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Market Diseases of Beets, Chicory, Endive, Escarole, Globe Artichokes, Lettuce, Rhubarb, Spinach, and Sweetpotatoes

Abstract

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This handbook contains descriptions and color plates of economically important postharvest diseases and disorders of these nine commodities with recommendations for their control. It is intended for use as a ready descriptive guide by inspectors, produce handlers, marketing specialists, and research workers. The listed references, which are not intended to be all inclusive, supplement the subject for the user.

KEYWORDS: Beets, chicory, endive, escarole, globe artichokes, lettuce, postharvest diseases and disorders, rhubarb, spinach, sweetpotatoes.

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H.E. Moline and W.J. Lipton

Preface

This is an extensive revision of Agriculture Handbook 155 by Glen B. Ramsey, B.A. Friedman, and M.A. Smith, first published in 1959 and reprinted in 1967. This handbook is one of a series designed to aid in the recognition and identification of market diseases, to provide information on factors causing the diseases, and to present control measures for reducing the economic losses caused by these diseases during marketing. This handbook is designed for use by market inspectors, research workers, shippers, receivers, carriers, and others concerned with maintaining the quality of fresh produce during marketing.

Other publications in this series are—

28 Market Diseases of Tomatoes, Peppers, and Eggplants (reprinted 1982).
184 Market Diseases of Cabbage, Cauliflower, Turnips, Cucumbers, Melons, and Related Crops (out of print).
189 Market Diseases of Grapes and Other Small Fruits (out of print).
303 Market Diseases of Asparagus, Onions, Beans, Peas, Carrots, Celery, and Related Vegetables (reprinted 1982).
376 Market Diseases of Apples, Pears, and Quinces (printed 1971).
398 Market Diseases of Citrus and Other Subtropical Fruits (reprinted 1983).
414 Market Diseases of Stone Fruits: Cherries, Peaches, Nectarines, Apricots, and Plums (printed 1972).
479 Market Diseases of Potatoes (printed 1978).

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Market Diseases of Beets, Chicory, Endive, Escarole, Globe Artichokes, Lettuce, Rhubarb, Spinach, and Sweetpotatoes

H.E. Moline and W.J. Lipton[1]

Beets

Garden beets (*Beta vulgaris* L.) are grown for their fleshy roots and succulent tops, which may be used as greens. Edible roots are a rich red, of moderate size, smooth and sweet, and with a fine texture.

The early crop is usually marketed bunched in a fresh, crisp condition with tops attached and can be stored at 0°C[2] for 10-14 days. The leaves and crowns are susceptible to decay by bacterial soft rot pathogens. Cercospora leaf spot can disfigure leaves, although table beets are somewhat resistant. Foliar diseases, such as curly top virus or rust (caused by *Uromyces betae* Tul. ex Kickx), may severely damage leaves, and the reduced leaf area may cause dwarfing and poor root development. Growing roots are susceptible to black rot, crown gall (caused by *Agrobacterium tumefaciens* (E.F. Smith and Townsend) Conn), fusarium rot (caused by *Fusarium* spp.), and root rot (caused by *Pellicularia filamentosa* (Pat.) Rogers).

Topped beets free from diseases and without mechanical wounds may be stored for 3 to 5 months at high relative humidity (95 percent) without significant losses. Occasionally stored roots are affected by black rot, blue mold rot, fusarium rot, internal black spot, or scab.

Bacterial Soft Rot

(Causal Organism *Erwinia carotovora* subsp. *carotovora* (Jones) Bergey et al. and Other Related Bacteria)

Bacterial soft rot is most often found on damaged leaves and crowns of young beets shipped and marketed as whole plants and on beet tops marketed as greens. The rot first appears on damaged leaf tissues as darkened, water-soaked areas, which may increase rapidly in size at moderate temperatures. Decay tissues become soft and slimy, giving off a disagreeable odor. (See also Spinach, Bacterial Soft Rot, p. 39.)

[1]Respectively, research plant pathologist, Horticultural Crops Quality Laboratory, Beltsville Agricultural Research Center, Beltsville, MD 20705; retired, Agricultural Research Service, U.S. Department of Agriculture, Fresno, CA.

[2]For °F, see conversion table on p. 86.

Black Rot

(Causal Organism *Phoma betae* Frank)

Black rot may affect garden beets, but usually it causes only slight loss except in topped beets that have been held in storage. The disease is seldom found on young bunched beets on the market.

Decayed beets in storage usually show black rot at the tip of the root, although decay may occasionally occur at the crown and at wound sites. Because beet roots are dark red, small lesions can easily be overlooked. Decay may not be observed until the affected tissues become black and slightly sunken or until a flat, grayish-white surface mycelial mat becomes evident. Internally the decayed areas are dark brown to black, with a sharp line of demarcation between healthy and diseased tissues (pl. 1). Initially invaded tissues appear brown and water soaked, but as decay progresses, the tissues turn black and somewhat granular, eventually becoming dry and spongy. With advanced decay, cavities lined with mycelium may be observed within the spongy areas of larger lesions. Although considerable grayish white mycelium develops on the surface of older lesions under humid conditions, pycnidia have not been found on decayed beets.

The temperature range for growth of the black rot fungus in culture is from 2° to 35°C, with an optimum of 24°. Beets artificially inoculated through small wounds develop decayed areas about 5 mm in diameter at 7° and 10 mm at 13° within 6 weeks; however, decay develops more rapidly on old beets than on young ones.

Because the disease also attacks seeds and seedlings, affected plants that survive at these stages of development and produce marketable roots can also have the fungus in the crown, where it may remain dormant for some time. However, in storage it often becomes active, penetrating the roots and causing a dry black rot. Natural infection may also occur through wounds or follow infection caused by diseases.

Currently there are no approved chemical control methods, but close topping of roots and storage at 0°C with high relative humidity and adequate air circulation will retard black rot development.

Reference: *2.*

Cercospora Leaf Spot

(Causal Organism *Cercospora beticola* Sacc.)

Cercospora leaf spot is an important field disease of beets. It is also of importance at the market, because it disfigures infected leaves; then bacteria may enter through these infected areas and cause soft rot.

Lesions appear as small spots with gray to brown centers and reddish-purple margins on leaves and petioles. Spots may drop out, leaving ragged leaves that may collapse and die. The causal fungus can survive from season to season on plant debris in the field. Removal of beet trash and deep plowing are recommended control measures. Garden beet varieties are somewhat resistant to the disease.

Reference: *5*.

Scab

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

Scab is rare on beets, but occasionally it causes considerable damage in heavily infested soil. The pathogen is also the cause of common scab of potatoes. Scab lesions on infected beet roots are superficial, much like those found on potatoes except that they are more protruding and rounded. Affected roots are usually so conspicuously blemished that they are seldom offered for sale on the market (pl. 2).

Beets should not be grown in soil that has produced scabby potatoes. Acid soil tends to repress scab incidence. Varietal resistance occurs.

References: *1*, *3*.

Internal Black Spot

Internal black spot is a serious disorder of garden and canning beets in many areas. On the market, it can be found on topped and stored beets but seldom on young bunch beets. The disorder appears when plants are grown in soils deficient in boron. Although it can occur in many soil types, it is most often serious in alkaline soils, where boron is unavailable to the plants.

Internal black spot appears as irregular patches of dark tissues near the center of the root. The necrotic areas are hard but do not dry; they form cavities or cause unusual shrinkage. Occasionally affected tissues near the root surface may crack allowing secondary decay fungi to invade. Beets may be severely affected without showing external root symptoms; however, foliar symptoms such as twisted, bent, uneven development of leaf blades may be observed on young plants grown in boron-deficient soils. Beets showing these symptoms should be marketed early as bunched beets. The disease can be prevented by applying borax to the soil. Local horticultural authorities should be consulted for recommended rates. Resistant beet varieties are also available.

Reference: *6*.

Freezing Injury

Beets begin to freeze between −1.1° and −1.7°C. Frozen root tissue may appear slightly water soaked with areas of white tissue. Severe freezing causes external and internal water-soaking and may produce blackening of the ring and rays of conducting tissue. These beets become soft and susceptible to decay.

Beets should not be held at temperatures below 0°C; if frozen, they should be thawed slowly and used as soon as possible. If frozen beets are warmed quickly to temperatures above 5°, decay may spread rapidly.

Reference: *4*.

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Chicory, Endive, and Escarole

Chicory (*Cichorium intybus* L.) has small, torpedo-shaped, leafy heads, which are blanched during growth in the dark. The production of blanched chicory is minimal in the United States; however, chicory is imported primarily from Belgium to supply the fancy food trade. This type sometimes is called "witloof," which is Flemish for white leafed. Endive and escarole both belong to the species *Cichorium endivia* L. Endive has narrow, curled, finely divided leaves, whereas escarole consists of a loose head composed of broad leaves that tend to be thick and somewhat twisted and wavy. All these salad vegetables are subject to the same diseases that affect lettuce, including lettuce mosaic, aster yellows, sclerotinia rot, and gray mold rot. Consequently, several of them are discussed under lettuce, including marginal browning.

Bacterial Soft Rot

(Causal Organism *Pseudomonas marginalis* (Brown) Stevens)

Bacterial soft rot caused by *P. marginalis* is the principal disease of chicory imported from Europe and also occurs on endive and escarole. The disease may start at the leaf tips or margins and then progress toward the center of the leaves. The infection also may originate on the broad midribs if they have been injured by abrasion or bruising or at the base of the small head. Eventually the entire head may become dark brown and slimy. (Pls. 3 and 4.)

Bacterial soft rot spreads most rapidly between 24° and 27°C but also between 2° and 9°. The incidence of the disease likely can be minimized by (1) cleaning knives and any containers used during harvest, (2) washing the heads with chlorinated water, followed by removal of excess moisture, (3) careful handling of the product to prevent physical injury, (4) prompt cooling to 0°, and (5) shipping and holding it as close to this temperature as feasible throughout marketing.

Reference: *2*.

Black Heart (Brown Heart)

Black heart (brown heart) affects endive and escarole. The disorder is characterized by marginal blackening or browning of the heart leaves (pl. 23). In severe cases, the entire head may be affected. The problem is analogous to tipburn in head lettuce and has a similar etiology; that is, it is related to calcium nutrition and the water status of the plant during growth. In endive and escarole, the disorder can be prevented by spraying the plants during growth with a solution containing calcium. Since the marginal tissue is dead, it is subject to bacterial soft rot if temperatures are not ideal and free moisture is present. Therefore, the postharvest consequences of black heart can be reduced by keeping the heads as close to 0°C as possible throughout marketing. Even though drying conditions might reduce the hazard of decay following black heart, they also would lead to highly undesirable wilting of the heads.

References: *3-5*.

Irradiation Injury

Gamma irradiation at 25 krad or more induces the development of reddish-brown spotting along the midribs of the leaves, sunken discolored areas on the leaves, and a browning of the heart leaves (pl. 5). Consequently, gamma irradiation cannot be used to control postharvest decay in chicory, endive, and escarole.

Reference: *1*.

