustules, sometimes develop (Fig. 33). Another symptom may be a scurfy appearance on the skin, which, upon examination with a microscope, reveals spore masses (Fig. 34).

Disease Cycle

Powdery scab spores are disseminated on seed or by soil or water movement. The spores also adhere to equipment, crates, and sacks, and even remain viable in the manure of animals that have digested them. The spores survive in the soil or on seed tubers, and can persist for 6 years. The spores germinate to release zoospores, which can infect the plant through root hairs and lenticels.

Conditions That Promote Disease

Ideal conditions for powdery scab include high soil moisture and low soil temperature (58 to 68°F) . In addition, fields or parts of fields that are poorly drained have a higher incidence of powdery scab.

Disease Look-alikes

Tubers
common scab, rhizoctonia

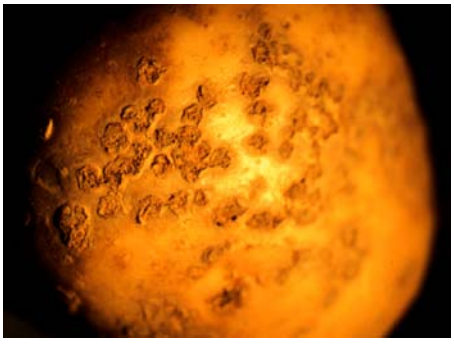
Management/Control

- Disinfect equipment.
- Plant clean seed.
- Plant less susceptible (russet-skinned) varieties.
- Do not use manure as fertilizer if animals have ingested infected potatoes.
- Improve soil drainage.
- Withhold irrigation during tuber set.
- Rotate out of infested fields for 3 to 5 years.

29. Powdery scab galls on roots.

30. Early symptoms of powdery scab lesions.

31. Pimple-like powdery scab pustules.



32. Typical powdery scab symptoms.

33. Powdery scab canker stage.

34. Russetlike powdery scab symptoms.

Gray Mold

Causal organism
Botrytis cinerea Pers. (fungus)

Affects
foliage and tubers

Symptoms

Symptoms of gray mold include lesions similar to those caused by early blight (concentric rings) or late blight (dark watery decay), occurring at leaf margins or tips (Fig. 35). Lower leaves that are chlorotic from shading break down in a slimy rot. A grayish mold is visible on the infected leaves and stems (Fig. 36). Although tuber rot is uncommon, a dry rot occurring in storage has been attributed to gray mold.

Disease Cycle

Infections become apparent on senescent plant parts. The spores of this fungus are ubiquitous and are disseminated by wind and rain.

Conditions That Promote Disease

Ideal conditions for gray mold include excessive humidity, relatively cool temperatures, and shading of foliage.

Disease Look-alikes

Foliage
late blight, early blight

Management/Control

- Protectant fungicides.

35. Botrytis on leaf.

36. Botrytis sporulation on stems.

Sclerotinia Stalk Rot (White Mold)

Causal Organism
Sclerotinia sclerotiorum (Lib.) De Bary (fungus)

Affects
stems

Symptoms

Initial symptoms are the presence of individual wilted plants within a canopy of healthy-looking plants. Water-soaked lesions appear on the main stem of the wilted plants. As the lesions dry out, they become a bleached tan color. Under humid conditions, these lesions expand and may girdle the stem, causing the plant to wilt. White mold is often present on the stem, especially near the soil line (Fig. 37). Black, hard, irregularly shaped structures, called sclerotia, develop on or in the decaying stems.

37. Sclerotinia mycelium growth on stem.

Disease Cycle

Sclerotia survive in the soil for several years between susceptible crops such as beans, soybeans, or sunflowers. Sclerotia lying near the soil surface germinate when the crop canopy shades the soil and soil moisture remains high for several days. Sometimes the sclerotia germinate directly, producing a white fungal mat; however, in most cases a mushroomlike structure, called an apothecium, develops from the sclerotia. The apothecia are produced for 2 to 8 weeks beginning at row closure, and they eject spores onto the foliage. These spores typically infect dead or dying tissue that may be in contact with healthy tissue. As infected stems decay, sclerotia are formed in the lesions. These sclerotia will fall into the soil as the plant tissue decays. It is known that the sclerotia can survive in the soil for a minimum of 3 years.

