Identifying Diseases of Vegetables
Michigan State University Extension Service
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J. K. Springer, Rutgers University
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INTRODUCTION

Accurate disease identification is the first step in planning an effective and efficient disease-control program. Literally hundreds of specific vegetable diseases exist. Although a vegetable grower will encounter only a few during any one season, he must be able to distinguish significant and potentially serious diseases from those of lesser importance. The aim of this publication is to help in the diagnosis of vegetable diseases. It describes many major diseases that have distinctive symptoms, but many other diseases (caused by living and nonliving agents) are not described. If you are not confident of your diagnosis, seek assistance from your local Extension office.

Current recommendations for disease control in vegetable crops are listed in pest-control guides that are revised each year; the guides may be obtained from the Extension office in your county.

ASPARAGUS

RUST, caused by the fungus Puccinia asparagi, appears as red or brown elongated spots on asparagus spears, shoots, or needles. The discoloration is due to dusty fungus spores produced in small pustules; a reddish color predominates at first but becomes blackish later in the season. The discoloration can make entire plantings look like they ripened prematurely. The rust fungus passes its entire life cycle on the asparagus. Black weather-resistant spores overwinter on old asparagus stems and stubble. Heavy dews favor development of the disease.

FUSARIUM WILT and CROWN ROT, caused by species of Fusarium (F. oxysporum and F. moniliforme), is characterized by the production of weak, spindly spears in the spring. As the season progresses, shoots from severely infected crowns may exhibit a brilliant yellow coloration and they may exhibit a limited amount of vascular discoloration. Feeder roots are frequently rotted and discolored, with the discoloration extending into the storage roots. Stems infected with the stem miner frequently exhibit extensive Fusarium lesions near the soil line. Affected crowns are found to have a low number of shoot buds and a reddish-brown discoloration of tissue when cut in cross section. Damping-off is common in crown nurseries. Plants weakened by adverse growing conditions and by extending harvest too long are most severely affected by Fusarium wilt and crown rot.
BEANS

ROOT ROT is caused by a complex of several different soil-borne fungi. Symptoms vary, depending on organisms present and on environmental conditions. Root rot should be suspected whenever plants wilt and die, leaves turn yellow or drop off, plants are stunted, or pods are small with under-sized seed. Characteristic symptoms caused by four major root-rot fungi are described here.

a. Fusarium Dry Root Rot is caused by *Fusarium solani* f. sp. *phaseoli*. Symptoms appear soon after seedlings emerge. The taproot is first slightly discolored, gradually becomes brick red, and finally becomes brown with longitudinal cracks. Bottom roots usually are killed; new fibrous roots may form just above the discolored area and just below the soil surface. Continuous bean cropping allows a buildup of the fungus in the soil. The fungus can survive for 5 years or longer in the absence of beans.

b. Rhizoctonia Root Rot, caused by *Rhizoctonia solani*, is characterized by seed rot and a water-soaked stem rot near the soil line which in new seedlings results in wilt and death. More commonly, slightly sunken reddish-brown longitudinal stem cankers appear near the soil line on older plants. As inner stem tissue is invaded, it becomes brick red.

c. Pythium Root Rot and Wilt, caused by *Pythium* sp., are characterized by colorless to dark brown wet rot near the soil line. Young plants and sometimes older plants wilt and die. Stems are hollow and feel like soda straws.

d. Thielaviopsis Black Root Rot, caused by *Thielaviopsis basicola*, is characterized by a dark brown to black rot of the taproot.
ROOT KNOT, caused by the *Meloidogyne* sp. of nematode, appears as swellings on roots. The disease is discussed with tomato diseases.

**Bacterial Blights** of beans and lima beans are caused by several specific kinds of bacteria, each causing a different disease. Bacteria that cause these blights overwinter in the seed and in residues of diseased plants left in fields; syringae blight bacteria also overwinter in several woody plants — including lilac, cherry, pear, poplar, rose and forsythia. Bacteria are spread in splashing rain, by workers and on implements.

a. **Halo Blight**, caused by the bacterium *Pseudomonas phaseolicola*, is characterized by numerous small dead leaf spots with yellow haloes. At lower temperatures haloes may be up to 1/2 inch in diameter; at high temperatures haloes may be absent and entire leaves may be killed as the bacteria move systemically in the plant. Under humid conditions a cream-colored ooze is produced in pod spots. Halo blight is favored by cool wet weather.

b. **Common Blight and Fuscous Blight** of beans and lima beans are caused by the bacterium *Xanthomonas phaseoli*. Disease is characterized by large dead areas on leaves. Spots begin as small water-soaked or light-green areas which later dry out and turn brown with a narrow yellow halo. On susceptible varieties, spots can expand and coalesce to affect entire leaflets. Similar water-soaked spots on pods coalesce into irregular blotches. Under moist conditions, a yellow ooze is produced in spots on pods. Common blight is favored by warm wet weather.
c. Brown-Spot (Syringae) Blight is caused by the bacterium *Pseudomonas syringae*. Symptoms, more common on lima beans than on other beans, include small reddish-brown irregular circular leaf spots, with distinct margins and a darkening of some veins on the lower surface of the leaf. As spots enlarge the centers turn gray and drop out. Pod spots are more elongate than leaf spots.

**Angular Leaf Spot**, caused by the fungus *Isariopsis griseola*, affects beans and lima beans. Leaf spots appear first on the oldest leaves; the spots are dark brown to gray with a distinct margin, are angular as delimited by leaf veins, and sometimes are covered with a gray mold on the lower leaf surface. Severely spotted leaves senesce prematurely and drop off. The fungus can survive for 2 years in residue from diseased plants and in soil. Fungus spores can be spread long distances on seed, and short distances by wind, splashing water, insects, and implements. Disease is promoted by wet conditions caused by frequent rainfall, poor drainage, and slow drying conditions.

**Cercospora Leaf Spots** are caused by the fungi *Cercospora canescens* and *C. cruenta*. Leaf spots caused by *C. canescens* are circular to slightly angular with a gray center and a reddish border. Lesions on lima beans generally are smaller and have more intense red borders than those on other beans.

Spots produced by *C. cruenta* occur on stems, leaves, and pods of mature and senescent plants. Leaf spots are brown to rust-colored, irregular in size and shape, angular, and form a checkerboard pattern. The fungus appears as a dark fuzzy growth on the undersurface of the leaf. Tissue at the center of leaf spots often drops out, producing a shot-hole effect.
ANTHRACNOSE of beans, caused by the fungus *Colletotrichum lindemuthianum*, is characterized by black sunken lesions on pods, cotyledons, and stems. Spots are about 1/2 inch in diameter and usually are covered by a salmon-colored ooze during moist conditions. Pod spots are most conspicuous. Veins on lower leaf surfaces commonly turn black. On lima beans, spots resembling sooty mold develop on leaves and pods; spot margins are diffuse, even on veins on the lower leaf surface. Presence of a diffuse margin helps distinguish anthracnose from syringae blight of limas. The anthracnose fungus overwinters in bean seed and in field soil on residues from diseased plants. The fungus is spread by wind or rain, animals, workers, and implements. Cool wet weather promotes disease development.

POWDERY MILDEW, caused by the fungus *Erysiphe polygoni*, begins as faint discolored leaf spots from which a diagnostic grayish white (talcum-like) powdery growth spreads to all above-ground parts. Young leaves are dwarfed and curled and may turn yellow and drop. Pods are dwarfed and distorted. Powdery mildew usually develops on mature plants late in the season.

MOSAIC symptoms include stunting of plants; mottling, puckering, stunting, and vein-dying of leaves; dying-back of shoot tips; and sometimes distortion and stunting of pods. Common Bean Mosaic (BV-1), Bean Yellow Mosaic (BV-2), and Peanut Stunt (PSV) are three bean virus diseases. BV-1 is seed-borne and overwinters in sweet white clover. BV-2 and PSV are not seed-borne. BV-2 overwinters in clovers and in gladioli. PSV overwinters in sweet white clover. All three viruses are spread from diseased plants to healthy plants by aphids, by leaves rubbing against each other, and by workers handling healthy plants after working with diseased plants.
DOWNY MILDEW OF LIMA BEANS is caused by the fungus *Phytophthora phaseoli*. Disease is conspicuous because of a white downy mold on pods; mold seldom develops on leaves. Infected pods shrivel, die, and turn black. Young shoots, flowers, and leaves also are affected, and leaf veins may become purplish and distorted. The downy mildew fungus overwinters in diseased seed and in refuse from diseased plants. In wet weather, the fungus grows, reproduces, and is spread rapidly by wind. Susceptible plants can be destroyed in a few days.

GRAY MOLD, caused by the fungus *Botrytis cinerea*, is chiefly a pod disease on beans. It is characterized by a distinctive grayish powdery mold on bean pods. The causal fungus is present on most dead organic matter in fields. Here the fungus grows and produces dry reproductive spores which are spread by wind. Wet conditions promote disease development.

WHITE MOLD, caused by the fungus *Sclerotinia sclerotiorum*, is characterized by a diagnostic white cottony growth on pods and stems. Small, hard, black seed-like structures (sclerotia) often form in the white mold growth. Rotted pods become wet and soft. Affected plants often die. The causal fungus overwinters in residue from diseased plants in and near bean fields. Fungus spores are produced during wet spring weather and are carried to bean plants by wind. The fungus gets its start on dying blossoms and on injured tissue. Prolonged wet conditions promote disease development.

RUST, caused by the fungus *Uromyces phaseoli typica*, is characterized by reddish dusty spots which occur mostly on lower surfaces of leaves but also on pods. It is most common on mature plants. The causal fungus overwinters on residue from diseased plants. Dusty spores produced in leaf and pod spots can be spread long distances by wind and short distances by movement of workers and implements.
LIMA BEAN POD BLIGHT, caused by the fungus *Diaporthe phaseolorum*, causes irregular brown patches on leaves. Later, small black pycnidia (fungus reproductive structures) appear arranged in concentric rings within leaf spots and on pods. In these pods, seeds may not form; if they do they may be shriveled. The disease-causing fungus overwinters on seeds and in residue from diseased plants. Sticky spores are produced in the pycnidia on leaves and pods. Wet conditions promote production and spread of spores and development of the disease.

CERCOSPORA LEAF SPOT, caused by the fungus *Cercospora beticola*, is characterized by spots that are brown to gray with distinct reddish-purple borders. The fungus overwinters in residue from diseased plants or on seed and is spread by splashing water, insects, tools and implements used for cultivation, workers, and wind. High humidity and moderate temperatures promote disease development.

PHOMA HEART-ROT, caused by the fungus *Phoma betae*, is characterized by seedling damping-off, leaf spots, and root rots. Leaf spots are light brown, have poorly defined margins, and can enlarge to about 1 inch in diameter. Root rots begin as water-soaked areas that turn brown and finally black. Rots are dry and firm unless invaded by soft-rot bacteria. The causal fungus overwinters on seed and in residue from diseased plants, and is spread by splashing or running water. Plants weakened by adverse growing conditions are most likely to be affected.
ROOT ROT COMPLEX is caused primarily by *Pythium ultimum* with *Rhizoctonia solani* as a secondary invader or as a primary invader in older beets. Symptoms include preemergence and postemergence damping-off, root rot, stem rot, and external and/or internal dry rot of fleshy roots. *Pythium* and *Rhizoctonia* fungi are natural inhabitants of soil. Root rot is most prevalent in cool wet soil, in fields planted yearly to beets, and in plantings exhibiting poor vigor.

**SCAB**, caused by *Streptomyces scabies*, the same fungus that causes potato scab, is characterized by corky spots on the surface of beet roots. Acidity levels above pH 5.2 promote fungus growth and disease development.