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Globe Artichokes

Globe artichokes are the flower buds of *Cynara scolymus* L. The edible part consists of the fleshy, tender base of the bracts (scales) and the fleshy receptacle (flower base).

Gray Mold Rot

(Causal Organism *Botrytis cinerea* Pers.: Fr.)

The light-brown to almost black lesions of gray mold rot may appear anywhere on the bud, and the gray web of mycelium sometimes is evident (pl. 6). The lesions most frequently occur on wounds, such as abraded surfaces, the cut end of the stem, or the split tips of the bracts. Frost-blistered surfaces also may be sites of infection. Gray mold rot in the field tends to be particularly troublesome during long spells of cool, wet weather. Temperatures near freezing, whether before or after harvest, slow the spread of the disease.

Under humid conditions, the lesions of gray mold rot are moist to wet, odorless, and reddish brown or brown, and the borders are definite and slightly water soaked. Under dry conditions, the advancing edge is not water soaked, and the affected tissues are dark brown, dry, and firm. Internally, decayed tissue is brown and firm in the bracts and stem but somewhat spongy in the less fibrous, edible base. The symptoms of gray mold rot and bruising of the bracts resemble each other, but decay tends to penetrate deeper than bruises.

Gray mold rot, by far the most common market disease of globe artichokes, is caused by *B. cinerea*. This fungus is found wherever vegetables are grown. Under humid conditions, spores are produced abundantly and are carried about by air currents. Any type of wound facilitates infection, but the fungus can readily penetrate moist, unbroken tissue. Tissue that is dead or dying, weakened by freezing or mechanical injury, is more readily infected than vigorous, healthy tissue. The pathogen thrives under a wide range of temperatures. Its spores can germinate, grow, and sporulate between −2° and 32°C, with an optimum of about 24° to 25°. The fungus grows very little at −2° to 0° but still sufficiently to become established in the plant tissue. Consequently, the artichokes must be kept at desirably low temperatures throughout their marketing period.

Losses from gray mold rot can be minimized by rapidly cooling the buds to below 5°C after harvest and by maintaining them between

0° and 3° throughout marketing. However, gentle handling is still important, because physical injuries can accelerate decay development as much as a 10° rise in temperature. Optimum refrigeration is particularly important for prepackaged artichokes, because the humid conditions inside the packages are ideal for the rapid development of decay when temperatures are above about 5°.

References: *2-4*.

Freezing Injury

Artichoke bracts freeze at −1.4° to −1.1°C. The freezing point of the fleshy receptacle has not been reported. In slightly frozen buds, the epidermis of the bracts becomes detached and forms whitish to light-tan blisters. When the blisters are broken, the underlying tissue turns brown. Light freezing detracts from the appearance of artichokes, but it does not impair their edibility in any way. Severely frozen buds turn black and become unsalable. Such severe freezing discolors internal tissues near the juncture of the bud and stem before other parts of the fleshy receptacle are affected (pl. 7).

The visible damage from freezing can be minimized by gentle handling to prevent opening of the blisters and thus darkening of the exposed tissue. To ascertain whether freezing has been severe, cut the buds lengthwise to check whether or not the inner tissue is brown.

Reference: *5*.

Irradiation Injury

Gamma irradiation of globe artichokes at doses of 100 krad or above induces the development of dark sunken pits on the stem, a brown scuffed-appearing discoloration on the outer bracts, reddish-brown spots on the inner bracts, and a blackening at the bases of the florets (pl. 8). The internal discolorations develop at lower doses than the externally visible injuries. Decay of globe artichokes cannot be controlled by gamma irradiation.

Reference: *1*.

Mechanical Injury

During handling and packing, the surfaces of the artichoke bracts are commonly abraded and the tips often are split. The abraded surface commonly turns an unsightly brown or black. Consequently, rubbing the buds against each other or against the sides of the container should be minimized. Splitting of the bract tips is serious only when the buds are held under conditions favoring decay, because decay frequently starts at the injured tips.

References: *3, 4*.

Wilting

Wilted buds are soft and pliable. Severe wilting, induced by loss of water, causes the bracts to fold inward and thus gives the entire bud an unsightly appearance.

Normal washing or hydrocooling followed by prompt cooling to below 5°C and by marketing at between 0° and 5° minimizes the problem of wilting. Packaging in *perforated* plastic bags or box liners also reduces the chance of wilting. However, the buds should be cooled to the desirable temperature range *before* they are placed in the bags or liners, and they must be maintained in that range or else decay can become serious.

Reference: *4*.

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Lettuce, Whole

All lettuce on the market, whether the head or leaf type, belongs to the species *Lactuca sativa* L. The major types are the crisphead, butterhead, romaine or cos, and loose leaf or bunching. Most of the information about the various diseases and disorders is based on research with the crisphead type. However, all these types are subject to the bacterial and fungal diseases discussed here. In contrast, the physiological disorders do not affect all types of lettuce similarly, and for most of the leafy types, relatively little information is available.

Since all parts of a head, except the small stem, are edible, any defect detracts from the market quality of the head. In crisphead lettuce that is shipped with the outer, less desirable wrapper leaves attached, the latter are often a source of decay that can spread to the inner, desirable leaves. Removal of the outer wrapper leaves tends to reduce the incidence of decay in the edible part during prolonged marketing periods. Thus, packaging of individual wrapped heads limits spread of diseases. Particular care should be taken with naked-packed lettuce to exclude heads that show any decay at harvest. Careful handling and prompt cooling to and shipment between 0° and 2.5°C also limit the development of various diseases that affect lettuce.

References: *8, 20.*

Bacterial Soft Rot

(Causal Organisms *Pseudomonas* and *Erwinia* spp.)

Bacterial soft rot is the most serious market disease of lettuce. Affected tissue is various shades of green and brown or tan. As the decay develops, the tissue becomes soft and slimy when the humidity is high or free moisture is present. Under dry conditions, the affected areas may dry up and become papery in texture or fall out and thus produce a shothole effect. In severe cases, the entire head may become a slimy mass, but the disease does not cause a putrid odor. (Pls. 9 and 10.)

The exudate of bacterial soft rot from rotted tissue in contact with underlying leaves sometimes produces spotting symptoms, which resemble those of russet spotting. The ability to distinguish between these two defects may occasionally be important; this task is aided by the following table.

Table 1
Characteristics and origin of spotting for bacterial soft rot and russet spotting on lettuce

	Origin of spotting	
Characteristic	Bacterial soft rot	Russet spotting
Color	Tan to brown; water soaked.	Tan, brown, olive.
Shape	Mostly elongated.	Irregular.
Surface	Glistening; mostly sunken; epidermis always affected.	Dull, not always sunken; epidermis not always affected.
Other	Frequently associated with internally discolored veins; obviously decayed tissue often near or on adjacent leaf.	Veins not discolored internally; not associated with decayed tissue.

Bacterial soft rot may be induced by one or more of the following bacteria: *Pseudomonas marginalis* (Brown) Stevens, *P. cichorii* (Swingle) Stapp, or *Erwinia carotovora* (Jones) Bergey et al.; other bacteria occasionally may be involved.

Bacterial soft rot may occur on any type of lettuce, endive, and related crops from any growing region. The bacteria attack tissue that previously has been invaded by fungi, that has been injured in some other manner such as mechanically, or that is dead. When lettuce is held above 3°C and moisture is available to the organism, bacterial soft rot likely will affect lettuce that has been damaged mechanically, that has been injured by exposure to freezing temperatures, or that exhibits some physiological disorders.

Bacterial soft rot develops at any temperature at which lettuce is normally held. However, its development is much slower between 0° and 3°C than at higher temperatures; it is very rapid above about 15°.

The incidence of this decay can be minimized by careful handling of lettuce, by rapid precooling, and by maintaining it between 0° and 2.5°C throughout marketing. Additionally, lettuce infected with any type of disease should not be shipped, especially for long distances.

References: *2, 3, 5, 6, 16, 18.*

Downy Mildew

(Causal Organism *Bremia lactucae* Reg.)

In early stages of this infection in the field, light-green to yellowish areas appear on the upper (adaxial) surface of wrapper leaves of crisphead lettuce. Under conditions of high humidity and moderate temperatures, a fuzzy, whitish-gray mold develops on the lower (abaxial) surface of infected areas. The lesions eventually can turn brown, may enlarge and coalesce, and may turn soft and slimy as secondary decays enter. Generally, the lesions are well defined by the veins. If transit temperatures are higher than desirable, downy mildew may spread from the wrapper leaves to the outer head leaves. (Pl. 11.)

On butterhead lettuce, the lesions are less well defined by the veins than on crisphead lettuce, but otherwise the symptoms are similar.

Downy mildew is induced by the fungus *B. lactucae*, of which many virulent forms have been identified. The fungus can be highly destructive in lettuce grown under cool, moist conditions. In the United States, it can be particularly serious in the lower Rio Grande Valley of Texas in midwinter and in the Santa Maria Valley of California in spring and fall. The disease has been found in all lettuce-producing areas of the United States and Europe, but it is a relatively minor problem on the market.

The most efficient means of controlling downy mildew is to select resistant cultivars. Systemic fungicides also effectively control the disease. However, any fungicide used on lettuce for this purpose must be approved by the appropriate regulatory agencies. The post-harvest development and intensification of the disease can best be controlled by removing the wrapper leaves before the lettuce is packed and shipped. This is particularly important for lettuce harvested in fields in which downy mildew is widespread. Additionally, rapid precooling to the desired temperature and holding the lettuce between 0° and 2.5°C throughout marketing will minimize the adverse inpact of this disease.

References: *1, 5, 18, 21*.

Gray Mold Rot

(Causal Organism *Botrytis cinerea* Pers.: Fr.)

Tissue affected by gray mold rot appears water soaked, grayish green or brown, and, in severe cases, soft and slimy. At these later stages of development, the characteristic smoky-gray mycelium and spore masses frequently appear (pl. 12). Gray mold rot is incited by the fungus *B. cinerea.* The fungus has a wide temperature tolerance and grows between about −2° and 32°C, although it develops most rapidly between about 20° and 25°. Gray mold rot is one of the two most important diseases of head lettuce on the New York market; however, it can develop wherever lettuce is grown, whether in fields or in greenhouses. The disease also affects chicory, endive, and similar salad vegetables.

There is no absolute control for gray mold rot because the fungus grows under such a wide temperature range. However, its destructiveness can be minimized by rapidly precooling the lettuce and holding it between 0° and 2.5°C during marketing. Development of resistant cultivars holds some promise. Minimizing any type of physical injury to the lettuce is an important control measure, since spores of *Botrytis* do infect undamaged lettuce leaves only if a food source, such as juice from wounded tissue, is available on the surface.