Conditions That Promote Disease

Cool temperatures (61 to 72°F) and damp conditions are required for this disease. High N fertility, which promotes lush, dense plant canopies, can produce high relative humidity and long periods of free moisture within the canopy, increasing the incidence of white mold. Older tissue appears to be more susceptible than young tissue.

Disease Look-alikes

Foliage
blackleg, black dot

Management/Control

- Rotate with graminaceous crops and rotate out of susceptible crops for 4 or more years.
- Perform light, frequent irrigation of coarse, heavy soils, or less frequent irrigation of light soils.
- Apply foliar fungicides.
- Flooding of fields between crops destroys the sclerotia.

Common Scab

Causal Organism
Streptomyces scabies (Thaxter) Waksman and Henrici (actinomycetes)

In soils with a pH below 5.5, the acid-tolerant species *S. acidiscabies* causes acid scab.

Affects
tubers

Symptoms

Lesions typically are circular, raised, and tan to brown in color, with corky areas that develop randomly across the tuber (Fig. 38). Lesions may become irregular in shape when they coalesce (Fig. 39). A superficial corklike layer (russet scab) occasionally appears instead of the circular lesions. In other cases, the lesions are one-half inch deep (pitted scab) (Fig. 40). These pitted scab lesions are dark brown to black, and the tissues underneath are often straw-colored and translucent. More than one type of symptom may be present on a single tuber. Symptoms usually are not noticeable until late in the growing season.

Disease Cycle

The pathogen usually is introduced into the soil on seed pieces, and survives indefinitely once the soil is contaminated. The organism can survive on decaying plant debris and is spread by water or by infested soil on equipment. As soon as tuberization begins, the newly formed tubers are susceptible. They become infected through the stomata or lenticels. Mature tubers with a well-developed periderm are no longer susceptible to infection.

Conditions That Promote Disease

A soil pH from 5.5 to 7.5 is most favorable for common scab; acid scab favors a soil pH from 5.0 to 5.5. Other conditions that promote common scab include continuous cropping with potatoes, coarse soils that dry out quickly, and legumes (especially red clover) that have been cut down and left on the field.

Disease Look-alikes

Tubers
rhizoctonia, powdery scab

Management/Control

- Avoid planting scabby seed.
- Increase the time between potato croppings in infested fields. Rotate with crops such as alfalfa, rye, and soy beans.
- Avoid rotations with carrot, beet, spinach, turnip, and radish.
- Maintain soil pH at or slightly below 5.5.
- Avoid overliming the soil.
- Maintain soil moisture levels during and after tuber set.
- Fungicide seed treatment will reduce scab.
- Plant cultivars with some degree of resistance (Superior, Monona, Norchip, Atlantic, Kennebec, Norland).
- Green manure crops such as rye, millet, and oats may reduce the incidence of common scab.
- Avoid applying animal manure to fields where potatoes will be planted.
- Applications of sulfur or acid-forming fertilizers such as ammonium sulfate lower the soil pH.

38. Typical common scab symptom.

39. Common scab with many scab lesions.

40. Deep-pitted common scab.

Blackleg and Soft Rot

Causal Organisms
Erwinia carotovora subsp. *atroseptica* (Van Hall) Dye and *Erwinia carotovora* subsp. *carotovora* (Jones) Dye (bacteria)

Affects
stems and tubers

Symptoms

Stems infected with blackleg have an inky black decay that usually begins at the decaying seed piece (Figs. 41 and 42). In severe cases, entire seed pieces or developing sprouts rot prior to emergence, resulting in an uneven stand count. Leaves of infected plants tend to roll upward at the margins, become chlorotic, and wilt (Fig. 43). Plants are often stunted and appear stiff before wilting and eventually dying. In wet weather, the decay on the stems is soft and slimy, but under dry conditions, infected tissues may become dry and shriveled. Tubers produced by infected plants may have symptoms ranging from slight vascular discoloration at the stolon end to soft rot of the entire tuber.

Aerial blackleg, a related disease, is caused by soft rot bacteria external to the seed piece and can occur when bacteria enter wounds caused by hail, windblown sand, insect feeding, or cultivation. Symptoms are similar to blackleg, but the rot does not originate from the seed piece (Fig. 44).

Tubers with soft rot have brown, slightly sunken, water-soaked areas on the surface (Fig. 45). Advanced disease symptoms include slimy, completely rotted tissues with a foul odor (due to invasion by secondary organisms) (Fig. 46).