**BORON DEFICIENCY** causes black spots inside beet roots and large black dry rots on the root surface. Dead cross-hatched areas may appear on the inner concave surface of leaf stalks; young unfolding leaves may turn brown or black and die. A heart-rot may develop in the root where leaves were killed. Also, dead areas may develop at cambial rings within fleshy tap roots. Boron deficiency is most prevalent in alkaline soils high in calcium, and is promoted by dry conditions.
CARROTS

LEAF SPOTS are caused by the fungi *Cercospora carotae* and *Alternaria dauci* and by the bacterium *Xanthomonas carotae*.

Cercospora leaf spots are brown to gray and are more prevalent on young foliage than on old foliage. Alternaria leaf spots generally are dark brown to black and are more prevalent on older foliage than on young foliage. Xanthomonas leaf spots are similar to Alternaria leaf spots; the two cannot be distinguished without microscopic examination. Yellow margins may be present around spots caused by each organism. The fungi and bacteria are seed- and soil-borne. *Cercospora* and *Alternaria* spores are spread by wind. *Xanthomonas* cells and also the fungus spores are spread in splashing and running water, wind-blown soil, and on implements. *Cercospora* and *Alternaria* can infect leaves only when they are wet. *Xanthomonas* can infect leaves when the relative humidity is high (90 to 100%) for a 2- to 3-day period.

ROOT KNOT infected carrots may have forked roots and irregular round galls and spindle-shaped enlargements on the tap and side roots. These symptoms are caused by the same kind of root knot nematode (microscopic worm) that causes root galling on tomatoes, cucurbits, lettuce, and other vegetable crops. Several species of the root knot nematode (*Meloidogyne* spp.) may be involved. Only the northern species (*M. hapla*) is thought to overwinter in northern areas exposed to cold winter temperatures.

ASTER YELLOWS of carrots, caused by a mycoplasma, is characterized by production of yellowish dwarfed leaves, usually arranged in a tight rosette. Older leaves may develop reddish margins. The root at the crown bulges up into a cone and hair-like roots develop on the taproot. The mycoplasma overwinters in many perennial weeds and is spread by leafhoppers.
STORAGE ROTS of carrots are caused by fungi and bacteria. In a New York study, crater rot caused by the fungus *Rhizoctonia carotae* caused the most rot during the first 4 months of storage. During the latter half of the storage period, most of the rots that developed were gray mold caused by *Botrytis cinerea*, crown rot caused by *Rhizoctonia* sp., and black rot caused by *Stemphylium radicinum*. Other storage rots include bacterial soft rot caused by *Erwinia* spp. of bacteria, cottony (watery) soft rot caused by *Sclerotinia sclerotiorum*, wooly soft rot caused by *Rhizopus* spp., Fusarium dry rot caused by *Fusarium roseum*, and licorice rot caused by *Centrospora acerina*. The New York study revealed that the single most important factor affecting losses from storage rots was speed of cooling after harvest. The more rapidly carrots were cooled to the 31 or 32°F storage temperature, the less rot that developed. Soil moisture conditions and mechanical injury also affected incidence of rot. More rot developed in stored carrots from poorly drained than from well-drained soil. Carrots mechanically injured during harvest and during preparation for storage were more likely to develop rot. High relative humidity, a requirement for long-term storage, did not result in excessive rot in carrots cooled promptly after harvest. Storage crates were not an important source of disease organisms.
LEAF BLIGHTS most important on celery are caused by two fungi: i) Cercospora apii, ii) Septoria apiicola. Both fungi overwinter on and in affected seed and in residue from diseased plants. Wet weather promotes fungus reproduction. Splashing rain is important for the spread of Septoria, whereas air currents are important for spread of Cercospora. Both Septoria and Cercospora can be spread by movement of workers, animals, and implements through fields.

a. Cercospora Blight appears first as yellow spots visible on both sides of the foliage. These spots enlarge rapidly, become ashen-gray in color, take on a dry papery texture, and usually do not have a distinct margin. Black specks do not develop within leaf spots caused by Cercospora. A few spots are sufficient to kill a leaf. Similar symptoms develop on stems and leaf petioles.

b. Septoria Blight symptoms include a yellowish speckling which turns tan to yellowish gray with time. The spot margins may be slightly darker. Spot size is variable with a maximum diameter of about 1/2 inch. A diagnostic characteristic of Septoria blight is the presence of very small, widely separated black pycnidia (speck-like fungus reproductive structures) associated with, and usually within, spots. Both leaves and petioles are affected.

BLACK-HEART, caused by calcium deficiency within the plant, affects center leaves. The first symptom is water-soaked tips on the youngest leaves. These areas turn brown and may enlarge until all leaves and petioles near the center of the plant are affected. Black-heart results when insufficient calcium is available to the plant. The disease appears to be promoted by dry conditions and by potassium levels that are high in relation to calcium levels.
12 CELERY

PINK ROT, caused by the fungus Sclerotinia sclerotiorum, describes symptoms that develop on mature celery. In addition, the fungus causes damping-off in infested seedbeds. The pink rot phase is characterized by rapid development of basal crown and petiole rot. Plants appear to suddenly wilt and collapse in the field. This rotted area is watery, pinkish, and in moist conditions may become covered with conspicuous white mold which sometimes contains hard black sclerotia (pea-sized fungal reproductive structures). The sclerotia persist for many years in soil. The disease develops best under moist conditions in cool to moderate temperatures (up to about 77°F).

BACTERIAL SOFT ROT is caused by Erwinia carotovora and some other bacteria. Affected areas appear water-soaked, develop a soft decay, and have a distinctive foul odor. The bacteria usually infect plants through wounds or other injured areas. Warm wet conditions promote disease development.

YELLOWS, caused by the fungus Fusarium oxysporum f. sp. api, is characterized by plant stunting and yellowing. Plants tend to be brittle and taste bitter. Water-conducting tissue, exposed by splitting the plants vertically through the crown and petioles, may be yellowish-brown to red. As the disease progresses crowns and roots may rot. Continuous celery culture permits the fungus to build up in the soil. The disease is most destructive during warm seasons. Yellows was an important celery disease until resistant varieties became available in 1952. Recent reappearance of the disease in California suggests development of a strain of the fungus that can infect some varieties previously considered resistant.
**Nematodes** (microscopic worms) may cause plants to be stunted, of poor color, and prone to wilting during moisture stress. Above-ground symptoms result from nematodes attacking the roots. Different nematodes cause different root symptoms. Root knot nematodes (*Meloidogyne* spp.) cause distinct swellings on the roots. Several other nematodes including *Pratylenchus* sp. and *Paratylenchus* sp. cause root stunting and discoloration. Most nematodes can persist in soil for several years. Symptom severity depends on nematode population levels in the soil, growing conditions, and age of the plant.

**Rhizoctonia stalk rot**, caused by *Rhizoctonia solani*, is characterized by sunken, brick-red lesions on the stalks and at the base of plants.

**Mosaic** can be caused by several viruses including cucumber mosaic virus (CMV) and celery mosaic virus (CeMV). Symptoms caused by these two viruses are similar and it may be difficult to distinguish the two diseases on the basis of symptoms.

a. **Cucumber Mosaic Virus** causes a mottling of celery leaflets and sunken, buff-colored streaks and spots on petioles. CMV has a wide host range and overwinters in many cultivated and wild plants. CMV is spread by aphids and by mechanical means.

b. **Celery Mosaic Virus** infected plants usually are stunted and have a flattened appearance. Leaflets often exhibit a prominent mosaic, although sometimes only a faint mottle will appear. Leaflets often are considerably more narrow than normal. Sometimes the leaflet margins curl upward and raised areas occur on upper leaf surfaces. Foliage on some plants is yellow or bronze. Petiole mottling frequently appears as light patches against a darker background. CeMV affects only celery, carrot, and closely related weeds. CeMV is spread by aphids and by mechanical means.
CRUCIFERS

Cabbage, Cauliflower, Broccoli, Brussels Sprouts, and Turnip

WIRESTEM, BOTTOM ROT, and HEAD ROT are caused by *Rhizoctonia solani*. This fungus also is a common cause of damping-off. Wirestem is characterized by stems that are darkened and girdled near the soil line. Affected plants are weak, produce small heads, and sometimes wilt and die. Bottom rot develops on plants after they have been transplanted to the field. Dark slightly sunken spots develop on basal leaves near the soil. In moist conditions and in storage, rot spreads to adjacent leaves and causes a head rot. The causal fungus is present in all field soil. Disease is promoted by moist conditions.

WHITE ROT is caused by the fungus *Sclerotinia sclerotiorum*. Symptoms can appear on leaves or petioles nearest the ground or on the top of cabbage heads. Infected areas first appear as water-soaked spots; these soon enlarge to irregular-shaped areas which become covered by white mold. The fungus grows upward over the maturing plant, often producing a soft water-soaked mass. Numerous black sclerotia (seed-like fungus reproductive structures) form on and in diseased parts. Severely affected plants may wilt or topple. Sclerotia produced by the fungus can survive in soil for many years.
**ALTERNARIA LEAF SPOT**, caused by the fungus *Alternaria brassicae*, is characterized by distinct spots with concentric rings on the lower leaves; the dark dusty fungus growth develops on these spots during moist periods. During storage, spots enlarge. Soft rot bacteria may enter through dead leaf spots. The fungus overwinters in seed and in residue from diseased plants. Wet conditions promote disease development.

**BLACK LEG** is caused by the fungus *Phoma (Plenodomus) lingam*. Symptoms begin as dark sunken cankers at the base of the stem and as light brown circular leaf spots. Stem cankers enlarge and girdle stems, causing plants to wilt. A diagnostic feature of black leg is the presence of distinct black pycnidia (speck-size fungus reproductive structures) within stem cankers and leaf spots. The causal fungus overwinters on seed and in residue from diseased plants; the fungus can persist in residue for 2 to 3 years. The fungus can be carried on seed and on transplants; it can be spread within fields when diseased and healthy plants are dipped in the same water, when workers and implements move through fields that include diseased plants, and by splashing and running contaminated water.
DOWNY MILDEW, caused by the fungus *Peronospora parasitica*, is most serious in seedbeds and appears as small leaf spots which first are yellow and later turn brown with bluish-black lace-like markings. In moist weather, a white downy mold develops on the underside of the leaf spots. Vascular tissue becomes discolored. In turnip and radish, roots also can be affected. They become discolored internally and during storage dry out more rapidly than do roots from plants free of mildew. The causal fungus overwinters on seed, in crucifer weeds, and perhaps in soil. Disease is promoted by cool wet weather in spring and fall. Downy mildew can predispose plants to bacterial soft rot.

BLACK ROT, caused by the bacterium *Xanthomonas campestris*, affects young as well as mature plants. Affected seedlings turn yellow and die. On older plants, yellow wedge-shaped areas appear at leaf margins and expand toward the center of the leaf; affected areas later turn brown and die. Vascular tissue is black in veins within affected areas. This discoloration develops from leaf margins toward the base of the plant. Heads are dwarfed and lower leaves fall off. Frequently symptoms are most severe on one side of the head. Soft rot often develops on affected heads. The black rot bacterium overwinters on seed and in residue from diseased plants; it persists in residue for 1 to 2 years. As with the black leg fungus, the black rot bacterium is seed-borne and is spread on seedlings and by movement of contaminated water.
FUSARIUM YELLOWS, caused by the fungus *Fusarium oxysporum* f. sp. *conglutinans*, is most severe on susceptible cabbage varieties but also affects other crucifers. Affected plants have a sickly, dwarfed, yellow appearance. In affected leaves, edges frequently become purple and bases become brown. Lower leaves drop one by one. Vascular tissue in veins turns dark in affected sides of leaves and plants. This discoloration develops from the base of the plant toward leaf margins. The causal fungus can persist in soil for many years. Disease development is promoted by high soil temperatures.

CLUBROOT, caused by the fungus *Plasmodiophora brassicae*, causes wilting and yellowing of above-ground parts. The diagnostic symptom is the presence of large spindle-shaped galls on roots. The causal fungus is soil-borne and persists in soil for at least 7 years. Soil pH of less than 7.2 favors disease development.