References: *1, 6, 18, 21.*

Watery Soft Rot (Sclerotinia Rot)

(Causal Organisms *Sclerotinia sclerotiorum* (Lib.) DBy. and *S. minor* Jagger)

Tissue affected by watery soft rot is water soaked and light or pinkish brown. In severe cases, a white cottony mold may develop on the surface of the leaves. Although watery soft rot may start anywhere on a head, infection most commonly occurs near the soil level. Severely affected heads are a wet leaking mass of tissue (pls. 13 and 14). On the market, it would be unlikely, but not impossible, to see the black resting bodies of the fungus, called sclerotia. *Sclerotinia sclerotiorum* is responsible for inducing much of the watery soft rot seen on markets, but *S. minor* is most common in the Salinas Valley, CA.

Even though sclerotinia rot is found in all lettuce-growing areas, it is of relatively minor importance on the market. Apparently either affected plants are not harvestable, or if a mild field infection exists, the lettuce would not be shipped long distances. Losses from sclerotinia rot are most common under cool, moist conditions, particularly when the soil surface is wet. Infection may occur between 0° and about 27°C, with an optimum of about 18° to 21°. The presence of wounded tissue enhances the chance for infection, but it is not an essential precondition.

Preventing infected lettuce from entering the marketing channels is the best method to avoid major postharvest losses from sclerotinia rot. Consequently, outer wrapper leaves should be carefully trimmed before the lettuce is packed. Prompt and thorough precooling and shipment between 0° and 2.5°C will slow development of the disease. Maintaining a dry soil surface as far as possible, treating the soil with fungicides, and developing resistant cultivars are ways to combat sclerotinia rot before harvest.

References: *1, 5, 18, 21.*

Viruses and Related Diseases

Aster Yellows

Lettuce heads seriously affected with aster yellows likely would not reach the market, because the plants are stunted and thus would not be harvested. If affected heads do reach the market, they would be soft and have curled heart leaves. They may exude latex, which then would dry and leave a pink to tan residue on the leaves.

Aster yellows is believed to be caused by a mycoplasma. The disease tends to be much more common in lettuce grown in the Eastern and Midwestern United States than in the Far West. Since the disease is spread by leafhoppers, eradication of these insects and the weeds that harbor the infectious agent is the only means of control.

Reference: *22.*

Big Vein

Big vein is characterized by a translucent clearing of the veins, which makes them appear unusually large and prominent. The leaves of affected heads tend to be crinkly, stiff, and thicker than in normal heads. Overall, the heads appear coarse; however, the disease does not seem to reduce the storage life of affected lettuce.

The agent that induces big vein is not known, but it appears to be a viruslike entity introduced into the plant through the roots by a soil fungus, *Olpidium brassicae* (Wor.) Dang. Symptoms of big vein are most serious when the air temperature during growth is about 14°C. Root temperature of 14° to 24° has no effect on the development of the symptoms. When the air temperature is above 24°, almost no symptoms develop, regardless of the root temperature. Consequently, big vein is most commonly seen during cold, wet weather and in lettuce grown in heavy soils. It can occur in all lettuce-growing areas of the United States and also has been reported from other continents.

Planting of resistant cultivars provides the best control of lettuce big vein. Fumigation of the soil and careful control of irrigation help to reduce its incidence, but these procedures are not always commercially feasible.

References: *20, 21*.

Lettuce Mosaic

This disease derives its name from the green and yellow mottling that is noticeable in leaves of young plants. In mature heads that normally would be on the market, the mottling usually is absent or indistinct; if it is present, it would be most noticeable near the margins. Even if the mottling is not evident, heads with lettuce mosaic tend to be dull green to slightly yellow, and the marginal serrations are apt to be particularly prominent in relatively young leaves.

Lettuce mosaic is caused by a seed-transmitted virus that is spread by the green peach aphid (*Myzus persicae* Sulzer). The means of transmission allows for highly effective control measures if used. They are (1) indexing of seed lots to contain 0 infested seeds in 30,000, (2) use of resistant cultivars, (3) prompt cultivation of abandoned fields, and (4) control of weeds on the periphery of fields, since many weeds are hosts to the virus. There is no clear evidence that lettuce affected by mosaic deteriorates more rapidly than healthy lettuce, except in the cultivar 'Climax' and close relatives (see Internal Rib Necrosis and Rusty-Brown Discoloration). However, since the virus generally reduces the vigor of all lettuce, it is reasonable to assume that virus-infested heads would have a shorter market life than normal ones.

References: *1, 21.*

Internal Rib Necrosis. Internal rib necrosis is characterized by a diffuse, dark, gray-green or occasionally coal-black discoloration. It usually starts at or near the junction of the leaf with the stem, but it can extend several centimeters along the midrib. Since the lesions are mostly subsurface, they have a diffuse appearance, but they may reach the surface in severe cases. Most commonly the cap leaves, outer head leaves, and some of the small inner head leaves are affected; the wrapper leaves are affected only occasionally (pl. 15).

Internal rib necrosis is induced in the cultivar 'Climax' by lettuce mosaic virus alone. However, in the presence of lettuce mosaic and beet western yellow viruses, the cultivars 'Vanguard' and 'Vanmax,' which are related to Climax, also may be affected. The symptoms may be present at harvest, but the incidence and severity increase thereafter at temperatures recommended for lettuce, but the lesions tend to become darker as temperatures increase.

Internal rib necrosis may be controlled by replacing the susceptible cultivars with resistant ones. Until this occurs, strict observance of the seed indexing program for the control of lettuce mosaic will provide the only sure control.

The discoloration associated with internal rib necrosis resembles old lesions of rib discoloration, but the latter are mostly near the middle of the midrib rather than near its base.

References: *16, 20, 21.*

Rusty-Brown Discoloration. The name of this disease aptly describes the symptoms. The discoloration may affect only the midribs, but entire leaves and heads may be affected. The discoloration tends to follow the veins, but it is not confined to them. In some cases, the veins may be normal and interveinal tissue discolored. Generally only leaves in the outer half of the head are affected, although the entire head may be involved. Only the epidermis and one to four adjacent cell layers are normally affected, but distinct sunken lesions may be present in severe cases. (Pl. 16.)

Rusty-brown discoloration originates before harvest, but it can become much worse thereafter, particularly at temperatures recommended for lettuce. The disease is confined to the cultivar 'Climax' and is induced by infection of the heads with lettuce mosaic virus. The symptoms are more intense in carbon dioxide-enriched atmosphere than in air.

Rusty-brown discoloration can be prevented by growing resistant cultivars or by planting disease-free seeds.

References: *11, 16, 20, 21.*

Disorders and Physical Injuries

Brown Stain and Heart Leaf Injury

Excess carbon dioxide (CO_2) in the atmosphere surrounding lettuce can result in several distinctly different symptoms of injury. The principal ones are brown stain and heart leaf injury.

Typical lesions of brown stain measure about 0.5 by 1.0 cm and have distinct margins that often are darker than the slightly sunken centers. This appearance produces a halo effect. Brown stain occurs on both leaf surfaces, often on or near the midrib and toward the base of the leaf. Lesions most commonly develop on the head leaves just under the cap leaf, but they also may develop on leaves deeper in the head. The heart and wrapper leaves are not affected by brown stain. Young lesions may show no discoloration, but as they age they become tan, brown, or even black. When CO_2 injury is severe, these lesions may coalesce and thus be several centimeters in length (pl. 17).

Brown stain lesions do not always have the characteristic halo appearance. They occasionally resemble russet spotting (see p. 28). When uncertainty exists, examination of the heart leaves may resolve the problem. Although the heart leaves show neither type of spotting, they may have reddish-brown margins or be completely discolored when excess CO_2 causes the injury. Also, examination of several heads may help resolve the issue, because some may show the typical brown stain symptoms.

Brown stain is aggravated when lettuce is simultaneously exposed to relatively high concentrations of CO_2 and low concentrations of oxygen (O_2) (10 percent or below). Similarly, the addition of carbon monoxide (CO) at about 1 to 1.5 percent also aggravates the development of CO_2 injury. If high levels of CO_2 and CO and low levels of O_2 coincide, the damage is most severe.

Injury from CO_2 can be prevented readily by assuring that gas exchange in a transport vehicle or storage room is sufficient to prevent accumulation of CO_2 produced during respiration. In situations where gas exchange must be restricted, such as when controlled atmospheres are deliberately used for the transit of lettuce, some respiratory CO_2 can be absorbed by placing hydrated lime in the loading compartment.

Low O_2 levels also can injure heart leaves, but in this case the discoloration is more brown than red and the injury commonly is accompanied by a flat, sweet flavor. Rusty-brown discoloration resembles the broad discolored areas sometimes induced by high levels of CO_2 along the midribs; however, brown stain extends along the veins into the leaf blades, whereas CO_2 injury does not follow the veins.

Lettuce differs substantially in its susceptibility to brown stain. Cultivar and area of production seem to be the main factors involved. Lettuce produced in the coastal valleys of California is more susceptible than lettuce grown either in the desert areas of California or Arizona or in the San Joaquin Valley, CA. The basis for this difference is unknown.

References: *13, 16, 20.*

Heart leaf injury is sometimes the first and only symptom of CO_2 injury. Heart leaves so injured have reddish-orange margins in mild cases; in severe cases, the entire leaflet may be discolored. Heart leaf injury is more frequent and more severe in soft than in firm or hard heads. In soft heads, the margins of the inner, green leaves also may be discolored, but they usually become grayish rather than reddish orange.

Occasionally, excess CO_2 induces a yellowish to reddish-brown discoloration of midribs and adjacent tissue. The dead areas lack a definite margin and tend to extend along the main curvature of the midribs so that they appear to be corrugated. However, this symptom by itself is not sufficient evidence that the lettuce has been injured by excess CO_2. If lettuce is exposed to 20 percent CO_2, a level not normally reached during marketing, the leaves will become water soaked and droplets of exudate will appear on the surface. (Pl. 18.)

The various symptoms of CO_2 injury can be induced by exposing head lettuce to more than 1 percent CO_2 while being held in the temperature range most desirable for it. The longer the storage period, the more likely the injury will occur. However, the injury tends to be less severe at temperatures above the range that is otherwise ideal for lettuce. The injury may be relatively mild when the lettuce is removed from an atmosphere that contains undesirably high levels of CO_2, but it may become very prominent after a few days in air at about 10°C.

Butt Discoloration

The milky latex that leaks from the cut stem of a lettuce head gradually turns pink and eventually reddish brown or brown. This butt discoloration is due to the oxidation of the latex on exposure to air and occurs rapidly at high and slowly at low temperatures. However, other unknown factors affect the rate at which the discoloration occurs. In some heads the discoloration occurs within 1 week at temperatures recommended for lettuce, and in others the same degree of discoloration may require 2 weeks. Consequently, this symptom is not a reliable indication of lettuce freshness.

The postharvest darkening of the cut stem can be slowed by holding the lettuce in an atmosphere that contains 0.5 percent oxygen (O_2) or 1 to 3 percent carbon monoxide (CO). However, both of these modifications are effective only while the lettuce is held under these conditions. Once it is removed from the modified atmosphere, discoloration proceeds fairly rapidly. Since 0.5 percent O_2 approaches the lower limit of safe O_2 concentration for lettuce and since the use of CO is inherently dangerous to people, the use of these procedures cannot be justified on an objective basis to control butt discoloration.