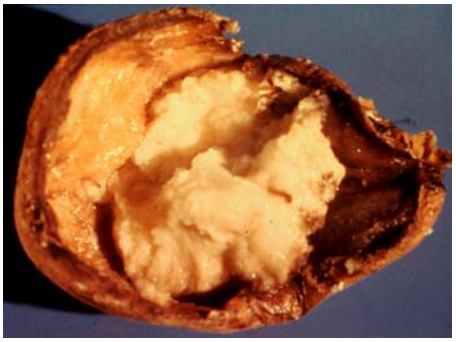
41. Blackleg on lower stem.

42. Blackleg on lower stem.

43. Plant wilted from blackleg.

44. Aerial blackleg.

45. Soft rot symptoms on outside of tuber.



46. Soft rot inside tuber.

Disease Cycle

The primary inoculum for blackleg is on or in seed tubers. Bacteria can be spread during seed cutting and handling. After being planted, the seed pieces decay, releasing bacteria into the soil and sometimes infecting the stem of the host plant. Bacteria may move in soil water and contaminate developing tubers of adjacent plants. Bacteria can enter lenticels, growth cracks, or harvesting injuries.

The primary inoculum for soft rot of tubers comes from decaying seed pieces, infected plants, infested soil, contaminated seed cutting, or harvesting equipment. Infection occurs through lenticels or wounds.

Conditions That Promote Disease

High soil temperature and seed bruising favor preemergence blackleg. Cool, wet soil at planting followed by high temperatures after emergence favor postemergence blackleg. Extremely wet conditions at planting or harvesting promote soft rot. Excessive weeds may harbor the soft rot bacteria. Soft rot infections increase when immature potatoes are harvested or when the temperature is above 70°F during harvesting. Excessive bruising, improper wound healing, or free moisture and poor air circulation in storage increase soft rot incidence.

Disease Look-alikes

Stems
late blight

Tubers
late blight, ring rot

Management/Control

- Warm seed pieces to 55 to 60°F before planting.
- Plant clean seed.
- Avoid planting when soil temperature is below 55°F.
- Plant seed in well-drained soil.
- Frequently clean and disinfect seed cutting and handling equipment as well as harvesting equipment.
- Avoid excessive irrigation.
- Remove infected plants as soon as they appear.
- Harvest only dead vines, preferably when the temperature is between 50 and 65°F.
- Avoid harvesting under extremely wet conditions.
- Prevent condensation in the storage pile.

Ring Rot

Causal Organism
Corynebacterium sepedonicum (Spiek. and Kott.) Skapt. and Burkh. (bacterium)

Affects
foliage and tubers

Symptoms

Foliage

Foliage symptoms include wilting of stems and leaves, along with chlorosis and necrosis of leaves. Lower leaves usually wilt first and are paler in color than healthy leaves. Later, the tissue between the veins turns yellow, and eventually the entire stem senesces and dies. Foliar symptoms alone are not usually enough to accurately diagnose ring rot.

Tubers

In the tubers, a creamy, yellow- to brown-colored cheesy rot develops in the vascular ring (Fig. 47). Squeezing tubers expels creamy, cheeselike ribbons of odorless bacterial ooze. The vascular ring may separate from adjacent tissues (Fig. 48). Slightly sunken, dry, cracked areas may form on the outer surfaces of severely diseased tubers (Fig. 49). Occasionally, symptoms develop only in the bud end. Symptoms in tubers frequently do not appear until after several weeks in storage.

Disease Cycle

Ring rot bacteria overwinter primarily in infected seed tubers. Bacteria also can survive on unharvested tubers in the field and can survive 2 to 5 years in dried slime on crates, bags, and harvesting or grading machinery. The bacteria do not survive in soil in the absence of potato debris, but can survive on volunteers. Infection occurs through tuber wounds, especially when they come in contact with contaminated machinery. During seed cutting, the bacteria are transmitted readily to healthy seed pieces. After infection, the bacteria invade the vascular system.

Conditions That Promote Disease

Wet soils at planting when the temperature is 64 to 72°F increase the chance of infection. The disease develops most rapidly when soils are dry and temperatures are between 75 and 90°F.