EDEMA appears as small brownish gray wart-like growths on the leaf surface. These growths are thought to be initiated by leaf injury caused by sand or insects. Edema usually develops during cool nights following warm muggy days. Under these conditions water uptake is faster than water loss; consequently, the leaf epidermis bursts and expanding leaf cells are exposed and become corky.

BACTERIAL SOFT ROT is caused by *Erwinia carotovora* and some other bacteria. Affected areas appear to be water-soaked, develop a soft decay, and have a foul distinctive odor. Affected cabbage and cauliflower heads decay rapidly and turn dark. The bacteria usually infect plants through surface areas injured by insects, cold, or mechanical means. Warm wet conditions promote disease development.
CUCURBITS

Cucumber, Muskmelon, Cantaloupe, Watermelon, Squash, and Pumpkin

POWDERY MILDEW, caused by the fungus *Erysiphe cichoracearum*, affects cucumber, muskmelon, pumpkin, and squash. It is caused by a fungus that appears as a white powdery growth on leaves. Crown leaves are affected first and may wither and die. The fungus can be introduced on greenhouse-grown plants or by wind from areas with relatively warm winter climate where the fungus can overwinter. Disease development is favored by high temperatures.

DOWNY MILDEW on cucumber and muskmelon is caused by the fungus *Pseudoperonospora cubensis*. Irregularly shaped yellowish to brown spots appear on upper sides of leaves, usually at the center of plants. Under moist conditions, a purplish mildew develops on the underside of leaf spots. Leaves die as spots increase in size. Spread is rapid from the crown toward new growth. The causal fungus overwinters in areas with a relatively warm climate and can be introduced to other areas by wind. Moist conditions favor disease development.

TARGET SPOT, caused by *Corynespora cassicola*, is similar to downy mildew in appearance. Leaf spots begin as small yellow flecks which become angular or as circular spots with light brown centers and dark brown margins. Spots vary from 1/8 to 3/8 inch in diameter. Lesion coalescence may result in large areas of dead tissue, which may shred and fall out.

CERCOSPORA LEAF SPOT, caused by *Cercospora citrullina*, affects cantaloupe and watermelon. Leaf spots are small, dark brown to black with a white center, and may have a yellow halo.
ALTERNARIA LEAF SPOT, caused by the fungus *Alternaria cucumerina*, occurs primarily on muskmelons but also on cucumbers and other cucurbits. Leaf spots are small, circular, and water-soaked at first, and then expand up to 1/2 inch in diameter with dark concentric rings within the spots. Spots coalesce to affect large areas of leaves and cause defoliation that begins on crown leaves. This disease-causing fungus overwinters on and in seed, as well as in residue from diseased plants. Fungus spores (reproductive structures) are spread by wind, by running and splashing water, on workers, and on tools and implements. Weak and senescing plants are more susceptible to Alternaria leaf spot than are vigorous plants.

ANTHRACNOSE, caused by the fungus *Colletotrichum lagenarium*, affects cucumbers, muskmelons, and watermelons. Muskmelon and cucumber leaf spots begin as yellowish or water-soaked areas that enlarge rapidly, turn brown, and shatter to form a ragged hole within the spot. Leaf spots on watermelons turn black. Elongated dark spots with light centers often develop on petioles and stems and can cause death of tissue beyond these spots. Young fruit may be killed, but large fruit usually develop depressed dark-bordered cankers with creamy pink-colored ooze in the center. The fungus overwinters in seed and in residue from diseased plants, and is spread in splashing water. Humid weather and frequent rains promote disease development and spread.
ANGULAR LEAF SPOT, caused by the bacterium *Pseudomonas lachrymans*, affects cucumber, squash, and pumpkin and is characterized by conspicuous leaf symptoms. Stem and fruit symptoms occur, but are less conspicuous. Leaf spots are angular and irregular in shape and size. Spots, water-soaked at first, later turn gray or tan and finally drop out, leaving ragged holes. Fruit infections appear as small sunken water-soaked spots; fruit rot soon follows. Bacteria which cause this disease overwinter on seed and persist in crop residue from diseased plants. Splashing rain and workers spread the bacteria within fields.

SCAB, caused by the fungus *Cladosporium cucumerinum*, affects muskmelons and susceptible cucumber varieties. Dry corky spots, up to 1/2 inch in diameter, develop on cucumber and green muskmelon fruit. Under moist conditions a dark olive-green velvety growth covers the spot; this growth distinguishes scab from angular leaf spot on cucumber fruit. Spots also develop on young terminal stem growth and on petioles. When spots girdle young stems and petioles, growth beyond the spot dies. Affected areas on very young leaves are irregular in shape; the areas dry up. The disease-causing fungus overwinters on seed and in residue from diseased plants. Disease development is promoted by moist humid conditions and by cool night temperatures.
**PYTHIUM COTTONY LEAK** is caused by *Pythium aphanidermatum*. The fungus can cause damping-off or vine cankers during unusually wet seasons, but fruit rot usually is the most prevalent symptom. The fungus penetrates fruit wounds and old flower parts, as well as plant parts touching the soil. Fruit rot begins as a dark green water-soaked area. Wet mushy rot develops rapidly and may become covered with white cottony mold during wet weather. The fungus will spread by fruit-to-fruit contact and can cause rapid fruit rot in transit.

**BELLY ROT** is caused by *Rhizoctonia solani*, a common soil-borne fungus. The rot develops on the belly (that area of the fruit in contact with the soil) of the cucumber fruit. Young fruit exhibit a yellowish brown superficial discoloration which develops into sunken irregular spots on the underside of the fruit. Large water-soaked decay areas develop on mature fruit. Belly rot proceeds rapidly at temperatures exceeding 82°F; in periods of high humidity, a dense mold growth may develop on fruit spots.

**CHOANEPHORA WET-ROT**, caused by the fungus *Choanephora cucurbitarum*, is a summer squash fruit rot that affects wilted blossoms and spreads to attached fruit. Infected fruit rot rapidly and fungus mold appears on the rotted area. The fungus growth resembles small black-headed pins stuck into the fruit. The disease-causing fungus is spread by insects, wind, and splashing water. Disease development is promoted by high-moisture conditions.

**FUSARIUM FRUIT ROT** on muskmelons usually is caused by *Fusarium roseum*, a soil-borne fungus. Usually, ripe fruit are affected. The fruit spots are from 1/2 to 1 inch in diameter and about 1/2 inch deep. Internal rotted tissue is whitish to rose-colored, dry and spongy; this rotted tissue can be removed easily from surrounding unaffected tissue. White mold develops on the surface of the fruit spot during wet conditions and during storage.
**BLACK ROT and GUMMY STEM BLIGHT** apparently are caused by the same fungus, *Didymella bryoniae* (also called *Mycosphaerella melonis*). Different symptoms develop on different cucurbits. Winter squash, pumpkins, and gourds are affected most by black rot. Black rot starts as irregular circular fruit spots that are faded green or yellow, later gray to brown, and finally black. The fungus penetrates the rind and causes a dry rot. Other rot organisms may follow and cause a wet rot that affects the entire fruit. Muskmelons, cucumbers, and watermelons are affected most by gummy stem blight, which begins as pale brown or gray spots on leaves, petioles, and stems. Stem spots appear first at the nodes and elongate into stem streaks; a gummy exudate frequently appears near stem streaks. Leaves on affected vines turn yellow and die. Entire plants occasionally are killed. Tiny black pycnidia (pimple-like fungus reproductive structures) develop on fruit, stem, and leaf spots. The fungus overwinters in seed and residue from diseased plants.
MOSAIC VIRUSES are important on muskmelons, summer squash, and cucumbers. Three viruses that affect cucurbits are cucumber mosaic virus (CMV), watermelon mosaic-2 (WM-2), and squash mosaic virus (SqMV). CMV affects many vegetables and other plants unrelated to cucurbits. WM-2 affects legumes in addition to cucurbits. Vines on mosaic-infected plants are stunted, and new leaves are dwarfed, mottled, and sometimes distorted. On CMV-infected muskmelons and cucumbers, new leaves sometimes wilt and die; old crown leaves may turn yellow and dry up, resulting in a slow decline of affected plants. CMV and WM-2 overwinter in some biennial and perennial plants and usually are carried to new plantings by aphids. SqMV overwinters and is introduced to new plantings in infected seed. Within plantings, CMV is spread chiefly by aphids (but also by cucumber beetles), WM-2 is spread by aphids, and SqMV is spread by cucumber beetles and workers.
BACTERIAL WILT, caused by the bacterium *Erwinia tracheiphila*, is characterized initially by wilting and drying of individual leaves which also may exhibit cucumber beetle injury. Later, leaves on one or more laterals or entire plants wilt. Wilted parts may appear to recover at night, but they wilt on successive sunny days and finally die. Two diagnostic tests for bacterial wilt are as follows:

   i) Cut a wilted stem near the crown and squeeze sap from the newly cut stem, watching for a white exudate from the vascular bundles. Then touch a clean knife blade to the cut surface and slowly withdraw the blade from the stem. Watch for a white ooze that strings out in a fine thread between the newly cut stem surface and the knife.

   ii) Put two cut ends together and squeeze; then separate the ends and look for sticky strands. Presence of the white exudate and stringing out of this ooze is a positive test for bacterial wilt.

Positive test results appear to be easier to obtain for cucumber and for some squash than for muskmelon. The disease is more prevalent on cucumber and muskmelon than on pumpkin and squash. Wilt-causing bacteria overwinter in cucumber beetles. The bacteria are carried to plants when beetles feed.

FUSARIIUM WILT OF MUSKMELON, caused by the fungus *Fusarium oxysporum f. sp. melonis*, is characterized by stunting, yellowing, wilting, and dying of vines. A streak, at first water-soaked and later turning yellow to tan and finally dark brown, often appears at the soil line on one side of the vine; this symptom is diagnostic. The disease-causing fungus survives in soil for many years. High soil temperatures favor disease development.
LATE COLLAPSE OF MUSKMELON is characterized by a sudden collapse of plants. Collapse occurs on bright sunny days late in the season following heavy rains and cold nights that cause a significant drop in soil temperature. Temperatures of 60°F or lower at the 4-inch soil depth have been correlated with the collapse. Collapse can be severe after cool wet weather because i) the soil cools to the critical level quickly, and ii) cool wet weather favors root rotting, an additional stress that promotes wilting.

FUSARIUM WILT OF WATERMELON, caused by *Fusarium oxysporum* f. sp. *niveum*, is characterized by seedling damping-off, and by stunting, wilting, and death of established plants. Wilt symptoms develop in one or more laterals, usually starting at vine tips, and continue until the plant dies. Vascular tissue may be discolored, and a white mold may develop on dead vines. The disease-causing fungus is soil-borne and can persist in soil for many years. The fungus can be introduced on seed or in soil that is transported by equipment, drainage water, or workers.

ROOT KNOT, caused by the *Meloidogyne* nematode, appears as swellings on roots. The disease is discussed with tomato diseases.
VERTICILLIUM WILT, caused by the fungus Verticillium spp., is a prevalent and destructive eggplant disease. It causes stunting of plants and interveinal yellowing, wilting, and dying of leaves. Plants usually survive in this condition, but a few may die. Woody tissue in the lower stem is discolored brown. The disease is caused by the same soil-borne fungus that causes wilt of tomatoes, potatoes, strawberries, and brambles. The fungus is able to persist in soil for many years. Presence of root knot or root lesion nematodes may increase disease severity.

SOUTHERN BLIGHT, caused by the fungus Sclerotium rolfsii, is characterized by softening of crown and external root tissue. Fungus mold and tiny brown sclerotia (fungus reproductive structures) grow over the base of the stem and nearby soil. This disease is discussed with pepper and tomato diseases.
**PHOMOPSIS BLIGHT**, caused by the fungus *Phomopsis vexans*, affects all above-ground plant parts at all stages of development. Spots generally appear first on seedling stems or leaves. Spots may girdle seedling stems and kill the seedlings. Leaf spots are clearly defined, circular, up to about 1 inch in diameter, and brown to gray with a narrow dark brown margin. In time the center of the spot becomes gray, and black pycnidia (fungus reproductive structures that appear as small specks) develop in this area. Affected leaves may turn yellow and die. Fruit spots are similar to those on leaves but are much larger; affected fruit are first soft and watery but later may become black and mummified. *Phomopsis* persists on and in seed, and overwinters in residue from diseased plants. It is spread by splashing water. Disease is promoted by wet weather and high temperatures.