Reference: *20*.

Freezing Injury (Blistering)

The separation of the epidermis from the underlying tissue, which gives frozen tissue its characteristic blistered appearance, is the most common sign of freezing in lettuce. When the skin is still intact, the injury gives the lettuce a silvery appearance. Once the skin is ruptured in any way, the dead cells below will turn tan; if the cells are protected from drying, they tend to remain white. The blistering may involve only a small area of a leaf or it may encompass the entire surface depending on the severity of the exposure to freezing temperatures (pl. 19). Severely frozen lettuce is water soaked and mushy once the tissue has been thawed (pl. 20). Lettuce freezes at $-0.4°$ to $-0.8°C$. Freezing may occur in the field or during vacuum cooling, transit, or storage.

The stage at which the freezing occurred can be determined with reasonable confidence when a load of lettuce arrives with freezing damage. Field freezing tends to be randomly distributed through the load, and the blistering of the outer leaves is the main symptom. In-transit freezing tends to be confined to or is more severe along the periphery of a box of lettuce or of the load, and the leaves are typically water soaked and flaccid. If freezing occurred during vacuum cooling, only a part of the load likely would show the damage, because generally only part of a transport vehicle is loaded from a given vacuum-cooling run. However, freezing during vacuum cooling is very rare because of safeguards built into the equipment.

Damage from freezing exposures in the field can be minimized if harvest is delayed until after the lettuce has completely thawed. Lettuce that froze in transit should be thawed at about 5°C before being handled in any way, because frozen tissue is highly sensitive to mechanical injury. Such thawed lettuce will be marketable if freezing was slight. Lettuce that has sustained freezing damage must be held as close to 0° as feasible and utilized promptly, because the damaged tissue tends to be susceptible to decay at undesirably high temperatures.

Prevention of postharvest freezing depends on the operator of the cooling, transit, and storage equipment, as the case may be. Careful calibration, adjustment, and maintenance of thermostats and other refrigeration-related equipment are essential.

References: *13, 16, 20.*

Irradiation Damage

Gamma irradiation at a dose of 25 krad induces a reddish-brown spotting, especially along the midribs. Similar spots often are sunken when they occur on the leaves (pl. 21). The severity of the injury increases substantially as the dose is increased to 200 krad. Irradiation also tends to increase the severity of pink rib, especially at the higher doses. Consequently, irradiation is not suitable for controlling decay or insects in harvested lettuce.

Reference: *4.*

Marginal Senescence (Marginal Browning)

Marginal senescence is characterized by a cream to brown discoloration of the margins of wrapper and outer head leaves (pls. 22 and 23). Initially the discolored parts are pliable, but unless humidity is very high, they tend to dry out and become papery. The margins of the discoloration are not always clearly defined. The etiology of the development of marginal browning has not been thoroughly investigated. Stress induced in the leaves by excessive accumulation of salts in the soil is one possible cause. Aging of the tissue also may be a contributory factor because the disorder tends to be most common in hard heads.

Since causes of marginal senescence have not been clearly identified, recommendations for control are lacking. The problem of serious decay following marginal senescence can be minimized if affected lettuce is precooled rapidly and then held at desirable temperatures (0° to 2.5°C) throughout marketing. Lots of lettuce in which marginal senescence is widespread should not be shipped.

Marginal senescence sometimes resembles symptoms of tipburn. However, tipburn also occurs on inner head leaves, and its lesions often show a dark-brown flecking, which is absent in marginal senescence.

Reference: *1*; J.K. Stewart, pers. commun.

Mechanical Injury

Mechanical injury of lettuce can take many forms. The heads or leaves may be crushed, bruised, or torn; the surface may be abraded; and occasionally the head leaves of crisphead lettuce may be separated from the stem.

Mechanical injury can be caused by a multiplicity of procedures to which the lettuce is exposed during marketing. During harvest, the lettuce may be cut so high that some of the head leaves are detached from the stem; therefore the cut surface of the leaves often becomes discolored. The same type of damage may occur during trimming of the lettuce immediately after harvest. Leaves may be crushed during packaging or closing of the boxes, during their loading into the transit vehicle, from overhead weight during transit, or as a result of a sudden impact. Similar hazards exist during handling of the boxes at wholesale and retail levels. Thus, lettuce can be mechanically damaged anytime between harvest and consumption.

Mechanical damage likely cannot be completely prevented. However, certain practices will minimize the problem: (1) Use containers that will accommodate the lettuce without undue force being applied during packing and closing of the boxes; (2) use strong enough boxes to protect the lettuce; they should not just surround the lettuce; (3) institute handling methods that will minimize the chance of rough treatment; and (4) provide sufficient and properly trained supervisors. Injured tissue is particularly susceptible to invasion by decay organisms. Consequently, mechanical injury should be prevented whenever feasible, but the virtual inevitability of some mechanical injury occurring emphasizes the importance of maintaining the lettuce at desirable low temperatures (0° to 2.5°C) throughout marketing.

The pink discoloration of bruised rib tissue sometimes resembles pink rib. However, mechanical injury and pink rib can be readily distinguished, because in the latter there is no evidence of external physical damage.

References: *2, 9, 10, 20.*

Oxygen Deficiency

Reddish-brown discolored heart leaves sometimes are the first visible and only symptom of low oxygen (O_2) injury. The wrapper and cap leaves may have shiny to water-soaked, gray, dead patches even when dead heart leaves are not obviously present. Young head leaves may have shallow, reddish-brown spots on the midribs, usually on the inner (adaxial) surface. A sweet odor and flat sweet flavor also are characteristic of low O_2 injury, but they disappear almost completely within 3 days or less after the lettuce is removed into the air. In contrast, the visible injuries become more intense after removal of the lettuce to air. (Pl. 24.)

The discoloration of the heart leaves can be induced when lettuce is held at 10°C with less than 0.5 percent O_2. Other injuries appear only when the O_2 level drops to 0.25 percent or less. These symptoms can develop within 1 week at temperatures recommended for postharvest handling of lettuce.

Dangerously low O_2 concentrations are unlikely to be reached during transport or storage of lettuce in normal atmospheres. However, if lettuce is shipped or stored in controlled atmospheres, O_2 deficiency must be prevented by careful monitoring of the O_2 concentration throughout the period. If the atmosphere is adjusted only initially, leakage from outside must be adequate to maintain an O_2 level of 1 percent or higher.

Low O_2 injury of the heart leaves resembles that induced by high CO_2, but with high CO_2 the injury is more red than brown and the sweet and flat off-flavor is absent.

References: *16, 20.*

Ozone Damage

Concentrations of ozone below 0.1 ppm maintained for 2 days or longer at 2.5°C induce slight to moderate yellowing or browning of areas between the veins. However, these mild symptoms are visible only after about the fifth day following removal of the lettuce from the ozone-enriched atmosphere. Exposure to 0.1 ppm ozone results in brown flecking of midribs and yellowing of the interveinal tissue after 3 days. Severe water-soaking follows exposure of lettuce to ozone at 0.3 ppm or higher concentrations for 2 or more days. If the exposure continues for 4 days, the tissue will appear transparent. (Pl. 25.)

Ozone gas, which is occasionally touted as a useful inhibitor of decay in fresh produce, causes the injury; ozone, as contained in smog and applied to young lettuce plants, induces similar symptoms. The obvious solution is to prevent lettuce from coming into contact with ozone at any concentration.

References: *19, 23.*

Pink Rib

The name exactly describes the symptoms of the disorder. Three types of pink rib have been described. The most common is a diffuse pink rib around air spaces commonly found in large midribs. Although the pinkiness is mostly associated with the area around air spaces, pink walls also may occur in groups of cells distant from air spaces. This type of pink rib usually is confined to the thick basal part of midribs in large head leaves and is more intense on the inner (adaxial) than on the outer (abaxial) side of the rib. The second type of pink rib involves the tubules that contain the milky, white latex found in lettuce. In this type, the discoloration is due to the oxidation of latex that has escaped from the laticifers (tubules that contain the normally milky white latex). In the third type, xylar pink rib, only the walls of some water-conducting elements are pink. They may be scattered singly or in groups among normal cells. Diffuse pink rib may occur by itself, but it always accompanies the other two types. (Pl. 26.)

No specific cause of pink rib has been identified, but some preharvest and postharvest factors affect its incidence and severity. Since diffuse pink rib frequently is associated with disrupted cells, it is reasonable to assume that rapid growth affects eventual development. Also, senescence seems to be involved, because pink rib is much more common on hard than firm heads and can occur on the former at time of harvest. Also, higher than desirable postharvest temperatures encourage the intensification of pink rib. Diffuse pink rib is not aggravated by exposure to ethylene, and no microorganism has been implicated in its occurrence. Xylar pink rib may possibly be associated with infection by a bacterium.

The incidence and severity of pink rib can be minimized by (1) avoiding harvest of hard heads, (2) prompt precooling to between 0° and 2.5°C, (3) maintaining the lettuce at that temperature range throughout marketing, and (4) possibly instituting cultural practices to minimize excessively rapid growth. Holding lettuce in atmospheres with reduced O_2 levels does not prevent pink rib occurrence; on the contrary, O_2 at about 2 percent tends to aggravate its development during 1 week at 10° or 1 month at 2.5° or 5°.

References: *16, 20.*

Rib Discoloration (Brown Rib)

Circumstantial evidence strongly suggests that rib discoloration and brown rib are the same disorder; consequently, they will be treated as such.

The yellow to black lesions characteristic of rib discoloration generally develop on the inner surfaces of the midrib and of secondary ribs of cap leaves and in one or more of the next four or five younger leaves. Older or younger leaves sometimes also are affected. The discoloration commonly is found at the maximum curvature of the midrib and below the surface, although the epidermis also can be involved. Sometimes a subsurface cavity is associated with rib discoloration. The lesions tend to darken during storage; in severe cases, they may be sunken and occasionally cracked. They frequently become a focus for decay development during prolonged storage. (Pl. 27.)

Rib discoloration develops before harvest, and no specific cause has been identified. The disorder appears more commonly when day temperatures exceed about 27°C or when nights are between 13° and 18° than during cooler periods. This finding suggests that conditions favoring rapid growth also tend to favor the development of rib discoloration. Additionally, hard to overmature heads more frequently are affected than less mature ones.

Lettuce from any growing region may develop rib discoloration, particularly during hot weather. Since rib discoloration appears before harvest, postharvest control is not feasible. However, some measures can be taken before or after harvest to reduce its incidence and minimize its adverse effect on quality. Cooling the lettuce with sprinklers during hot weather tends to reduce the incidence of the disorder. Avoiding harvest of hard or overmature heads serves the same end. If rib discoloration is present, cooling the lettuce rapidly and keeping it at 0° to 2.5°C will reduce the chance of decay developing in the lesions. Resistant cultivars likely are the best long-range solution to the problem.

Rib discoloration and pink rib superficially resemble each other, but cross sections of the latter are decidedly pink, whereas those of mild rib discoloration are yellowish to tan.