Disease Look-alikes

Foliage

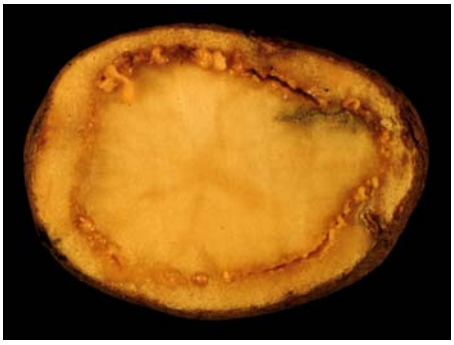
verticillium wilt, blackleg

Tubers

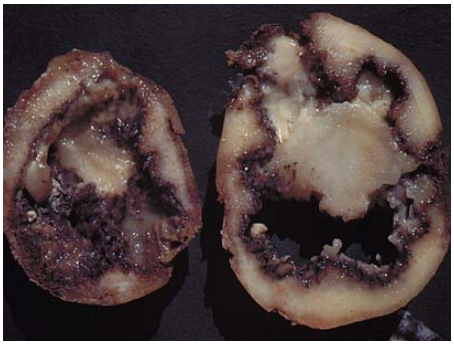
verticillium, soft rot

Management/Control

- Use only disease-free, certified seed.
- Use proper sanitation during seed handling. Containers, tools, and implements should be cleaned properly and disinfected before use and between seed lots.
- Quaternary ammonium compounds, hypochlorites, phenolic compounds, and iodine compounds all are effective disinfectants.
- To be effective, disinfectants must be present on the surface being treated for at least 10 minutes.
- Dispose of all infected tubers as soon as possible.
- Do not plant clean seed in a field that may contain volunteer plants from a previously infected crop.
- Never plant contaminated seed.



47. Ring rot in vascular tissue of tuber.



48. Ring rot in more advanced stage.

49. Ring rot symptoms on outside of tuber.

Viruses

Causal Agents
Potato Leafroll Virus (PLRV), Potato Virus Y (PVY), Potato Virus X (PVX), Potato Virus S (PVS), Potato Virus A (PVA), and others.

Affects
foliage

Symptoms

PLRV

Current-season infections (transmitted by aphids) may have no visible symptoms, although younger leaves may roll up and appear yellowed or slightly pinkish (Fig. 50). On plants that are infected with diseased seed pieces, the lower leaves roll up and have a leathery texture (Fig. 51). The plants may be somewhat stunted and appear upright (Fig. 52). Some varieties develop symptoms in the tubers called net necrosis, an internal browning that fans out from the center pith area (Fig. 53).

PVY

Symptoms vary depending on the cultivar. Current-season infection may have no symptoms, but the tubers may become infected. Plants grown from infected seed pieces may develop severe mosaic, mottle, and necrosis (Fig. 54).

PVA produces a mild mosaic.

PVX and PVS may be completely symptomless; however, more than one virus frequently occurs in an infected plant. Infection with both PVS and PVY causes severe mosaic symptoms.

Disease Cycle

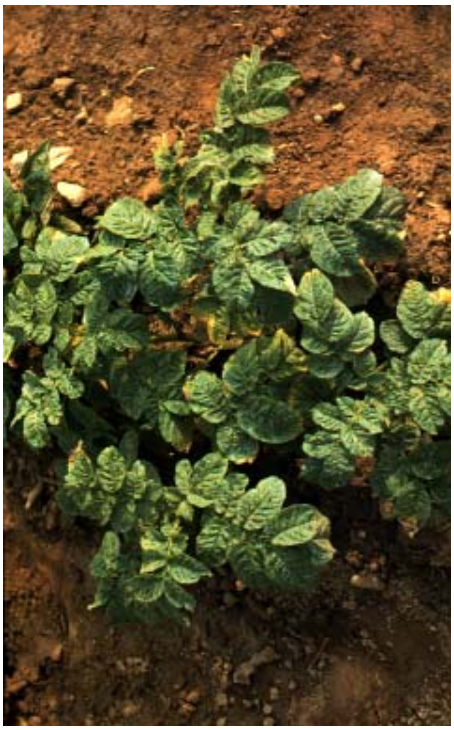
All viruses are tuber borne. Several of the viruses are transmitted mechanically from plant to plant or from seed piece to seed piece. PLRV is transmitted persistently by aphids. PVY, PVA, and PVS are transmitted nonpersistently by aphids and also are transmitted mechanically. PVX is transmitted only by mechanical means.