**ANTHRACNOSE FRUIT ROT**, caused by the fungus *Colletotrichum* sp., appears as small spots on ripe fruit. Fruit spots are sunken and, although variable in size, usually are less than 1/2 inch in diameter. Fruit with many spots will drop from the plant, leaving the pedicel still attached. The anthracnose fungus overwinters in soil and in residue from diseased plants.

**ALTERNARIA BLIGHT**, caused by the fungus *Alternaria solani*, occurs on eggplant as well as tomato. Leaf spots are dark and leathery and range up to 1/3 inch in diameter. When spots are numerous, leaves die prematurely and drop. Fruit also may be spotted.
LETTUCE

RHIZOCTONIA BOTTOM ROT, caused by the fungus *Rhizoctonia solani*, starts on leaves next to the ground and later progresses into the head. Affected areas become dark brown and slimy, but later may dry out—leaving an erect mummified plant. *Rhizoctonia* persists in field soil. Disease is promoted by moist conditions.

DOWNY MILDEW, caused by the fungus *Bremia lactucae*, affects seedlings and mature plants. Symptoms appear first on oldest leaves. Yellowish or light green blotchy areas appear on the upper sides of leaves. A white downy mold then appears on the undersides of the leaf spots; finally the affected areas die. The fungus overwinters in residue and in wild lettuce plants. Fungus spores are spread by wind. Spore production is favored by temperatures cooler than 65°F and by relative humidities approaching 100 percent.

SCLEROTINIA DROP symptoms, caused by the fungus *Sclerotinia sclerotiorum*, begin on the stem near the soil surface. A severe wet rot develops rapidly and spreads downward to the roots and upward through the head. Once the base of a leaf is rotted, the leaf wilts, withers, and dies. These symptoms successively develop from outer leaves to inner leaves. The head becomes a wet slimy mass. During wet conditions a white cottony mold develops on rotted plant parts; hard irregular black sclerotia (pea-sized persistent fungus structures) may be present in the mold. *Sclerotinia* reproduces in soil planted to susceptible crops (such as tomatoes, cabbage, celery) and then can persist as sclerotia for many years in soil. Wet conditions favor disease development.

BOTRYTIS GRAY MOLD, caused by the fungus *Botrytis cinerea*, appears on plants at all stages of maturity. Affected seedlings look like they have damping-off. On older plants, rot begins on the stem or on lower
leaves where they touch the soil; a slimy rot spreads upward into the head. The diagnostic feature of gray mold is development of a dense fuzzy gray mold on exposed surfaces of affected areas. Dark hard sclerotia (pea-like structures that function as overwintering fungus "seeds") may develop on affected heads. *Botrytis* is present wherever plants are grown. Disease development is favored by moist conditions.

**ASTER YELLOWS**, caused by a mycoplasma, is characterized by a yellowing and curling of the youngest leaves. At heading time, heart leaves remain dwarfed and curled and heads remain soft. The mycoplasma overwinters in many perennial weeds and is spread to lettuce by leafhoppers during their feeding activities.

**MOSAIC** can be caused by several viruses, including lettuce mosaic virus (LMV) and cucumber mosaic virus (CMV). Symptoms caused by these viruses are similar. Infected plants are stunted, yellowish, and do not head properly. LMV is seed-borne; CMV overwinters in many perennial wild and cultivated hosts. Both viruses are spread by aphids and by mechanical means.

**BIG VEIN**, a disease characterized by virus-like symptoms, may be caused by a viroid (a type of infectious nucleic acid). Young plants that are infected develop a characteristic clearing of the area around leaf veins; these plants remain small and stunted and never produce marketable heads. In more mature plants, a distinctive clearing or yellowing of tissue next to major veins appears. These plants appear to have "big veins." Infected plants are more upright than usual and leaves are ruffled. The causal agent is soil-borne; a water mold, *Olpidium brassicae*, is the vector. The causal agent persists in soil for at least 10 years. Symptoms develop best between 42 and 60°F; at higher temperatures, leaf symptoms fade.
ONIONS

PURPLE BLOTCH, caused by the fungus *Alternaria porri*, may develop where white specks associated with *Botrytis* blight are present on leaves. Purple blotch begins as water-soaked spots which rapidly turn brown. As spots expand they become zonate, purplish with a darker margin surrounded by a yellow zone, and may attain a size of 1 by 2 inches. In moist weather, spots become covered with a brown dusty-appearing mold. Affected leaves and seed stalks may break over where large spots are present. The fungus overwinters in residue from diseased plants. Long periods of rain or heavy dew promote disease.

DOWNY MILDEW, caused by the fungus *Peronospora destructor*, infrequently appears on young plants as white specks resembling *Botrytis* blight. Symptoms usually appear after leaves are 6 inches long and on oldest leaves first. On these leaves, a white to purplish mold develops on elongated leaf spots during cool moist weather. The spots become pale green, then change to white or tan. As leaves are affected down to the leaf sheath, they drop over and dry up. The downy mildew fungus overwinters in onion bulbs and sets and in residue from diseased plants. Fungus spores (microscopic fungus "seeds") are spread by air currents. Cool moist weather promotes disease development.

BOTRYTIS LEAF BLIGHT (BLAST) symptoms, caused by *Botrytis* spp., appear first as numerous white specks on the leaves. As spots expand, the leaves die from the tips and turn brown. Plant tops may be killed and topple over within a week; all plants in a field may be affected. *Botrytis* spp. are present in all fields where plants are grown. Fungus spores (microscopic dry reproductive structures) are spread by air currents and wind. Leaf blight frequently develops where leaf tissue has been injured by thrips, mildew, ozone, sand blasting, or other agents.
WHITE ROT, caused by the fungus *Sclerotium cepivorum*, appears first on leaves. Yellowing and die-back progress from leaf tips downward. Below ground, a wet rot develops on roots and at the bulb base. Affected plants may be pulled easily from the soil because most roots are destroyed. A white superficial fluffy mold develops on and in affected bulbs. Tiny black sclerotia (fungus reproductive structures), about 1/50 of an inch in diameter, form on the mold and in the bulb. Sclerotia persist in soil for many years and can be spread with soil in running water, on implements, and with seedlings. Disease is most prevalent in cool seasons and in poorly drained areas.

FUSARIUM BASAL ROT, caused by *Fusarium* spp. of fungi, appears in the field and in storage. The fungus can attack crowns and roots in the field following injury or infection by other disease-causing organisms. When this occurs, tops may turn yellowish and wilt. Diseased bulbs may not have visible outward symptoms; dry outer scales appear normal but the inner neck tissue may feel soft. One or more inner scales may be water-soaked and later turn brown; white mold develops between diseased scales during moist conditions. When conditions are dry, diseased tissue is firm, dried and shriveled. When conditions are moist, other organisms may cause a soft watery rot. Symptoms develop slowly and although most infection likely occurs in the field, symptoms may not appear until storage. The basal rot *Fusarium* spp. persist in soil and are spread in water, soil, air, and on insects and implements. The fungus usually enters plants through areas injured by maggots, burned by fertilizer, bruised during harvest, or infected by fungi which cause smut or pink root. Disease is most severe when onions are grown in poorly drained soil and stored where humidity is high.
BOTRYTIS NECK ROT, caused by Botrytis spp. of fungi, is seldom seen in the field; symptoms usually are first noticed in storage. The neck tissue may shrivel. In cross-section, the scales appear as if they have been cooked; tissue is soft and brownish. A gray powdery-appearing mold may appear between the scales and small black sclerotia (hard pea-like structures) may form on dried scales. Soft rot bacteria may follow neck rot and cause the onion to become soft, watery, and foul-smelling. Botrytis spp. are present wherever plants are grown. Neck rot develops only on onions that are injured or diseased. Infection is promoted by prolonged wet conditions.

BACTERIAL SOFT ROT, caused by Erwinia carotovora and Pseudomonas spp. of bacteria, usually begins in the field but appears in storage. The bacteria enter onion neck tissue through dead or senescent leaves and move down through individual scales into the bulb. Water may drip from the neck when affected tissue is pressed. Affected tissue is wet, slimy, and foul-smelling. Soft rot bacteria live in soil and can be spread by maggots, implements, or workers to the injured or weakened onion tissue during the growing season. Infection occurs most frequently and disease development is most rapid in moist conditions.

SMUDGE, caused by the fungus Colletotrichum circinans, usually appears as a dark green or black smudge, up to about 1 inch in diameter, on the bulb or neck. The spot may be uniformly black but usually is composed of dark concentric rings. The dark portion is covered with stiff bristles. The fungus overwinters on sets and in soil. Spores, produced by the fungus when it is actively growing, are spread by wind, splashing water, and on tools and clothing. Disease development is promoted by fairly wet soil and temperatures of 75 to 85°F.
SMUT, caused by the fungus *Urocystis cepulae*, appears as gray-colored streaks on leaves, leaf sheaths, and bulbs. The streaks are filled with dusty fungus spores. Affected leaves twist and bend and seedlings may be killed. Only immature tissue is susceptible. This includes young initial leaves and also young tissue protected within the sheath at the base of the plant. Immature tissue enclosed in the sheath can become infected only from an outer scale that is diseased. Therefore, smut-free sets and seedlings will remain disease-free, even in smut-infested soil. The smut fungus overwinters in smut-infested soil. Disease development is promoted by cool soil conditions.

PINK ROOT is caused by the soil-inhabiting fungus *Pyrenochaeta terrestris*. Affected roots turn pink, shrivel, and die. New roots continue to be killed. Plant tops may be little affected but bulbs are reduced in size. The fungus lives indefinitely in soil and is spread with soil. Disease is able to develop under a wide range of moisture and temperature conditions.

CANKER and LEAF SPOT are caused by the same fungus, *Itersonilia perplexans*. Leaf spots appear as small silvery areas. These areas enlarge to irregular shapes and become brown with an indistinct dark border. Cankers are most prevalent near the shoulder of the root. The cankers begin where rootlets are attached to the taproot. Affected areas are first brown to reddish-brown; they later become black as cankers develop and as affected areas become depressed. The causal fungus overwinters in "field-stored" parsnips and possibly in residue from diseased plants. Disease is promoted by cool wet conditions.
ROOT ROTs are caused by several specific soil fungi. These fungi cause conspicuously discolored and rotted areas on the main root and at the base of the stem. It is difficult to distinguish between root rots caused by these fungi. Several fungi may cause root rot on the same plant. Specific symptoms, characteristic for some root rots, are noted below. Diseases are named after the organism that causes the rot.

These root-rot fungi persist in soil and in residue from diseased plants. In addition, Ascochyta is seed-borne. Excessive soil moisture, whether from heavy rainfall or from poor drainage, favors root rots. Root rots are more likely to develop on weak, slow-growing plants than on those that are vigorous and more rapid in growth.

a. Aphanomyces Root Rot, caused by the fungus Aphanomyces euteiches, is characterized by water-soaking, softening, and slight discoloration of the taproot and lower stems. Often the outer root tissue can be readily slipped from the central woody root tissue.

b. Fusarium Root Rot symptoms, caused by the fungus Fusarium solani f. sp. pisi, appear on the stem below the soil line just above the region of seed attachment. Affected stem areas turn reddish to dark brown. Internal woody stem tissue sometimes turns brick red.

c. Rhizoctonia Root Rot symptoms, caused by the fungus Rhizoctonia solani, usually begin underground on the stem and on roots. Affected areas are brown to reddish brown, sunken, and eroded.

d. Ascochyta Root Rot symptoms, caused by Ascochyta spp. of fungi, begin as purplish streaks above and below ground on the stem, and particularly at nodes. Streaks enlarge into dark brownish purple areas which may girdle the stem and extend several inches above the soil surface.