References: *12, 16, 20.*

Russet Spotting

The name for the disorder is based on the small, tan, brown, or olive spots that are randomly distributed over the affected leaf. In severe cases, the spots may coalesce and form irregularly shaped discolored areas. Spots on the midribs usually are longitudinal and pitlike, but those on the blade appear shallow, roundish, and somewhat diffuse. They may be on the veins, between the veins, or both. The spots tend to appear first on the outer (abaxial) side of midribs of outer head leaves, where they also tend to be most severe. Russet spotting affects leaf blades in advanced stages of the disorder. The spots generally are depressions of the surface, but internal spots may appear on the midribs and large veins. These subsurface lesions appear dark and diffuse as viewed through the outer healthy cell layers. Even though russet spotting generally progresses inward, absence of spots on outer head leaves does not preclude their presence on inner leaves. Wrapper leaves seem to escape this disorder. (Pls. 28 and 29.)

Russet spotting sometimes resembles the symptoms of carbon dioxide excess and early infections of bacterial soft rot. The distinctions are clarifed in the relevant sections.

Exposure of lettuce to ethylene is the major cause of russet spotting. Concentrations as low as 0.1 ppm can induce the disorder in some lots of lettuce. The rate and severity at which the disorder develops increase as the concentration increases up to about 10 ppm.

Russet spotting can develop even when ethylene is not introduced into the atmosphere that surrounds the lettuce. The following conditions favor development of the disorder: (1) Shipping heads that are hard and old at harvest; (2) holding lettuce with decayed produce; (3) storage temperatures between about 3° and 5°C; (4) storage that exceeds 10 days; (5) field temperatures that exceed 30° for 2 or more consecutive days at about 9 to 14 days before normal harvest; and (6) possibly, infection of the head with lettuce mosaic during development.

Russet spotting occurs sporadically in lettuce from any source, although cultivars differ in their susceptibility to the disorder.

Russet spotting can be prevented, or at least minimized, by observing the following precautions: (1) Keep lettuce in surroundings that are essentially free of ethylene. This means that lettuce should not be stored or shipped with any products, such as apples, pears or plums, or melons, that emit substantial amounts of ethylene at temperatures recommended for lettuce. Additionally, electric-powered vehicles should be used in confined spaces, since engines powered by fossil fuels emit ethylene during operation. (2) Avoid shipping hard lettuce. (3) Avoid holding decayed or sound lettuce with other produce that shows substantial decay. (4) Maintain temperatures between 0° and 2.5°C. (5) Ship or store lettuce with a high potential for developing russet spotting in an atmosphere that contains 2 to 6 percent oxygen instead of the normal 21 percent.

References: *15, 16, 20.*

Solar Injury

Head lettuce grown in areas with high levels of solar radiation may show thin papery or bronze areas on the surface most directly exposed to the direct rays of the sun. Most commonly, it is the cap leaf that shows the damage. The next underlying leaf may have only a small yellow-tan spot on the outer surface immediately below the more severely injured leaf.

Solar injury likely will develop only during clear weather when mature or nearly mature heads are exposed to air temperatures of about 24°C or higher. Under those circumstances, parts of the head facing south or southwest may exceed 38°. Since the defect is induced in the field, nothing can be done to alleviate it after harvest.

Reference: *20.*

Tipburn

Tipburn is characterized by light-tan to dark-brown margins of leaves. The dead margins may be very narrow or extend inward 3 cm or more in severe cases. The lesions may be confined or they may encompass a major part of the margin. Tipburn usually is found on head leaves of various ages, but the outer leaves that have not yet folded over in crisphead types of lettuce occasionally may be affected. The youngest leaves in the center of a head rarely show tipburn in crisphead lettuce, although they may be encompassed in other types of lettuce. The large veins near the leaf margins may sometimes discolor before the typical symptoms appear. (Pls. 30 and 31.)

The development of tipburn is very complex; however, distribution of calcium in the plant is the chief factor involved. Insufficient calcium in cell walls weakens them and thus causes their collapse. The discoloration itself is due to the oxidation of latex that apparently spreads through the tissue from ruptured laticifers due to high pressure within them. The disorder develops most commonly during periods of rapid growth.

Tipburn occurs sporadically but can cause severe losses in almost all lettuce-growing areas, whether the crop grows outdoors or in greenhouses. Objectionably severe tipburn of head lettuce increases only slightly after harvest at normal temperatures during marketing. However, individual lots may diverge appreciably from this general trend. The best guarantee against objectionably high levels of tipburn on the market involves shipment of lettuce that is free or nearly free of tipburn at the time of harvest. When there is a substantial difference in incidence of tipburn at the time of harvest and the time of arrival at the market, two factors may be involved. First, the discoloration may have been so slight at harvest that it was not noticed, but darkening occurred during transit. Second, since the incidence of tipburn varies greatly from location to location, even within a given field, sampling done by regulatory agencies may not always be truly representative of the entire field. Since examination for tipburn destroys the head, the size of sample naturally must be limited.

Lettuce with tipburn is not necessarily more prone to decay than lettuce without tipburn. The hazard of decay development on tipburned tissue is substantial primarily when temperatures are undesirably high, when free moisture is present, or both. Aggravation of tipburn and development of decay in affected lettuce can be minimized during transit by holding the lettuce between 0° and 2.5°C throughout marketing.

There is no postharvest control for tipburn. The best preventative is to plant cultivars that are resistant to the injury. Harvest before full maturity tends to lessen the incidence of tipburn, because it has had less chance to develop. Even though tipburn is induced by a deficiency of calcium in some cells, spraying calcium on crisphead lettuce plants is not useful, because the mineral will not reach the inner leaves, although it may be effective on leaf lettuce.

References: *7, 14, 17, 20, 22.*

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Lettuce, Shredded

Browning of the cut surface is the primary symptom of deterioration in shredded lettuce. It is caused by the oxidation of the cell contents that are exposed to air. This disorder can be minimized by a combination of the following procedures: (1) Cut the lettuce when it is between 0° and 2°C; (2) use a very sharp blade (this reduces the exudation of cell sap); (3) have the surface of the lettuce dry when cut; (4) place the lettuce in a sealed, permeable plastic film, such as 0.005-mm (2-mil) thick polypropylene. (This type of packaging results in a desirable low oxygen concentration (2 to 3 percent O_2); the concurrent accumulation of carbon dioxide, up to at least 10 percent, does not appear to injure shredded lettuce, even though it can cause severe injury in entire heads.) (5) Hold the lettuce between 0° and 2° until it is used; increasing the temperature above 2° results in rapid loss of quality; and (6) just before the lettuce is used, rinse it with ice-cold water for 5 minutes to restore freshness.

Use of chemical rinses either does not result in better quality or is detrimental. Reduced pressure storage also is harmful, because it induces severe browning and loss of desirable texture.

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Rhubarb

Rhubarb (*Rheum rhaponticum* L.) is grown for its thick, fleshy leaf stalks (petioles). Their marketability depends primarily on their tenderness and crispness, which are related to age, and on freedom from blemishes and decay. Anthracnose, foot and crown rots, and stem spot affect the leaf petioles and may cause losses on the market. Gray mold rot is the most important market disease of rhubarb.

Anthracnose

(Causal Organism *Colletotrichum erumpens* (Sacc.) Sacc.)

Anthracnose has been found on rhubarb in the field in several areas and on the market, where it is damaging because the lesions detract from the appearance of the product and may also allow invasion by secondary decay-producing organisms.

Lesions appear as soft, watery, translucent spots on leaf petioles. When the oval lesions attain a diameter of about 10 mm, numerous small black specks (spore-producing acervuli) appear in their centers. In advanced stages of infection, the whole petiole may be soft and rotted and covered with acervuli. This stage of decay is most often found on old wilted petioles in the field. Only the small spots that escape inspection by the packer are found on the market.

The pathogen produces abundant spore masses in the acervuli. Spores are spread by raindrops and insects from one petiole to another in the field and may be spread by contact even in the absence of wounds. Humid, warm weather favors infection and decay development.

Postharvest spread of the disease can be minimized by prompt, thorough cooling of petioles to near 0°C and by keeping them cold during marketing.

Bacterial Crown Rot and Bacterial Soft Rot

(Causal Organisms *Erwinia rhapontica* (Millard) Burkholder, *E. carotovora* subsp. *carotovora* (Jones) Bergey et al., and Other Associated Bacteria)

Rhubarb grown continuously in one place for many years may be subject to a serious bacterial rot of the crown buds. After death of the crown bud, laterals grow out, some of which may become infected and cause rot at the base or in the lamina. Crown rot is a field disease and diseased petioles are unmarketable. Bacterial soft rot (BSR) can cause serious losses in all areas where rhubarb is grown; however, it is usually present as a secondary decay, causing decomposition of stalks invaded by other pathogens, such as *Phytophthora* spp. and *Botrytis* sp. (see Phytophthora Rots, p. 37). It can quickly become the predominant cause of decay by the time such infected stalks reach the market.

Transit and marketing losses resulting from BSR can be minimized by rapid cooling of stalks and shipment at temperatures below 5°C. Rhubarb showing any evidence of phytophthora infection should not be shipped as BSR may follow and render stalks unmarketable.

References: *1, 3, 4.*

Gray Mold Rot

(Causal Organism *Botrytis* sp.)

Gray mold rot is the most serious transit and market disease of rhubarb. Although the causal fungus is present wherever the crop is grown, it seldom affects vigorously growing plants in the field. However, injured plants and old leaves become infected readily under humid conditions. The causal fungus produces great numbers of spores, which contaminate leafstalks during harvesting and packing.

On the market, gray mold rot lesions in their early stages appear as small red spots on the sides of leafstalks and as water-soaked areas at the base of the petiole or in injured tissue elsewhere. At this stage, mycelium and spores are not visible. Decay lesions enlarge rapidly, soon involving large parts of the petiole (pl. 32). Grayish mycelium and grayish-brown, granular masses of spores on the large lesions are characteristic signs of this disease. Most infections occur at the base of cut petioles that have been wounded during harvest, but they may also occur in apparently healthy tissues.

Maintenance of transit and storage temperatures near 0°C will retard but not stop development of gray mold rot during marketing.

References: *3, 5.*

Phytophthora Rots (Foot and Crown Rots)

(Causal Organisms *Phytophthora* spp.)

Foot and crown rots are widespread in all areas where rhubarb is grown commercially and are caused by one or more species of *Phytophthora.* Although different causal agents are involved, disease symptoms are very similar and may be considered as one disease.

The phytophthora foot and crown rots are primarily field diseases, but occasionally infected petioles are found on the market. Bacterial soft rot (BSR) follows these rots closely, and by the time diseased stalks reach the market, BSR may be the major cause of decay loss. The two diseases have often been confused on the market. Phytophthora rots are watery, greenish-brown, sunken lesions that appear first at the base of the petiole and progress rapidly through the petiole causing a brown decay. Secondary bacterial decay usually causes rapid decomposition of affected stalks.