Management/Control

- Sanitize equipment and storages.
- Plant only high-quality certified seed.
- Plant B-size seed.
- Plant resistant cultivars.
- Monitor and manage the aphid and leafhopper populations.

50. Leafroll on upper leaf.

51. Leafroll from infected seed piece.



54. Mosaic symptoms from Virus Y.

52. Plant stunted from leafroll.

53. Leafroll symptoms in tuber.

Brown Center and Hollow Heart

Brown center and hollow heart are physiological disorders that are unpredictable and impossible to grade out by conventional methods. These two disorders are distinct but closely related. An affected tuber can have a beautiful outward appearance but a hollow or brown center.

Symptoms

Brown center is characterized by light to dark brown discoloration in the center pith tissues of the tuber. Brown centers are referred to as incipient hollow heart. Hollow heart is split tissue in the pith accompanied by a brown to black discoloration around the split tissue (Figs. 55 and 56). Although hollow heart usually is found in larger tubers, smaller tubers also can be affected.

Hollow heart can begin at different times during the growing season. It usually starts early, shortly after tubers begin to form, but also may occur later in the season when tubers are enlarging. If initiated early, the cavity is usually at the stem end of the tuber, whereas late-starting hollow heart is closer to the bud end. Early hollow heart usually is preceded by a brown discoloration that indicates dead cells caused by plant stress. By contrast, discolored tissue does not appear in late-initiated hollow heart. Symptoms that begin during bulking occur because of a quick change in the tuber growth rate, which causes the internal tissue to split.

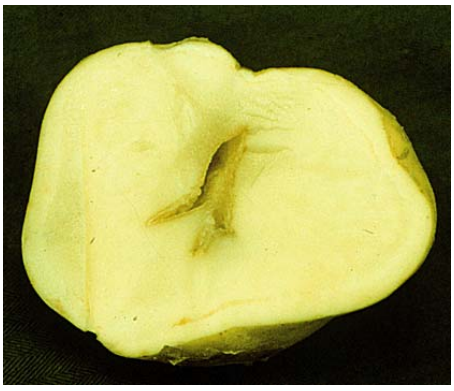
Conditions That Promote the Disorder

- Low soil temperatures (50 to 55°F continuously for 5 to 7 days during tuber initiation) and high moisture tend to favor hollow heart, as does heavy irrigation after the plants are stressed.
- Some potato cultivars are more susceptible: Atlantic is susceptible, whereas Norland and Superior seldom have hollow heart.
- Wide plant spacing promotes bigger tubers and tends to favor hollow heart. Applying a high rate of nitrogen late in the season can encourage hollow heart.
- A connection between calcium and hollow heart exists. In stressed plants, the availability of calcium decreases, which may cause weak tissue if the stress occurs at a critical time in the plant's growth. Complete control is difficult, if not impossible, and requires uniform growth and reduced plant stress.

55. Severe hollow heart with brown/black discoloration.

Management/Control

- Select plant varieties that are less susceptible.
- Select fields with an optimum level of fertility and pH. Be sure soils have adequate potassium. Avoid very acid soils with low cation exchange.
- Delay planting on fields that are prone to low soil temperature and excessive wetness, or that have had serious problems in the past.
- Plant for denser stands. Assure uniform spacing.
- Avoid excessive fertilization.
- Avoid excessive irrigation.
- Do not make side-dress applications of boron or calcium.
- High potassium levels can reduce hollow heart.



56. Hollow heart.

Internal Browning and Heat Necrosis

These two disorders are distinct but closely related.

Internal brown spot is characterized by small irregularly shaped blotches throughout the tuber tissue that may occur at any time during the growing season (Fig. 57). The symptoms tend to increase throughout the season and can continue to intensify in storage. Immature tubers stored at higher temperatures have a higher incidence of internal brown spot. The disorder has been associated with dry weather, high soil temperatures, and low or fluctuating soil moisture. Normally there are no external symptoms.

Heat necrosis is similar, but tubers may have lesions in the vascular tissue and external symptoms such as depressions or cracking in the skin. It occurs most commonly in tubers exposed near the soil surface.