FUSARIUM WILT and NEAR-WILT are two major wilt diseases caused by different races of the fungus Fusarium oxysporum f. sp. pisi. Symptoms and controls for these two wilts differ, although they are caused by related fungi. Fungi that cause both diseases can be introduced with the seed. Once present, these fungi persist indefinitely in soil.

Fusarium wilt often is detected by appearance of yellowing of lower leaves and stunting of plants. Leaflet margins curl downward and inward. The stem may be slightly swollen and brittle near the soil line. Internal woody stem tissue often is discolored, turning lemon brown to orange brown. Externally, the root system appears healthy; however, secondary root rots are likely to occur on plants wilted for long periods. Eventually, wilted plants may die.

Near-wilt symptoms are similar to Fusarium wilt symptoms. However, near-wilt plants die more slowly than
do Fusarium wilt plants. Also, internal woody stem tissue usually is brick-red in near-wilt plants. This discoloration extends throughout the plant.

**BLIGHTS** of greatest significance are Ascochyta blight and bacterial blight.

**a. Ascochyta Blight** is caused by any of three *Ascochyta* spp. of fungi. Symptoms develop on stems, roots, leaves, and pods. Black to purplish streaks develop on stems. Streaks are most conspicuous at the nodes and they enlarge into brown or purplish irregular-shaped areas from the root zone to about 10 inches up the stem. Root-rot symptoms are as described for Ascochyta root rot. Leaf spots are gray to purplish and may be very small and irregular or large and circular. Dark concentric rings sometimes form in leaf spots. Severely affected leaves may shrivel and die. Pod spots are gray to purplish, lack concentric rings, and are sunken. The blight-causing fungi are seed-borne. Abundant rainfall favors disease development and spread.

**b. Bacterial Blight**, caused by the bacterium *Pseudomonas pisi*, affects all above-ground plant parts. Seedlings from infected seed may die. On older plants, water-soaked spots develop on pods, stems, and leaves. In wet weather, spots enlarge and a white to cream-colored slimy ooze may collect on the spot surface. In dry weather, leaf spots dry up, turn brown, and become papery. Disease-causing bacteria overwinter in seed and are introduced into fields via seed. The bacteria probably do not overwinter in residue from diseased plants.
POWDERY MILDEW, caused by the fungus *Erysiphe polygoni*, is characterized by a white powdery talcum-like mold on leaves, stems, and pods. Tiny dark perithecia (fungus reproductive structures) may develop among mold strands late in the season. When pods are affected, seeds may be discolored gray or brown; the fungus can be seed-borne. Reproductive spores formed on the white mold and in perithecia are spread by wind. Germination of spores from the white mold is promoted by humid conditions but not by wet conditions. Powdery mildew is more important in southern states than in northern areas, presumably because fungus spores are available continuously in southern areas. In northern areas, powdery mildew is initiated by fungus structures introduced on seed or blown in by wind.

VIRUSES cause four important pea diseases. Each disease is caused by a different virus and has its own symptoms. Viruses that cause these diseases overwinter in certain plants (e.g., clovers, vetches, alfalfa) of the legume family. Aphids acquire virus from infected plants and transmit virus to other plants during their feeding activities.

a. Pea Enation Mosaic virus causes yellowish areas on leaves, blister-like ridges (enations) on undersides of leaves and on pods, pod distortion, and suture splitting.

b. Pea Stunt, caused by red clover vein mosaic virus, is characterized by light-colored veins, terminal rosetting, stunting, and poor pod set.

c. Bean Yellow Mosaic virus (BV-2) causes green and yellow mottle or mosaic patterns, and promotes growth from axillary buds.

d. Pea Streak, caused by a combination of the bean yellow mosaic and pea stunt viruses, is characterized by purplish brown flattened pods, purplish brown streaks on stems, death of veins, yellowing on some leaves, and eventual wilting and death of terminal growth.
PEPPERS

**BACTERIAL SPOT**, caused by the bacterium *Xanthomonas vesicatoria*, affects leaves and fruit of pepper and tomatoes. Leaf spots appear first on lower surfaces of leaves as small irregular water-soaked areas. Spots enlarge up to 1/4 inch in diameter, become purplish gray with black centers, and may have narrow yellow halos. Spots on upper surfaces of leaves are depressed; those on the lower surfaces are raised. Spotted leaves may become ragged. Uneven marginal leaf growth may cause twisting, and many leaves turn yellow and drop off, thus exposing fruit to direct sunlight which may cause sunscald. Fruit spots caused by the bacteria begin as water-soaked areas and then become raised and scab-like. The causal bacterium is seedborne. Seed and infected transplants are the principal sources of initial inoculum. The bacteria can survive for about a year in residue from diseased plants. Bacteria are spread from plant to plant by splashing water and by implements and workers in fields when foliage is wet. Disease development is promoted by moist conditions.

**CERCOSPORA LEAF SPOT**, caused by the fungus *Cercospora capsici*, is characterized by large circular or oblong spots on leaves and stems. Usually, spots have light-gray centers with dark brown margins and may be up to 1/4 inch in diameter. Severely affected leaves turn yellow and drop. The causal fungus is carried on seed and possibly survives one season in residue from diseased plants. Disease usually gets started in seedbeds. Disease development is promoted by prolonged periods of warm wet conditions.

**DOWNY MILDEW** is caused by *Peronospora tabacini*, a fungus that primarily attacks tobacco but occasionally affects pepper and eggplant in seedbeds. Affected seedlings may die. The fungus overwinters in soil. Spores may spread from tobacco seedbeds to pepper seedbeds. Moist cool conditions favor disease development.
SOUTHERN BLIGHT, caused by the fungus *Sclerotium rolfsii*, affects many vegetables, including beans, beets, cole crops, carrots, corn, cucurbits, eggplants, lettuce, onions, peas, peppers, potatoes, radishes, sweet potatoes, and tomatoes. Affected pepper plants wilt suddenly, turn yellow and finally brown. *Sclerotium* is a soil-borne fungus that attacks the crown of the plant. Crown tissue and external root tissue first become soft; fungus mold with tiny brown sclerotia (fungus reproductive and survival structures) then grows over the base of the stem and nearby soil. The fungus overwinters as sclerotia in soil. Southern blight is more important in southern areas than in northern areas.

PHYTOPHTHORA BLIGHT, caused by the fungus *Phytophthora capsici*, can affect all parts of the plant. Damping-off can develop on seedlings. Symptoms on older plants include root rot, stem canker, leaf blight, and fruit rot. Affected areas may be bordered by a white mold growth. Disease most frequently appears in the wettest areas of a field. Warm wet weather promotes disease development.

ANTHRACNOSE, caused by the fungi *Colletotrichum piperatum* and *C. capsici*, is characterized by circular sunken spots on green and ripe fruit. In moist conditions, pinkish to yellowish masses of glue-like spores, sometimes accompanied by tiny black bristles (setae), appear on the spots. The fungus overwinters on and in pepper seed, and in residue from diseased plants. Disease is promoted by wet conditions (heavy fog, dew, drizzle) and relatively high temperatures (90°F).

ALTERNARIA ROT is caused by a fungus, *Alternaria solani* or *Alternaria tenuis*. The fungus is reported to enter wounds (sunscald or punctures). Dusty black spores on fruit spots are characteristic.

BACTERIAL SOFT ROT, caused by the bacteria *Erwinia carotovora*, causes a depression at the fruit surface. Internal tissue rapidly becomes soft and watery. Soft rot bacteria usually are prevalent wherever fruit are grown and packaged; invasion usually is through a wound.
BLOSSOM-END ROT, caused by insufficient calcium when fruit are forming, develops at the blossom end of fruit and may affect up to half a fruit. Affected areas are first water-soaked but soon become dry, light-colored, and papery. Additional information is presented under blossom-end rot of tomato.

SUNSCALD, caused by intense sunlight, occurs on any part of the fruit exposed suddenly to direct sunlight. Wind whipping and leaf blights often provide conditions favorable for sunscald. Affected areas are first light-colored, soft, and slightly wrinkled; these areas later dry and become slightly sunken, whitish, and papery. Affected areas may become discolored when miscellaneous fungi grow on them.

VIRUSES that may occur on peppers include i) tobacco mosaic (TMV), ii) potato virus X (PVX), iii) cucumber mosaic (CMV), iv) tobacco etch (TEV), v) potato virus Y (PVY), and vi) alfalfa mosaic (AMV). Symptoms vary, depending on the virus or strain, the plant, time of year, and environmental conditions. The range of virus symptoms may include leaf mottling, puckering, or curling; stem and petiole streaking; rough, deformed, or spotted fruit; stunted plants; and blossom and fruit drop.

a. Cucumber Mosaic Virus (CMV) causes severe mosaic on pepper foliage; older leaves sometimes exhibit large dead rings. Fruit may be malformed, and conspicuous yellow concentric rings and/or spots are frequently observed on infected green fruit. Limited spread may occur in the field through handling plants. By far the most efficient and widespread vector is the green peach aphid; other aphids also may spread CMV. The virus overwinters in susceptible perennial plants such as catnip, chickweed, jimson weed, mallow, nightshade, pokeweed, wild lettuce, and others. CMV may persist in a very small percentage of seed from infected chickweed.
b. **Tobacco Mosaic Virus (TMV)**, on some pepper cultivars, causes very pronounced mosaic symptoms on the foliage, accompanied by leaf puckering and reduction in leaf size. Vein clearing of the young leaves becomes extremely pronounced. Older leaves fall prematurely. Yield is reduced because fewer fruit set and those that do set are small and misshapen. Many bell-shaped peppers are resistant to TMV. TMV commonly is transmitted by mechanical means — during handling, on tools, through infected debris in soil, and by seeds. TMV, the most persistent and highly infectious of all plant viruses, withstands heat and retains its infective capacity in a dry condition for many years.

c. **Potato Virus X (PVX)** causes a mild mosaic symptom with mild leaf puckering. Leaf size may be slightly reduced. The virus is spread by contact between diseased and healthy plants, during handling, and by chewing insects. PVX carries over in infected potato tubers; it can infect many different kinds of plants belonging to the potato-tomato family.

d. **Tobacco Etch Virus (TEV)** causes a very mild chlorotic mottle, with some foliar distortion. Large concentric rings and line patterns may be produced on leaves and on fruit. Fruit often becomes misshapen. Root necrosis occurs, causing some wilting. Wilted plants recover, but usually are stunted and bushy. Stems on old plants sometimes have reddish brown spots and are streaked. Bud drop may occur. TEV overwinters in weeds belonging to the potato-tomato family and is spread mostly by green peach aphids and occasionally by potato aphids.

e. **Potato Virus Y (PVY)** causes mild to severe mottling, depending on the particular virus strain involved. The virus is not seed-transmitted, but is spread by several aphid species; the green peach aphid probably is the most efficient vector.
f. **Alfalfa Mosaic Virus (AMV)** symptoms depend on the virus strain and the environmental conditions under which the crop grows. Yellow blotches or sometimes mosaic mottling, yellowish rings, spots, and other patterns appear on infected leaves. Severe leaf death also may occur. AMV overwinters in alfalfa plants; it is transmitted most commonly by the green peach aphid.

**RADISHES**

**DOWNY MILDEW** is caused by the fungus *Peronospora parasitica*. Leaf symptoms appear as small yellowish areas that later turn brown with bluish-black lace-like markings. In moist weather, a whitish downy mold develops on the underside of leaf spots. Roots also may be affected. Inner root tissue is discolored, sometimes with net-like brown or black areas. In advanced stages the skin is roughened by small cracks and the root may split. In the absence of leaf symptoms, downy mildew could be confused with black root. The mildew fungus overwinters in roots from diseased plants. Disease development is promoted by cool weather and prolonged moist conditions associated with dense fog, drizzle, and persistent dew in dense and shaded plantings.