The pathogens responsible for most of the foot and crown rots of rhubarb are *Phytophthora parasitica* Dast. and *P. cactorum* (Leb. & Cohn) Schroet. However, a closely related fungus, *Pythium ultimum* Trow, and other species of *Pythium* have also been associated with stalk rots in some areas.

Sorting to remove infected rhubarb at harvest will minimize the possibility of decay occurring during transit or storage. Transit and storage temperatures below 5°C will retard decay development.

References: *3, 5.*

Stem Spot (Leaf Spot)

(Causal Organism *Phyllosticta straminella* Bres.)

Stem and leaf spot disease is occasionally of importance on rhubarb from California, Illinois, and other North Central States. On the upper surfaces of infected leaves, small, greenish-yellow spots appear, which enlarge and become tan with wine-red margins as the lesions mature. Eventually parts of the dead tissues drop out, leaving ragged holes. When the stems are infected, the most serious loss generally occurs at the first cutting. Spots on infected stems are small, oval to oblong, and reddish brown. With age some spots may become elongate and extend 10 mm or more lengthwise along the stem. Small, black fruiting bodies (pycnidia) eventually appear in the dead tissue of stem and leaf spots. Other fungi may also invade stem spot lesions.

Infection may occur through healthy, uninjured tissues wherever the fungus comes in contact with moist stems. However, lesions develop so slowly that no new spots are likely to appear during transit.

Losses in transit and marketing of rhubarb may be reduced by not shipping spotted stems and by keeping the temperature near 0°C.

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Spinach

Spinach (*Spinacia oleracea* L.) is harvested and shipped to market as leaves and crown or as leaves and may be shipped loose or packaged in perforated plastic bags. Quality spinach should be dark, green, fresh, crisp, and free from blemishes and decay.

The more important field diseases of spinach include anthracnose (caused by *Colletotrichum spinaciae* Ell. & Halst.), bacterial soft rot (BSR), damping off (caused by *Pythium* spp., *Phytophthora* spp., and *Pellicularia filamentosa* (Pat.) Rogers), downy mildew, heterosporium leaf spot and other leaf spots, orange rust, white rust, wilt (caused by *Fusarium* spp.), and several virus diseases. In areas where air pollution is a problem, spinach may be severely injured by airborne chemicals. Nutritional diseases often characterized by leaf chlorosis are caused by the unavailability or deficiencies of magnesium, boron, and manganese. On the market, BSR, downy mildew, and white rust are of major importance.

Damage to the young leaves in the center of the plant caused by feeding of the seedcorn maggot larvae (*Delia platura* (Meigen)), the so-called budworm injury, and holes made on older leaves by feeding of the spotted cucumber beetle (*Diabrotica undecimpunctata howardi* Barber) constitutes important insect injuries observed on the market. Aphids on fresh spinach are occasionally a problem in the canning and frozen industries and in the prepackaging of fresh spinach.

Bacterial Soft Rot

(Causal Organism *Erwinia carotovora* subsp. *carotovora* (Jones) Bergey et al. and Other Species of Bacteria)

Bacterial soft rot (BSR) is the most important disease of fresh spinach on the market. Affected tissues are water soaked, muddy green, or greasy. Rapid softening and disintegration follow so that the decayed tissues soon appear wet and mushy and eventually have a putrid odor (pl. 33). Where the air is dry and moisture is lost rapidly from infected tissue, the decay may be checked, and the affected tissues become dry and brittle.

The soft-rotting bacteria are common in the soil and on plant debris. Spinach becomes contaminated with the bacteria while in the field or during harvesting and packaging. Infection almost always occurs through mechanical injuries, insect wounds, disease lesions, or other skin breaks or abrasions.

A combination of high humidity and high temperature favors development and spread of decay. Decay progresses rapidly above 7°C and at high humidity.

Harvested spinach should be handled as carefully as possible to minimize chances of mechanical injury. Rapid precooling to remove field heat and maintaining temperatures near 0°C during transit and marketing are essential to minimize losses from *E. carotovora,* the most serious postharvest pathogen of spinach. Removal of free water from the surface of washed leaves by centrifugation and subsequent vacuum cooling also reduce incidence of BSR.

References: *3, 5, 6.*

Downy Mildew

(Causal Organism *Peronospora effusa* (Grev.) Ces.)

Downy mildew is found in all commercial spinach-growing areas. Significant field losses occur regularly, especially in the coastal areas. During cool, rainy weather, the disease may be so serious that fields are left unharvested. Downy mildew is an important disease of fresh market spinach, because the leaf spotting detracts from the appearance and quality of harvested leaves, and lesions may allow entry of secondary soft rot bacteria.

The appearance of pale-yellow, irregularly shaped areas without distinct margins is the first sign of the disease (pl. 34). The spots are apparent on both upper and lower leaf surfaces (pl. 35). At high humidity, whitish-gray mycelium develops over the infected areas on either surface, although it appears first on the lower leaf surface and may precede discoloration of the leaf. In older lesions, purplish-gray fruiting bodies cover the mycelium. At very low humidity, yellowing may occur without signs of the mycelium. Severely infected leaves may dry up; under wet conditions they become water soaked and brownish and subsequently decay. Infection primarily occurs in the field, but the disease can become more prominent after harvest. Temperatures between 5° and 25°C and relative humidity above 85 percent favor infection.

The pathogen, *P. effusa,* is an obligate parasite and can grow and reproduce only while associated with living tissue. It attacks only spinach. The fungus reproduces primarily by means of spores (conidia), which form in great abundance under humid conditions and are spread by wind and rain. It is the presence of conidia and the stalks (conidiophores) on which they are borne that gives mildew its purplish-gray color.

Moisture on the leaf surface is necessary for germination of conidia and subsequent infection. Mildew is likely to be important following periods of fog or heavy dews and temperatures ranging from 5° to 25°C. At 15°-18°, infection of spinach leaves may occur within 3 hours after inoculation. Fruiting of the fungus on these new lesions may occur within 6 days of inoculation.

Oospores, or resting spores, which are produced in diseased leaf tissue, may be the means by which the fungus survives in the soil between crops and possibly on contaminated seed. The fungus may also survive in mild climates on volunteer spinach plants.

Spinach affected by mildew should not be shipped, and all spinach should be kept near 0°C during transit and marketing. Resistant cultivars provide the best long-range means of preventing losses from downy mildew.

References: *1, 4.*

White Rust

(Causal Organism *Albugo occidentalis*
G.W. Wils.)

White rust causes serious field losses in some seasons in Texas, Oklahoma, and Louisiana. The disease has also been reported in Arkansas and Virginia. On the market, white rust is at times an important disease of Texas-grown spinach.

The fungus develops within the leaf tissues and later produces numerous, tiny, blisterlike pustules (sori) on the lower leaf surface, which are filled with whitish masses of spores (pl. 36). Pustules may have a concentrically zonate pattern. A slight yellowing of the adjacent tissues that is apparent on both leaf surfaces accompanies the white pustules. The yellowed areas are indefinite in outline, and when seen from the upper leaf surface are similar to those caused by downy mildew (pl. 37). White rust usually appears first near the margins of the outermost leaves of the plant. Later the lower surfaces of all leaves may bear a few to many sori. Occasionally sori may appear on the upper leaf surface and petioles. Oospores, or resting spores, may develop and give a blackish appearance to affected tissues. Sometimes there is a yellowing and mosaiclike discoloration of affected leaves without the formation of sori. Leaves that are severely infected may develop brown, necrotic spots, and the entire leaf may turn brown.

The disease is favored by periods of clear, relatively warm, dry days with cool nights. The fungus apparently overwinters in the soil. Some weeds are susceptible to the white rust fungus, but spinach is the only commercial crop affected.

Removal of crop residues immediately after harvest to prevent oospore development in unharvested plants can minimize damage to subsequent spinach crops. Some resistant spinach varieties are available also.

Reference: *2.*

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Sweetpotatoes

The edible part of the sweetpotato (*Ipomoea batatas* (L.) Lam.) consists of the thickened roots of the plant. There are several varieties used for food in the United States. Roots should be firm, smooth, well shaped, and free from blemishes and decay.

Many diseases that attack plants in the field not only lead to reduced yield but also may affect the quality of the crops by causing poorly shaped, rough, or blemished potatoes. Feeding by the root-knot nematode (*Meloidogyne* spp.) may injure growing roots, but it is of minor importance on the market as damaged roots are culled at harvest. Some of the diseases that affect the growing plants also cause blemishes and decay of the roots during storage and marketing. Other diseases affect sweetpotatoes only after they have been harvested. Many of the storage diseases are less serious if sweetpotatoes are cured for 4 to 5 days at 29°C and a relative humidity of 85 to 90 percent and subsequently stored at 13° to 15° and a relative humidity of 85 percent or higher.

The most important parasitic diseases of sweetpotato in storage and on the market are black rot, charcoal rot, end and surface rots, Java black rot, rhizopus soft rot, scurf, and soil rot. The major causes of nonparasitic losses are bruising, chilling, and freezing injuries, growth cracks, and internal breakdown.

Bacterial Soft Rot

(Causal Organism *Erwinia chrysanthemi*
Burkholder et al.)

Bacterial soft rot (BSR) is normally of minor importance as a sweetpotato storage disease; however, isolated outbreaks have caused extensive losses of harvested and stored roots (pl. 38). The pathogen is spread to the field by infected, symptomless vine cuttings. High field temperature and moisture are predisposing factors to BSR. Sweetpotatoes that have become infected in the field decay rapidly during the curing process. The bacteria cause rapid decay of inoculated roots at 29°-32°C but cannot decay roots stored at 15°.

The initial symptoms of decay are dark water-soaked lesions that increase rapidly in size. The affected tissues soon become soft and watery; infected roots may be reduced to a watery mass within 4-5 days at 30°C. Decay can spread from infected to apparently healthy roots by contact during curing, because the bacteria produce extracellular enzymes capable of digesting host cell walls. Decayed tissues may appear hard and dried if temperature and humidity are reduced soon after infection begins. In such cases, lesions are surrounded by dark stains where watery exudate has oozed from the infected area or dripped from other infected roots (pl. 39).

Sweetpotatoes showing decay at harvest should be kept at 15°C and marketed promptly without curing, because decay will increase at the high temperature and humidity required for curing.

References: *14, 16.*

Black Rot

(Causal Organism *Ceratocystis fimbriata* Ell. et Halst.)

Black rot is one of the most serious and most widely distributed diseases of sweetpotatoes. Although it affects the plants in the seedbed and in the field, most damage occurs in storage and during marketing.

The early symptoms of black rot appear as circular, brown, slightly sunken, superficial spots about 5 mm in diameter. As they enlarge, they become black to greenish black (pl. 40). Small, black fruiting bodies (perithecia) are often present at this stage. To the unaided eye, they appear as black bristles. The rot is shallow and firm, rarely penetrating the center of the root. Affected internal tissues are dark (pl. 41) and have a bitter taste that affects the entire root when cooked.