Blackspot Bruise

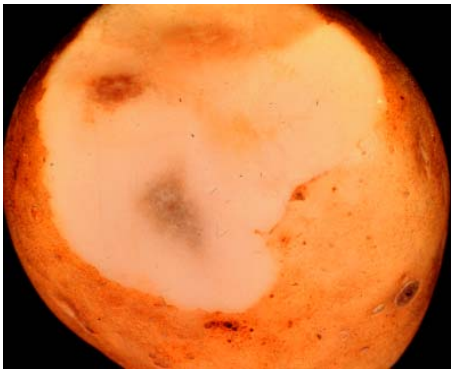
Blackspot is a direct result of a bruising force or an impact. An internal discoloration begins to develop just under the skin 6 to 8 hours after bruising has occurred (Fig. 58).

Tuber hydration is important. If a tuber is partially hydrated, it is less susceptible; fully hydrated and poorly hydrated tubers are susceptible. Tuber temperature also affects bruising. As the temperature drops, more bruising occurs. Fully killed vines reduce the impact of bruising, whereas green vines contribute to bruising. Dry soils contribute to bruising because the soil draws water from the tuber. Dry soil interferes with skin set and does not provide cushioning. Low potassium levels increase blackspot. Some potato varieties bruise more easily than others.

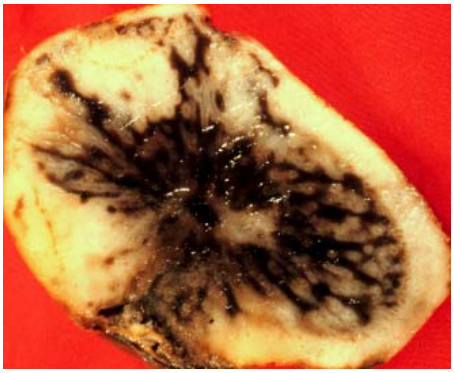
Blackheart

This injury occurs as a result of low oxygen levels in the interior of the tuber. An irregular black to blue-black pattern develops in the center of the tuber, and the border of the discolored area usually is very distinct (Fig. 59). The darkened areas are fairly firm. Blackheart can result when tubers are held in a low-oxygen environment or when gas diffusion into the tuber is slowed down because of extremely low (32 °F) or high (96 to 104 °F) temperatures. This condition can occur in the field when soils are flooded, or in poorly aerated storage.

57. Internal browning.



58. Internal blackspot.



59. Blackheart.

White Knot

White knot or starch spot is a disorder that results in the grade-out of finished product when tubers are processed into chips. It is also undesirable in table stock potatoes. White knot appears as a hard white lump in the tuber flesh several millimeters below the surface of the tuber (usually between the periderm and the vascular ring) (Fig. 60). No evidence on the outside of the tuber indicates that it is present. White knot has been found mostly in Atlantic, and usually is found when the specific gravity is high.

Physiologically Old Seed

Storing seed can affect its quality, not only because of the potential introduction of disease problems, but also because of aging. Table 1 describes the characteristics of young and old seed (Figs. 61 and 62).

Table 1. Characteristics of physiologically young and old potato seed.

Young Seed	Old Seed
slow emergence	rapid emergence
apical dominance	multiple stems
few main stems	increased stem branching
large, vigorous plants	small, weak plants
fewer tubers set	more tubers set
long bulking period	rapid bulking
long tuberization	uniform set
large tubers	small tubers
delayed senescence	early senescence
high yield	low yield

60. White knot.

61. Physiologically old seed with sprout.

62. Physiologically old seed producing tubers without foliage production.

Herbicide/Chemical Injury

A wide range of chemicals can cause abnormal foliage or tuber symptoms if applied improperly. Growth-regulating herbicides may cause leaf distortion similar to that caused by virus infections (Figs. 63 and 64). Vine-killing defoliants may cause necrosis at the stem end that resembles the browning caused by Verticillium wilt.

Air Pollution

Some potato cultivars are sensitive to various air pollutants. The most common problem is ozone damage. Ozone is a gas formed by the action of sunlight on products of fuel combustion. It usually forms over cities or industrial areas, but is moved by wind to rural areas. Symptoms vary, depending on the concentration and duration of exposure. Small dark purple spots, sometimes with chlorosis or often with a bronzed appearance, first appear between the veins on the upper leaf surface (Fig. 65). Older leaves turn yellow and may die prematurely.

63. Chemical injury.

64. Herbicide damage.

65. Ozone injury.

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