**BLACK ROOT**, caused by *Aphanomyces raphani*, affects only radishes. The first symptoms appear where side roots emerge. The skin turns purple to black in an area that finally girdles the root. The girdled area becomes constricted and may crack as unaffected tissue continues to grow. The black discolored area extends inward in radial streaks and generally remains firm. The black root fungus can persist in soil for long periods. Disease development is favored by warm weather.
SPINACH

BLIGHT symptoms, caused by cucumber mosaic virus (CMV), begin on young inner leaves and later appear on outer leaves. Leaves are mottled, curled, and wrinkled; later they become yellowish and finally die. Plants affected early are severely stunted. The virus overwinters in many perennial weeds, builds up in many vegetable crops (especially cucurbits), and is spread from infected plants by aphids. Symptoms develop much faster at high temperatures than at low temperatures.

BLUE MOLD (DOWNY MILDEW), caused by the fungus Peronospora effusa, affects only spinach. Initial symptoms are indefinite yellowish areas on upper leaf surfaces. On the corresponding lower surface, a gray to violet gray mold appears. Affected areas turn black and die. The disease may affect entire leaves and plants. In severe attacks, all plants in a field may be destroyed within a few days. The blue mold fungus overwinters in soil, in seed, and in spinach plantings. Fungus reproductive spores are spread from plant to plant by wind. Disease develops best in cool moist weather and is most prevalent in coastal areas.

WHITE RUST, caused by the fungus Albugo occidentalis, is characterized by white blister-like pustules, usually on the lower surface of leaves. The corresponding upper surface of leaves may be yellowish.
SWEET CORN

STEWART'S BACTERIAL WILT
of sweet corn, caused by the bacterium Xanthomonas stewartii, is more severe on young plants than on older plants. Symptoms appear first on leaves. Pale green to yellow streaks with wavy margins may extend the length of the leaf. These streaks usually change from pale green to yellow or brown. On young plants, brown discoloration and sometimes cavities may form in the center of the stem near the soil line. Early-infected plants may die; late-infected plants may be stunted or merely have streaked leaves. The disease-causing bacterium overwinters in flea beetles and is spread to corn when flea beetles feed on corn plants. Warm winters favor overwintering of flea beetles and usually precede seasons when Stewart's bacterial wilt is prevalent. Flea beetles carrying the bacteria can be expected if the sum of the average monthly temperatures (in °F) for December (D), January (J), and February (F) exceed 90. For example, if D = 34, J = 31, and F = 29, then D + J + F = 94, flea beetles may be abundant, and Stewart's wilt could be a problem.
LEAF SPOTS on sweet corn include northern corn leaf blight (NCLB) caused by *Helminthosporium turcicum*, southern corn leaf blight (SCLB) caused by *Helminthosporium maydis*, yellow leaf blight (YLB) caused by *Phyllosticta maydis*, anthracnose caused by *Colletotrichum graminicola*, and bacterial leaf spot caused by *Pseudomonas albo-precipitans*.

Size and color help distinguish the different fungal leaf spots from each other. Specific environmental conditions also favor development of each disease. For convenience of comparison, specific information on leaf spots is summarized in the accompanying table.

Bacterial leaf spot lesions are white to straw-colored and are about 1/16 inch wide and several inches long. The bacteria also can cause stalk, shank, and husk rot. Some southern grasses are hosts of this bacterium. Spread within fields is believed to be by machinery movement.

<table>
<thead>
<tr>
<th>Disease</th>
<th>Spot Size Length X Width (inches)</th>
<th>Spot Color</th>
<th>Conditions Favoring Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCLB</td>
<td>1 to 6 x 1/2</td>
<td>Grayish-green to tan</td>
<td>65 to 77°F, dew</td>
</tr>
<tr>
<td>SCLB</td>
<td>1/2 to 3/4 x 1/4</td>
<td>Tan with yellowish-to reddish-brown border</td>
<td>68 to 90°F, damp</td>
</tr>
<tr>
<td>YLB</td>
<td>1/2 x 1/10</td>
<td>Yellowish-cream to tan; sometimes with yellow halo</td>
<td>Cool, wet</td>
</tr>
<tr>
<td>Anthracnose</td>
<td>1/2 x 1/8 to 1/2</td>
<td>Brown with reddish-brown border</td>
<td>High temperature, dying leaves</td>
</tr>
<tr>
<td>Bacterial spot</td>
<td>Several x 1/16</td>
<td>White to straw-colored</td>
<td>High temperature</td>
</tr>
</tbody>
</table>

6 NORTHERN CORN LEAF BLIGHT

7 ANTHRACNOSE

8 NORTHERN CORN LEAF BLIGHT

9 YELLOW LEAF BLIGHT

10 BACTERIAL LEAF SPOT
COMMON RUST is caused by the fungus *Puccinia sorghi*. Rust begins as oval to elongate cinnamon brown pustules scattered over both surfaces of leaves. The pustules rupture and expose dusty red spores and later black spores. The red spores are spread by wind and can infect corn leaves directly; the black spores are overwintering spores which germinate and indirectly infect Oxalis, an alternate host for the corn rust fungus. In southern areas, red spores persist on corn from season to season, thus initiating early-season disease development. In northern areas, disease initiation depends on reintroduction of wind-borne red spores from southern areas or depends on development of special spores on the alternate host, Oxalis. Disease is promoted by cool temperatures (61 to 70°F) and 100 percent relative humidity.

SOUTHERN CORN RUST, caused by the fungus *Puccinia polysora*, generally is confined to the southeastern area in the United States. Southern rust pustules are lighter in color, smaller, more circular, and do not break open as early as common rust pustules. The southern rust fungus overwinters as spores on infected corn plants and in residue from diseased plants. Southern rust is favored by high temperatures (80°F) and high relative humidity.

SMUT, caused by the fungus *Ustilago maydis*, is characterized by the presence of large fleshy irregular galls on leaves, stems, ears, and tassels. Immature galls are white and spongy; mature galls turn brown and contain dark powdery spores. The smut fungus overwinters in soil. Smut development is favored by dry conditions and by temperatures between 79 and 94°F. Disease development is promoted by plant injury caused by hail, cultivation, and insects.
SORGHUM DOWNY MILDEW, caused by *Peronosclerospora sorghi*, affects corn and sorghum. The disease was first recognized in Texas in the early 1960's and has spread as far as New Mexico, Georgia, Illinois, and Indiana. Young plants are more susceptible to infection than old plants; the fungus usually becomes systemic, especially in young plants. Distinct yellow streaks, particularly at the base of the leaves, are diagnostic symptoms in the field. Tassel parts may become leaf-like on plants that are infected early. A downy white mold may appear on yellow affected leaf areas. Disease is promoted by warm and humid conditions. The Texas strain of the fungus appears to be better adapted to the relatively low North American temperatures (65°F best for reproduction; 50 to 68°F best for spore germination) than strains in warmer parts of the world. It is unknown how important this disease could become in North America.

CRAZY TOP is caused by a downy mildew fungus, *Sclerophthora macrospora*. It is characterized by partial to complete proliferation of the tassel; the normal flower parts continue to grow and become small leaf-like structures. Other symptoms include development of excessive ear shoots, increased number of internodes above ears and in shanks, excessive tillering, suppressed tassel and ear formation, and stunted narrow strap-like leathery leaves. The crazy top fungus overwinters in soil as resistant oospores (fungus reproductive structures). The disease is most prevalent in areas of fields where soil is flooded or waterlogged for 1 to 2 days before seedlings are 4 to 6 inches tall. When the soil conditions are wet, the oospores germinate to produce spores that can infect plants. The fungus moves and grows systemically in plants.
VIRUS-LIKE DISEASES are caused by several different viruses and mycoplasma; the diseases are characterized by symptoms common to several of the diseases. This has led to confusion in disease identification. Symptoms are helpful in the identification of the virus-like diseases; however, positive identification requires additional procedures conducted by virus-identification specialists.

a. Maize Dwarf Mosaic (MDM) symptoms are distinctive on plants in the pretasseling stage. Affected young plants have a fine stippling of dark green streaks on light-colored young leaves. Upper internodes are shortened. Older plants have yellowish leaves and are stunted; they produce excessive tillers and multiple-ear shoots with poor seed set. MDM is caused by a virus that overwinters in grasses. Several virus strains exist. Johnsongrass may be a major overwintering host for most strains; strain B does not overwinter in this host. At least 12 kinds of aphids transmit the virus from infected grasses to corn.

b. Maize Chlorotic Dwarf (MCD) symptoms appear first as a yellowing in the whorl. Infected plants then become stunted, usually with reddish leaves. MCD is caused by a virus that overwinters in Johnsongrass. The virus is spread by a leafhopper.

c. Corn Stunt is thought to be caused by a mycoplasma. Early symptoms are small circular to elongated yellowish spots at the base of leaves in young plants. These spots often coalesce and become elongated stripes that may be discrete or diffuse. As the plant develops, general yellowing, leaf reddening, ear shoot and sucker proliferation, and relatively short internodes become distinctive features of the disease. Corn stunt is widely distributed in southern areas of the United States. The mycoplasma is transmitted by at least five kinds of leafhoppers; it cannot be spread mechanically and is not seed-borne.
d. **Wheat Streak Mosaic**, caused by a virus, is widespread but of little economic importance on corn. Early symptoms are small yellowish spots or broken streaks at the tips of young leaves. The streaks may elongate. Older leaves may become yellowish near the tips. Ears may be poorly developed. The virus is transmitted in the field by the wheat curl mite, and can be mechanically transmitted. The virus overwinters in some cultivated and wild grasses; wheat, oats, barley, rye, stinkgrass, and species of foxtail and panicum are susceptible.

e. **Maize Streak**, caused by a virus, is characterized by narrow yellow streaks distributed uniformly over leaf surfaces; some of these streaks may grow together as they expand. Symptoms are most severe on plants that are infected early. Stalk internodes and leaf size are greatly reduced; ears may be partially filled.

As of 1982 the maize streak virus had not been reported in the United States.

**KERNEL RED STREAK** is caused by a toxin secreted by the wheat curl mite when it is feeding on corn plants. Red streaks appear on kernels. Usually the streaking is more pronounced in kernels near the tip of an ear. White corn is less severely affected than yellow corn.
BLACK ROT is caused by the fungus Ceratostomella fimbriata. Symptoms appear on the foliage and on fleshy roots. The foliage appears yellowish and sickly. On fleshy roots, depressed circular spots of various sizes develop. The spots are grayish black when dry and greenish black when moist. A shallow dry decay extends about to the depth of the vascular ring. The black rot fungus overwinters in diseased roots and in soil. Disease development is promoted by moist soil conditions.

SCURF, caused by the fungus Monilochaetes infuscans, affects only sweet potato. Scurf appears on fleshy roots as small brown superficial spots. The spots expand and coalesce, but remain superficial. In storage, affected tubers dry out and shrivel more rapidly than do healthy tubers. The scurf fungus overwinters in affected roots, in residue from affected vines, and in soil. Disease occurrence is promoted by wet heavy alkaline soil which contains abundant organic matter.

STREPTOMYCES SOIL ROT, also referred to as pox and pit, is caused by the fungus Streptomyces ipomoea. Symptoms begin as small dark dry surface spots. The dried tissue later falls out, leaving a pit or pox mark. Root growth around these spots is checked and, as other parts continue to grow, the root becomes distorted. Roots affected late, after most growth has occurred, become pitted but not distorted. The pox fungus lives, reproduces, and becomes prevalent in soil when sweet potatoes are repeatedly cropped. Disease occurrence is promoted by high pH.

SURFACE ROT is caused by Fusarium oxysporum. Infection occurs late in the season, close to harvest. Surface rot spots are circular, slightly sunken, and lighter in color and more superficial than are the black rot spots. Disease is more prevalent in years when a wet period precedes harvest. In storage, moisture is lost through the spots and the roots shrink and become mummified.
Tomato diseases are grouped into symptom categories to help with diagnosis. Categories include wilts, leaf spots and blights, fruit spots and rots, internal browning and graywall, viruses, and herbicide damage.