Infections by black rot occur in the field through wounds, dead root hairs, or apparently healthy tissues. The fungus persists from season to season in sweetpotato fields in roots, plant debris, and soil. Infection is favored by wet soil and warm temperatures. Although obviously infected potatoes are discarded at harvest, many black rot lesions are so small that removal of all infected roots is impossible. In storage, these small lesions may enlarge to about 10 mm in diameter within 4 to 6 weeks and account for the substantial decay losses in lots thought to be free of decay. Decay can also spread to healthy sweetpotatoes if healthy roots are washed in water with sweetpotatoes affected with black rot.

Control of black rot in storage can be increased by careful handling and discarding all visibly infected sweetpotatoes before storage. Roots harvested from soils known to be infested should be kept separate from those growing in disease-free fields and should be marketed early.

Special high-temperature curing (35°C for 4 days) reduces black rot development in storage. Heat treatment at 40° to 43° for 24 hours will prevent the development of black rot but may adversely affect root quality. Chemical treatments have not been consistently effective for black rot control.

References: *12, 17.*

Blue Mold Rot

(Causal Organism *Penicillium* spp.)

Blue mold rot is often found in chilled or frozen sweetpotatoes. The fungus may also be present as a secondary pathogen on roots decayed by other fungi such as *Rhizopus*. Fungal spores are in the air and on the surface of most fruits and vegetables, but they are unable to cause infection except through wound-damaged tissues.

Blue mold rot is a soft decay generally involving large areas surrounding mechanical injuries or lesions of other diseases. In chilled or frozen sweetpotatoes, the whole root is soon decayed, and the characteristic white and blue-green tufts of mycelium break through the epidermis. When many potatoes are infected, the lot has a musty odor.

The disease may be avoided if care is used to prevent chilling and mechanical injuries and if proper temperature and humidity are maintained.

Reference: *11.*

Charcoal Rot

(Causal Organism *Macrophomina phaseolina*
(Tassi) G. Goid.)

Charcoal rot is most important as a storage disease of sweetpotatoes grown in the South, but it causes some loss in storage wherever sweetpotatoes are grown. The fungus may injure growing plants in the field when the stem becomes infected at the soil line. Decay most often starts at the upper end of the sweetpotato and progresses throughout its length. In early stages, infection is characterized by a light-brown discoloration of the surface as well as the internal tissues. The discolored areas may be any size or shape, but there is a sharp line of demarcation between the diseased and healthy tissues. As the decay progresses, the affected areas remain firm and become dark brown. The skin later begins to shrivel as water is lost by evaporation. In the final stages of this disease the root is converted into a hard, dry, black mummy (pl. 42).

When a decaying potato is cut, usually three rather distinct color zones are in the affected tissues. The margin or advancing edge of the decay is light or cinnamon brown and slightly spongy in texture, the intermediate zone is reddish brown and firm, and the oldest part of the lesion (root end of sweetpotato or center of lesion) is grayish black to black, dry, and firm. On close examination of the grayish-black area, very small, black sclerotia are visible within the tissues. No sclerotia or fungal hyphae are visible on the surface of diseased sweetpotatoes.

Charcoal rot develops rapidly on uncured sweetpotatoes marketed soon after harvest. Slight infections at broken ends will develop in transit and result in substantial loss at the market. Optimal growth temperature of the pathogen is 31.5°C, but it will grow at 7.8° to 42°. Field infections will progress slowly at recommended storage temperatures, but the potential for rapid decay remains when temperatures are raised during transit and marketing.

Losses from charcoal rot may be reduced by not storing or shipping sweetpotatoes with even the slightest evidence of decay at broken or injured ends. Roots free from decay should be cured promptly by rapid wound barrier formation to protect them from decay.

References: *11, 20.*

Dry Rot

(Causal Organism *Diaporthe batatatis* Harter & Field)

Most losses from dry rot occur during storage and marketing. The disease is widely distributed but seldom causes extensive losses of sweetpotatoes in the field. The fungus attacks potatoes as a result of infections on slips in the seedbeds and diseased vines in the field.

Dry rot, even in its early stages, is characteristically a dark-brown, firm decay. In practically all cases, decay starts at the stem end of the potato. As infection progresses, the decayed tissues lose water quickly and the affected part becomes withered (pl. 43). Soon the diseased area becomes black and hard and the surface of decayed roots is covered with black, pimplelike pycnidia. These numerous black fruiting bodies in and beneath the skin of a sweetpotato with a hard, dry, black decay are diagnostic of this disease.

Dry rot does not develop as rapidly or cause as much loss as black rot, but inoculated sweetpotatoes may be completely decayed within 6 weeks at recommended storage temperatures.

Promptly curing under optimal temperature and humidity conditions favors rapid wound-cork formation and can prevent infections after harvest.

Reference: *10*.

End Rots and Surface Rots

(Causal Organisms *Fusarium* spp.)

Although end rots and surface rots may be caused by several different organisms that attack sweetpotatoes, most of them found on the market are due to various species of *Fusarium*. The pathogens live in the soil and invade roots through wounds, growth cracks, and small rootlets at harvesttime and during storage. Infection takes place most readily when potatoes are harvested during wet weather; consequently, end and surface rots are most serious in storage after wet seasons. Decay develops so slowly that conspicuous lesions are not usually evident until about 6 weeks after storage. Sweetpotatoes with many lesions shrivel badly in storage and are not marketable.

The early stages of infections are characterized by small, circular, light-brown, superficial spots. As the disease progresses, lesions enlarge and become slightly sunken, with sharp margins caused by the drying and shrinkage of affected tissues (pl. 44). Some rots remain superficial, not penetrating more than a few millimeters into roots, whereas others may spread to involve a major part of the infected root; however, all decayed tissues appear dry and sunken unless invaded by other organisms (pl. 45).

Although new infections may occur in storage if sweetpotatoes are not properly cured, it appears doubtful that new lesions develop in storage. Incipient infections do enlarge, however.

Sweetpotatoes should not be harvested during wet weather if it can be avoided. Prompt curing and proper storage conditions will reduce losses by assuring rapid healing of wounds made during harvesting.

References: *7, 18, 19.*

Java Black Rot

(Causal Organism *Lasiodiplodia theobromae* (Pat.) Griff. et Maubl.) (Synonyms *Diplodia tubericola* (Ell. & Ev.) Taub. and *Botryodiplodia theobromae* Pat.)

Java black rot affects sweetpotatoes during storage and marketing and may cause heavy losses. It can be found in most sweetpotato storages, but losses are usually more severe in the Southern United States and tropical areas than in more northern growing areas.

Within 10 days of infection, symptoms begin to appear, and within 1 month, inoculated sweetpotatoes can be completely decayed. Initially the decay appears brown and moderately firm. As it progresses, all the tissues become involved. The central part is light brown, and the skin and tissues just beneath change from dark brown to black as pycnidia form and push up through the skin (pl. 46). Within 3 to 4 weeks, these fruiting bodies form in such sufficient numbers that they create domelike elevations on the root surface. Eventually the root becomes a hard, black mummy.

Lasiodiplodia theobromae occurs in soils and in plant debris. No root infection appears to take place in the field except through wounds from digging and during handling for storage and marketing. The fungus grows at temperatures from 12° to 37°C, with an optimum of 29°-31°.

Careful handling of sweetpotatoes to avoid all unnecessary wounds at harvest and storage time and prompt curing under optimal conditions can minimize damage caused by Java black rot.

References: *1, 2.*

Rhizopus Soft Rot

(Causal Organisms *Rhizopus stolonifer*
(Ehr.: Fr.) Vuill. and *R. tritici* Saito)

Rhizopus soft rot is the principal cause of sweetpotato loss during storage and marketing. In most markets, it produces more wastage than all other sweetpotato diseases combined. All varieties are susceptible to the disease, and it occurs in roots from all production areas. Handling and storage methods probably have a greater effect on the subsequent development of decay than any natural susceptibility because of varietal characteristics. Since infections by *Rhizopus* spp. are dependent on wounds or injuries produced by other diseases, rhizopus rot is not an important field disease, but it may affect potatoes in the seedling bed.

Affected tissues first appear soft and watery, but change little in color. Later infected areas become light to dark brown. Freshly decayed areas will yield a yellowish-brown liquid when broken, but as water is lost from the decayed tissues, the area becomes withered and firm. Sweetpotatoes can be completely decayed within 4 to 6 days. Surface mold growth under moist conditions appears as coarse, white mycelium with numerous black sporangia. This growth is conspicuous at the ends and through breaks in the skin of infected sweetpotatoes held in a humid atmosphere (pl. 47). When roots decay under dry conditions, surface mold may not develop.

Infection by *Rhizopus* may occur at broken ends of the roots or at any unhealed wound. A high incidence of infection usually indicates that roots have been improperly handled or exposed to external stress after harvest. There is a positive correlation between weight loss during curing at 26°C and decay development after 5 months of storage at 15°. In research studies, weight loss was reduced by increasing the relative humidity from 80-90 to 90-97 percent for curing. When weight loss was less than 4 percent during curing, only 1 percent decay developed in storage. When curing resulted in weight loss of about 10 percent from injuries and low relative humidity, decay was as high as 25 percent after 5 months of storage.

Careful handling of roots during harvest and transport, together with prompt curing at optimal temperature and humidity, is of the greatest importance in preventing rhizopus soft rot during storage. When roots are washed, sorted, and packed after storage, additional wounding may occur. Several fungicide treatments have been developed that will reduce infections at new wounds when they are applied to roots during their preparation for market. Re-curing roots for 2 days at 29.5°C after being packed for market has been reported to reduce decay; however, this method has not been practical. Prompt shipment and marketing of washed, treated roots are the best means of minimizing losses.

References: *4, 21*.

Scurf

(Causal Organism *Monilochaetes infuscans*
Ell. & Halst.)

Scurf is one of the most common diseases of sweetpotatoes. It occurs on all varieties and appears to some extent on stocks from all shipping regions. Although the causal fungus may produce a brownish discoloration of any or all underground parts of the growing plant, the chief damage results from a reduced market value of the sweetpotatoes because of their blemished appearance. Otherwise, field, storage, and marketing losses are of little consequence.

On marketable roots, scurf appears as small, grayish-brown spots and blotches that are only skin deep. They may be found anywhere on the sweetpotato, but usually most are near the stem end. When numerous infections occur, the discolored spots often coalesce, making a continuous brown area (pl. 48). In extreme cases, the skin may crack when such extensive areas of the skin are killed; the sweetpotato loses moisture rapidly and becomes unmarketable. A few discolored spots cause no appreciable damage and are generally overlooked at the market.

Most of the infections occur in the field, but some new infections may be noted under humid storage conditions. Spots already present may also enlarge slightly during storage and transit. Usually shrinkage of the roots is slow in storage unless the temperature is high and the humidity low. Severely infected sweetpotatoes in hot, dry storage often crack and wither and become worthless within 4 to 6 weeks.

The causal fungus first infects seed roots, then slips, and on these it is spread to the field. Heavy soils containing abundant organic matter favor the development of scurf.