Wilts are caused by several agents. Four common wilts that can be confused with each other are Verticillium wilt, Fusarium wilt, bacterial wilt, and walnut wilt. Information on varietal resistance, range of crops affected, proximity to walnut trees, soil temperature, and past cropping history help determine which of the wilts is present. Usually a laboratory isolation is needed to verify the causal agent. Bacterial canker, southern blight, leaf roll, root knot, and stem rot — five other disorders often mistaken for wilts — also are described here.

a. Verticillium Wilt, caused by Verticillium spp. of fungi, affects many plants and is common on tomatoes, potatoes, eggplants, peppers, strawberries, and raspberries. Leaf symptoms appear on oldest leaves first and later develop on younger leaves. Leaves turn yellow, dry up (often without evident wilting), and drop prematurely. Shoot tips wilt slightly during the day. As defoliation progresses, tip leaves may curl upward at the margin but usually remain alive. Internal woody stem tissue, particularly at the lower part of the stem, is distinctly darkened. Disease is caused by a soil-borne fungus that can persist for many years. Disease is more prevalent in cool than in warm climates.

b. Fusarium Wilt, caused by the fungus Fusarium oxysporum f. sp. lycopersici, affects only tomatoes. Fusarium wilt, like Verticillium wilt, is characterized by leaf yellowing that progresses upward from the base of the plant. Unlike Verticillium wilt, wilting or yellowing may occur on only one side of a leaf midrib or on one side of a plant. Yellow leaves wilt noticeably before they die. Separate
shoots, and later entire plants, finally wilt permanently and die. Woody stem tissue often is discolored throughout the plant. Fusarium wilt is caused by a soil-borne fungus that can persist in soil for many years. Many tomato varieties are resistant to a common race (race 1) of this fungus; however, these “resistant” varieties may be susceptible to the recently detected race 2. Development of fusarium wilt is restricted by cool climate.

c. **Walnut Wilt** affects several kinds of plants when they are growing in the root zone of walnut and butternut trees. Tomatoes are particularly susceptible. Woody stem tissue in affected plants turns brown and plants soon wilt and die. The wilt is caused by a toxin produced by roots of the walnut tree; the toxin may persist after walnut roots are dead.

d. **Bacterial Wilt**, caused by the bacterium *Pseudomonas solanacearum*, affects several plant species, including tomatoes, potatoes, eggplants, and peppers. Disease is characterized by sudden plant wilting without leaf yellowing. Stem centers (pith) become water-soaked; they later turn brown and sometimes become hollow. Pith discoloration helps distinguish bacterial wilt from Verticillium and Fusarium wilts. Woody stem tissue turns brown and roots may start to form on the stem. The bacterium overwinters in cold-frame and greenhouse soils in northern areas, and in field soil in southern areas. The disease can be serious if transplants are infected.

e. **Bacterial Canker**, caused by the bacterium *Corynebacterium michiganense*, is characterized by wilting of leaflets on plants of all sizes. On older plants, leaves die from the margin inward toward the midrib. Symptom development often is one-sided; usually the leaflets on one side of the leaf are affected first. Eventually the whole leaf is affected. Diseased plants may wilt and die early but many survive, though unthrifty and wilted. Yellowish white streaks may appear on petioles and
stems and may develop into longitudinal cankers. Cavities may develop within stems. Spots develop on fruit. The disease-causing bacterium may survive for 1 year in residue from diseased plants. The bacterium also is seed-borne and therefore can infect and be spread on transplants.

f. Southern Blight is caused by Sclerotium rolfsii, a soil-borne fungus. The first above-ground symptom is plant wilting. The stem at the soil line displays a brown cortical soft rot, usually covered with whitish cottony mold embedded with tiny brown sclerotia (fungus reproductive structures). The fungus survives from season to season as sclerotia in soil. The fungus can be spread in running water, in infested soil, on tools and implements, in infected seedlings, and as sclerotia among the seed. Disease development is enhanced by high temperature and high humidity. The disease is rare in areas with cold winters.

g. Leaf Roll is characterized by upward curling of leaflets on older leaves. Leaf roll has been associated with varieties having a specific gene (wilty gene); symptoms usually are seen when plants have a heavy fruit load. Environmental factors reported to promote symptom development include high temperature, drought, and prolonged periods of wet soil conditions. In addition, TMV promotes leaf roll symptoms at all stages of plant growth in varieties with the wilty gene.

h. Root Knot can be severe on tomatoes, cucurbits, eggplant, lettuce, spinach, carrot, parsnip, and celery. Affected tomato plants usually are stunted and may wilt in hot dry weather. A diagnostic symptom is easily detected on roots of all affected plant species; roots contain elongated and round swellings (root knots) on both large and small roots. Root knot is caused by several species of the root-knot nematode (Meloidogyne spp.). Only the northern species (M. hapla) is thought to overwinter in areas with severe winters. The nematode may be introduced on transplants and then spread within and be-
tween fields in infested soil carried on machinery or in running water.

i. **Stem Rot** is caused by *Sclerotinia sclerotiorum*, a fungus that causes disease in beans, cabbage, carrots, celery, cucumbers, lettuce, onions, peas, pumpkins, squash, and many other species. A dry rot girdles the stem at ground level and eventually the plant wilts and dies. A diagnostic sign for this disease is presence of sclerotia (hard black pea-like structures) within the girdled stem. Sclerotia, produced by the fungus, act as resistant fungus "seeds" that persist in soil for many years. Long periods of cool wet weather promote fungus growth, fungus spread, and disease development.

**LEAF SPOTS and BLIGHTS**, caused by several different agents, include early blight, late blight, Septoria leaf spot, gray leaf spot and bacterial spot.

a. **Early Blight**, caused by the fungus *Alternaria solani*, can affect seedlings but generally is observed on older plants. On seedlings, dark spots develop on cotyledon leaves, stems, and true leaves. Spotted cotyledon leaves may be killed, and spotted stems may be girdled. On established plants, dark brown spots with dark concentric rings develop first on oldest leaves. Spotted leaves may die prematurely, resulting in substantial early defoliation, fruit sunscald, and poor fruit color (see the section on Tomato Fruit Rots for fruit symptoms). The disease-causing fungus overwinters in residue from diseased plants, where it can persist for at least one year. The fungus also is seedborne and can be introduced on seed and on transplants. Disease occurs under a wide range of weather conditions. It is promoted by heavy dews and rainfall and is severe on plants of poor vigor.
b. **Late Blight**, caused by the fungus *Phytophthora infestans*, affects both tomatoes and potatoes. On tomatoes, symptoms appear on foliage and fruit. Irregular greasy-appearing grayish areas develop on leaves. These areas expand rapidly during moist conditions and a white downy mold appears at the margin of the affected area on the lower surface of leaves. If the white fungus growth is not observed, leaves with suspicious spots can be put into a polyethylene bag containing a moist paper towel (to supply moisture) and held for one day to promote appearance of this diagnostic sign. (Fruit symptoms are described in the section on Tomato Fruit Rots.) The disease-causing fungus overwinters in southern frost-free areas, on winter-grown tomatoes and potatoes, and in northern areas in potato cull piles and in potato “seed.” It may be introduced to tomato fields on transplants or may be wind-borne from diseased potato and tomato plants in nearby fields. Disease development is promoted by cool wet conditions.

c. **Septoria Leaf Spot**, caused by the fungus *Septoria lycopersici*, is characterized by numerous small gray circular leaf spots with dark borders. A few black pin-point-size pycnidia (fungus reproductive structures) may be seen within the spot. The disease-causing fungus survives in residue from diseased plants, and on or in seed. Wet weather favors fungus growth, spread, and subsequent disease development.

d. **Gray Leaf Spot** is caused by the fungus *Stemphylium solani*. Only leaves are affected and the oldest are affected first. Numerous small dark brown spots appear and extend through to the undersurface of the leaf. These spots may enlarge to 1/8 inch in diameter. As spots enlarge they have a grayish brown glazed appearance. The centers of the spots often crack and finally the centers fall out entirely. When spots are numerous, affected leaves turn yellow and eventually wither and drop. When plants are severely affected, all leaves except those near the tips may be killed.
and few fruit are produced. Spots hardly ever form on stems. The fungus overwinters on debris from diseased plants and can persist in soil for several years. The disease, favored by warm moist conditions, is more prevalent in southern states than in northern areas.

e. Bacterial Spot, caused by the bacterium *Xanthomonas vesicatoria*, affects tomatoes and peppers. Symptoms include small dark greasy-appearing spots on leaves and stems. Blossom infections may cause blossom or fruit abortion. (Fruit symptoms are diagnostic and are described in the section on Tomato Fruit Rots.) Disease-causing bacteria may survive for one year in residue from diseased plants. The bacteria are seed-borne and therefore the disease can get started and be spread on transplants. Wet weather promotes bacterial growth; splashing rain favors spread; and driving rain assists entrance of bacteria into plants.

FRUIT SPOTS and ROTS frequently observed are anthracnose, soil rot, early blight, late blight, buckeye rot, blossom-end rot, bacterial spot, bacterial speck, bacterial canker, and ghost spot.

a. Anthracnose, a common rot on ripe fruit caused by the fungus *Colletotrichum coccodes*, first appears as small slightly sunken circular spots. Spots increase in size and the central portion darkens. Anthracnose spots on a single fruit often expand, merge, and cover a large area of the fruit. Spotted fruits may rot completely, often as a result of attack by secondary organisms. The anthracnose fungus overwinters in soil, in residue from diseased plants, and on and in seed. The fungus can become established on early blight leaf spots and on other dead areas on leaves. Fruit spots may develop where the fungus is splashed to the fruit, either from the soil or from plant parts. Green fruit can become infected, although spots will not appear until fruit ripen. Disease is prevalent on fruit that is overripe and in contact with soil. Wet weather promotes disease development.
b. Early Blight, caused by the fungus *Alternaria solani*, is more important on foliage than on fruit. On green or ripe fruit, spots usually begin at the stem end and develop into a black leathery sunken area, often with dark concentric rings. (Leaf symptoms and disease cycle information are presented in the section on Tomato Leaf Spots and Blights.)

c. Late Blight is caused by the fungus *Phytophthora infestans*. Although not common, it can be devastating on foliage as well as fruit. Grayish green water-soaked spots enlarge to indefinite size and shape on green fruit. Affected areas become dark brown, firm, wrinkled, and have a relatively definite margin. (See the section on Tomato Leaf Spots and Blights for leaf symptoms and disease cycle information.)

d. Buckeye Rot is caused by the fungus *Phytophthora parasitica*. It causes a fruit rot of tomato, pepper, and eggplant. The first symptom is a grayish green or brown water-soaked spot that usually occurs where the fruit touches the soil. In warm weather half the surface area on fruit may be affected. Dark zonate “buckeye” bands usually are present within the affected area. Buckeye rot has a smooth surface and lacks a sharply defined margin; these features help distinguish buckeye rot from late blight, characterized by a rough surface and a definite margin. The fungus lives in the soil. Disease is most prevalent in poorly drained fields and in regions subject to prolonged periods of warm wet weather.

e. Soil Rot, caused by *Rhizoctonia solani* (which also causes seedling damping-off), is characterized by slightly sunken brown spots about 1 inch in diameter. Dark narrow-banded concentric markings are distinct within new spots; later the center of the spot often cracks open. The disease-causing fungus is present in all field soil and affects tomato fruit whenever conditions are favorable. Disease is promoted by wet conditions and usually appears on ripe fruit in contact with soil.
f. **Bacterial Spot**, caused by the bacterium *Xanthomonas vesicatoria*, is characterized by a distinct fruit spot. Small dark raised spots, sometimes surrounded by water-soaked margins, appear on green fruit. Spots enlarge up to 1/4 inch in diameter and become brown and scabby. (Leaf symptoms and disease cycle information are presented in the section on Tomato Leaf Spots and Blights.)

g. **Bacterial Speck**, caused by the bacterium *Pseudomonas syringae pv. tomato*, affects only tomatoes. Small black specks appear on leaves, stems, fruit stems, and on fruit. The specks on fruit are most characteristic; they appear on young green fruit and are superficial, slightly raised, and about 1/16 inch in diameter. Tissue around fruit specks sometimes remains green longer than the rest of the ripening fruit. Disease-causing bacteria may overwinter on seed, in residue from diseased plants, or in soil. The bacterium can be introduced into fields on transplants. Wet cool conditions promote disease. Splashing rain and machinery movement through fields assist spread and entrance of bacteria into plants.

h. **Bacterial Canker**, caused by the bacterium *Corynebacterium michiganense*, is discussed under tomato wilts. The same bacterium also causes fruit spots. Spots are first small and whitish, but soon develop raised dark centers surrounded by a white halo which later turns brown.

i. **Ghost Spot** appears on green tomato fruit as whitish rings and spots 1/8 to 1/4 inch in diameter. These symptoms mark the spot where a fungus (*Botrytis*) entered the fruit but was killed by high temperature resulting from sunlight on the fruit. Low temperatures and high humidity promote fungus entrance into fruit.
j. **Blossom-End Rot**, caused by insufficient calcium when fruit are forming, is characterized by a large dry brown to black, and often depressed, leathery area at the blossom end of fruit. Calcium deficiency usually results from excessive nitrogen fertilization, rapid plant growth, and drastic fluctuations in moisture as caused by heavy rainfall, drought, and root pruning during cultivation.

k. **Catface** is an abiotic disease caused by factors that seriously disturb initial fruit development during blossoming. Symptoms are extreme malformation and scarring frequently associated with the blossom end. Two specific factors that may cause catface are cool weather during fruit set and injury from 2,4-D herbicide.

l. **Sunscald** is an abiotic disease caused by sudden exposure of fruit to direct sunlight, particularly during hot dry weather. Leaf blights and movement of foliage during picking often provide conditions favorable for sunscald. Sunscald, most prevalent on green fruit, appears as a whitish or yellowish patch on the side of the fruit toward the sun. When sunscald is severe, the affected area shrinks and forms a large flattened grayish white spot with a paper-like surface.

**INTERNAL BROWNING and GRAYWALL (BLOTCHY RIPENING)** are thought by some scientists to be two different disorders with similar symptoms. Affected green fruit has grayish brown blotches on the shoulders; internal wall tissue is brownish. As fruit ripens, discolored blotches are yellowish on an otherwise ripe fruit.

*Internal browning* is the name given to a fruit disorder caused by tobacco mosaic virus. Symptoms will develop on fruit approaching maturity if plants are infected at this late stage of fruit development. Fruit on one or two clusters may be severely affected while others may be symptomless. Symptoms are less likely to appear on fruit if plants are infected during an early stage of fruit development.

*Graywall* (blotchy ripening) is the name given to a fruit disorder that has
been associated with specific environmental factors and possibly bacteria. The cause is not clearly understood. Graywall is promoted by low light intensity (a condition prevalent among dense vines), low temperature levels, excessive soil moisture, excessive soil compaction, high nitrogen levels, and low potassium levels.

**VIRUSES and HERBICIDES** often cause leaf deformation that is most severe on new growth. Tobacco mosaic, cucumber mosaic, and 2,4-D are three common causes of these symptoms.

**a. Tobacco Mosaic** is caused by a virus that affects tomatoes, eggplants, peppers, and related plants. Symptoms on tomato foliage include light- and dark-green mottling with curling and slight malformation of leaflets. Sometimes green fruit are mottled. Affected plants may be stunted. The virus is very persistent and infectious, and can be spread by merely brushing against plants. The virus is not spread by aphids.

**b. Cucumber Mosaic** is caused by a virus that affects hundreds of unrelated plant species. Infected tomato plants are stunted, have short internodes, and may have extremely distorted and malformed leaves. Very narrow leaves are referred to as the “shoestring” symptom. Cucumber mosaic virus is not persistent in refuse, is more difficult than tobacco mosaic virus to transmit by rubbing, and usually is spread by aphids. Since aphids are responsible for most spread, infected plants may be widely separated within a field.

**c. Double-Virus Streak** is caused by a combination of tobacco mosaic virus (TMV) and potato virus X (PVX). Leaf symptoms include first a light-green mottling of leaves accompanied by development of numerous small grayish brown thin dead spots; severely spotted leaves may die. Later growth is mottled green and yellow, dwarfed and curled, with small irregular brown spots on the leaves. Numerous narrow dark brown streaks develop on stems and petioles. Shoot
**Tips** may die and infected plants are stunted. Fruit set is reduced; these fruit are rough with small irregular greasy-appearing brown patches. TMV overwinters in tobacco products; PVX overwinters in potato tubers. Both are spread by workers.

d. **Spotted Wilt** is caused by a virus that usually is spread by thrips. Foliage symptoms are similar to those of double-virus streak, except that spotted wilt symptoms are more severe. Growing tips usually are severely affected. Characteristic fruit spots are about 1/2 inch wide, have concentric rings, and usually are numerous. The rings may be alternately red and yellow and the center of the spot may be raised, which gives the fruit a rough appearance. The spotted wilt virus can overwinter in several weeds and ornamental plants.

e. **2,4-D Herbicide Injury** occurs in greenhouses and fields. Symptoms include downward bending of leaves and of growing points. New leaves do not expand normally; they are narrow and elongated, twist at the margin, and have abnormally pointed tips. Veins are prominent, light colored, and may appear parallel. Source of the herbicide often is not readily apparent. Possible sources include i) drift, ii) pesticides or fertilizer contaminated during storage, and iii) soil, equipment, tools, containers, clothing, and gloves contaminated from a previous herbicide use.

**LIGHTNING INJURY** appears as circular areas 10 to 60 feet in diameter. Injury is most severe at the center of these areas. Plants other than tomatoes, including weeds, are affected similarly within the area. First symptoms may appear within a few hours of injury. Leaves begin to droop and in the most severe cases the wilting is progressively rapid and permanent, followed by death. Stems, branches, and petioles show various degrees of shrinkage due to collapse of the pith. In many plants, stems become flattened and the internal stem tissue assumes a ladder-like appearance.
PHOTO CREDITS

Asparagus
1) MacNab; 2,3) Johnston

Beans
1) Jacobsen/Shurtleff; 2) Sherf;
3) Jacobsen/Shurtleff; 4) Sherf; 5) Springer;
6) MacNab; 7,8) Sherf; 9) Jacobsen/Shurtleff;
10) Hagedorn; 11) Sherf; 12) Hagedorn;
13) MacNab; 14,15) Simone;
16,17,18,19,20) Jacobsen/Shurtleff;
21,22) MacNab; 23) Mulrooney;
24,25) MacNab; 26) Jacobsen/Shurtleff;
27) MacNab

Beets
1) MacNab; 2,3) Abawi;
5,6) Jacobsen/Shurtleff

Carrots
1,2) Sherf; 3) Jacobsen/Shurtleff;
4) Sherf; 5,6) Jacobsen/Shurtleff;
7) Sherf;
8) Jacobsen/Shurtleff; 9) Sherf;
10) Jacobsen/Shurtleff; 11) Sherf

Celery
1,2) Jacobsen/Shurtleff; 3) MacNab; 4) Sherf;
5,6) Jacobsen/Shurtleff; 7) MacNab;
8,9) Jacobsen/Shurtleff; 10) Sherf; 11) Dunn;
12,13) Jacobsen/Shurtleff; 14) Springer

Crucifers
1) Jacobsen/Shurtleff; 2) MacNab;
3) Jacobsen/Shurtleff; 4,5) Simone;
6,7) MacNab; 8) Jacobsen/Shurtleff;
9) Sherf; 10,11) MacNab; 12,13) Sherf;
14) MacNab;
15) Jacobsen/Shurtleff; 16) MacNab;
17) Jacobsen/Shurtleff; 18) MacNab; 19) Sherf;
20,21) MacNab; 22) Sherf; 23) MacNab;
24) Jacobsen/Shurtleff; 25) Simone

Cucurbits
1,2) MacNab; 3) Jacobsen/Shurtleff;
4) MacNab; 5) Averre; 6) Gay; 7,8) Simone;
9) Jacobsen/Shurtleff; 10) MacNab;
11,12) Jacobsen/Shurtleff; 13,14) MacNab;
15) Jacobsen/Shurtleff; 16) Sherf;
17,18,19) Jacobsen/Shurtleff; 20,21) Sherf;
22,23) MacNab; 24,25,26) Simone;
27,28,29,30,31,32) MacNab;
33) Jacobsen/Shurtleff; 34,35) MacNab;
36) Averre; 37) MacNab; 38) Sherf;
39) MacNab; 40) Jacobsen/Shurtleff; 41) Sherf;
42,43,44,45) MacNab; 46) Sherf;
47,48) MacNab; 49) Sherf; 50) Springer

Eggplant
1) Sherf; 2,3,4) Gay; 5) Jacobsen/Shurtleff;
6) Averre; 7,8,9) Jacobsen/Shurtleff

Lettuce
1) Jacobsen/Shurtleff; 2) Sherf;
3) Jacobsen/Shurtleff; 4) MacNab;
5) Jacobsen/Shurtleff; 6) MacNab; 7,8,9) Sherf;
10,11) Jacobsen/Shurtleff; 12) Sherf

Onions
1) Jacobsen/Shurtleff; 2) Sherf; 3) MacNab;
4) Sherf; 5) Springer; 6) Sherf;
7,8) Jacobsen/Shurtleff; 9) Sherf;
10,11,12,13,14) Jacobsen/Shurtleff

Parsnips
1) Jacobsen/Shurtleff; 2) MacNab

Peas
1) MacNab; 2) Jacobsen/Shurtleff;
3,4,5) Hagedorn; 6) Sherf; 7,8) MacNab;
9) Sherf; 10) Nichols; 11) Sherf; 12) Boyle;
13) MacNab; 14) Sherf; 15) Hagedorn;
16) Sherf

Peppers
1) Jacobsen/Shurtleff; 2) Springer;
3,4,5) Averre; 6) Sherf; 7) MacNab;
8,9,10,11) Jacobsen/Shurtleff; 12) MacNab;
13) Sherf; 14) MacNab; 15,16) Sherf;
17) Springer; 18) Simone; 19) Sherf

Radishes
1) MacNab; 2) Jacobsen/Shurtleff; 3) Hartman

Spinach
1) Sherf; 2) Hartman; 3) MacNab;
4) Jacobsen/Shurtleff

Sweet Corn
1) Washburn; 2,3,4,5) MacNab;
6,7) Gregory; 8) Sherf; 9) Ayers;
10) Simone; 11) Jacobsen/Shurtleff;
12) MacNab; 13,14) Melching; 15) Sherf;
16) MacNab; 17,18,19,20) Bonde; 21) Ulstrup;
22) MacNab; 23) Jacobsen/Shurtleff;
24,25,26) Damsteegt; 27) Jacobsen/Shurtleff

Sweet Potatoes
1,2) MacNab; 3,4) Jacobsen/Shurtleff;
5) Averre

Tomatoes
1,2) MacNab; 3) Sherf; 4) MacNab;
5,6) Jacobsen/Shurtleff; 7) MacNab;
8) Jacobsen/Shurtleff; 9) Sherf; 10) Smith;
11) Jacobsen/Shurtleff; 12) Sherf;
13,14,15,16,17,18,19) MacNab;
20) Jacobsen/Shurtleff; 21) Simone;
22,23) Jacobsen/Shurtleff; 24,25,26) MacNab;
27) Jacobsen/Shurtleff; 28) Springer;
29,30,31) MacNab; 32) Jacobsen/Shurtleff;
33,34) MacNab; 35,36) Jacobsen/Shurtleff;
37,38,39,40,41) MacNab; 42) Sherf;
43) MacNab; 44) Sherf; 45,46) Springer;
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