Losses from scurf can be avoided by such field control measures as careful selection of disease-free seed stock, use of vine or sprout cuttings instead of pulled sprouts, and planting in soil that has not been infested by *M. infuscans.* Heavy, black, wet soils with much organic matter should be avoided if possible.

References: *13, 17.*

Soil Rot (Pox)

(Causal Organism *Streptomyces ipomoeae*
(Person and W.J. Martin) Waksman and Henrici)

Soil rot or pox is found in all important sweetpotato-growing regions of the United States. Although losses vary considerably from season to season, in many areas soil rot is considered one of the most important field diseases of sweetpotatoes. It seriously curtails the growth and yield of infected plants and blemishes roots so that their value may be greatly reduced.

Sweetpotatoes with evidence of soil rot on the market are characterized by having dry, brown pits or pox marks of irregular size and shape (pl. 49). The infected areas may vary in size from less than 4 to 12 mm in diameter. In the early stages, the superficial, brown, circular spots are smooth or slightly sunken, but as they enlarge, the epidermis cracks exposing a cavity with rough lining and irregular margins. These exposed tissues are firm and dry when found on mature roots at the market. Ordinarily they are not followed by soft rot or other secondary decays. Occasionally the root may be almost girdled by these blemishes, and in extreme cases the growth of tissues around the deep pits may result in misshapen potatoes.

The optimal growth temperature of *S. ipomoeae* is 31.7°C, with growth at 20° to 40°. The high soil temperatures in the Southern States appear to favor development of soil rot.

The causal organism inhabits the soil and invades potatoes through the small secondary rootlets. Most of the dissemination of the disease appears to be by transportation of infested soil on seed potatoes and by farm implements, animals, drainage water, or windblown dust. Experimental evidence indicates that the disease is not transmitted by using diseased roots for seed purposes if they have no infested soil on them.

Soil rot is most serious during dry seasons. When sufficient moisture is available, plants are able to continue to grow and produce some marketable potatoes even though they are diseased.

If disease-free soil is not available for growing sweetpotatoes, soil rot in infested soil can be controlled by adding sufficient sulfur to make it acid (pH 5.0). Sweetpotato varieties resistant to soil rot are also available.

References: *15, 16.*

Chilling Injury

Sweetpotatoes are subject to chilling injury when held at temperatures below 13°C for 10 days or more. These low temperatures cause tissue breakdown, which results from physiological changes in the sweetpotato. Internal discoloration from brown to slightly black is the principal symptom of chilling injury. Discolored areas may be somewhat scattered but are usually associated with the vascular elements in the central part of the sweetpotato (pl. 50). Flavor of cooked potatoes is also affected. In addition to tissue discoloration, chilling injury leads to the development of "hardcore" areas in cooked sweetpotatoes. Exposure of uncured roots to 1° for as little as 3 days causes significant hardcore. Properly cured sweetpotatoes are more resistant to chilling injury than noncured ones.

The danger from chilling and from associated decays can be prevented by avoiding exposure to temperatures below 13°C at any time during storage, transport, and marketing. Varieties also vary in their susceptibility to chilling injury.

References: *5, 6, 8.*

Freezing Injury

The average freezing points for 10 sweetpotato cultivars ranged from −1.9° to −1.2°C. Soluble solid content of roots is not consistently correlated with the freezing point.

Roots that have been only slightly frozen have a characteristic yellowish-brown discoloration of the vascular ring and internal vascular elements. The roots also appear yellowish green and water soaked (pl. 51). When freezing exposure has been so prolonged that ice crystals have formed, the tissues collapse immediately when thawed, and the sweetpotatoes become soft and flabby as water evaporates. Badly frozen roots are often invaded by rot-producing fungi before they dry up.

Freezing injury seldom occurs in storage because temperatures must be maintained well above freezing to prevent chilling injury. However, freeze damage does occur occasionally during winter transport to northern markets and during delivery to retail markets in severe weather. Heated vehicles for transport and market delivery during cold weather are essential to protect sweetpotatoes from both chilling and freezing injury.

Reference: *9.*

Internal Breakdown

Sweetpotatoes in storage sometimes develop a breakdown of internal tissues. In advanced cases, affected roots can be detected by their light weight and spongy texture. Cavities may form in roots as the tissues separate, and the spongy tissues may appear white or light yellow (pl. 52).

Pithiness, with subsequent internal breakdown, has resulted from excessive intercellular space in certain roots. This characteristic varies with the cultivar and growing conditions. Intercellular space may increase during storage and is most prevalent when roots are stored at temperatures above those recommended or at low relative humidity.

Curing sweetpotatoes longer than 1 week at 30°C increases the development of intercellular space, as does storage above 13°-15°. Cultivars vary in their susceptibility to internal breakdown. The disorder is least prevalent in cultivars with high dry-matter content, low intercellular space, low water-loss rate, and low respiration rate at harvest.

Measurement of intercellular space at harvest provides a useful index of susceptibility to internal breakdown. Because pithiness and breakdown occur during storage, those lots with a high proportion of intercellular space at harvest should be marketed early. Accurate control of storage temperature, humidity, and airflow can reduce the severity of internal breakdown.

Reference: *11*.

Internal Cork

Internal cork is a virus disease of sweetpotato characterized by dark-brown to black, hard, corky spots of irregular size and shape in the flesh of infected roots (pl. 53). The disease was first recognized in South Carolina and has since been reported in all States that grow sweetpotatoes commercially.

Occasionally a surface depression indicates a corky area beneath the skin, but usually the disease cannot be detected without slicing the root. The hard corky spots are sharply outlined and the surrounding tissue shows no sign of deterioration or decay. The spots remain hard and gritty even after baking, but the color, flavor, and texture of surrounding tissues are not affected. Slight symptoms may be visible at harvest, but they increase substantially during storage, especially at temperatures above optimum for sweetpotato storage. Cultivars vary in their susceptibility and symptoms. Sweetpotatoes known to be infected with internal cork should be marketed soon after harvest.

Reference: *3*.

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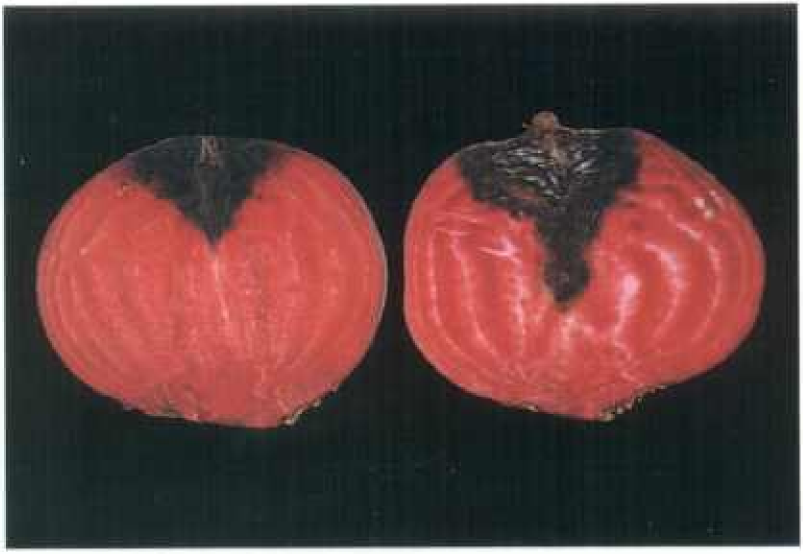
Color Plates



1 Black rot of beet, internal discoloration.

2 Beet scab.

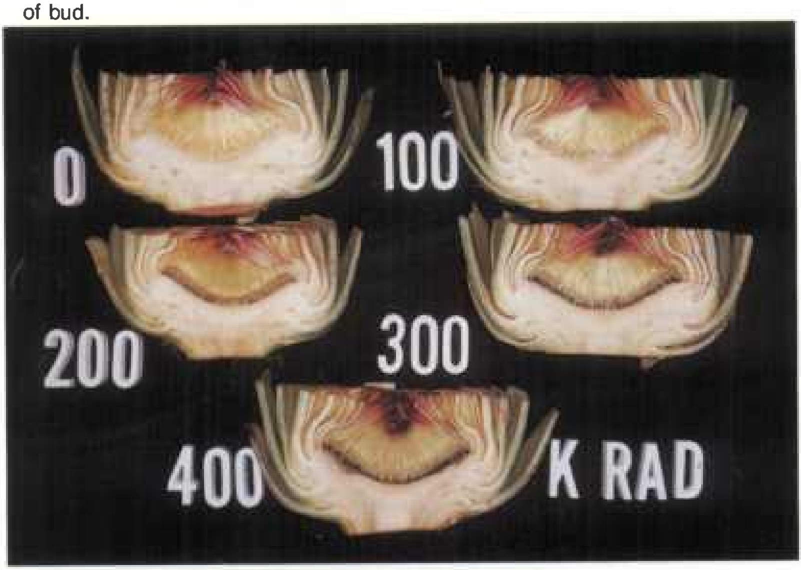
3 Bacterial soft rot of witloof chicory; normal head in center.

4 Bacterial soft rot of endive.

5 Gamma irradiation injury of endive; normal head on left.


6 Gray mold rot on artichoke buds; gray mycelium on some decayed bracts.

7 Freezing injury on artichoke buds; blistering on surface of bracts and darkening of young bracts at center of bud.



8 Irradiation injury causing discoloration at bases of florets induced by 100-400 krad doses of gamma irradiation.

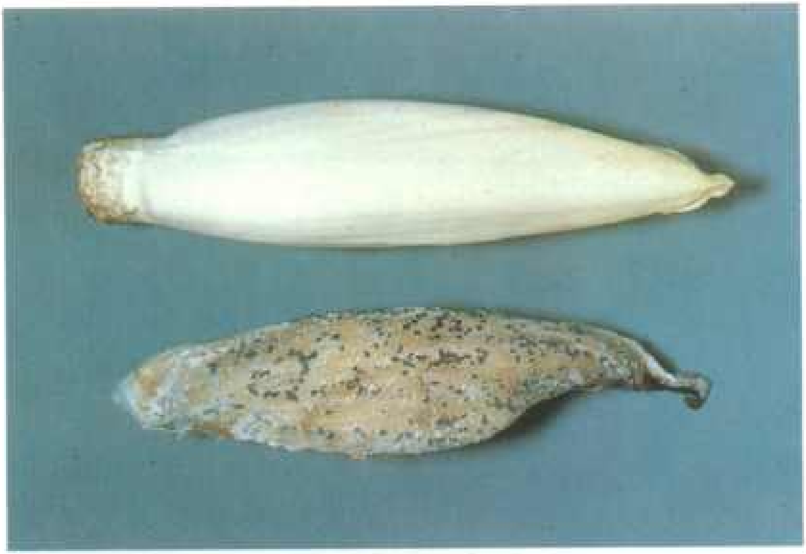

9 Bacterial soft rot of head lettuce, early stage.


10 Bacterial soft rot of head lettuce, advanced stage.

11 Downy mildew lesion on head lettuce.

12 Gray mold rot on head lettuce.

13 Severe watery soft rot of head lettuce.

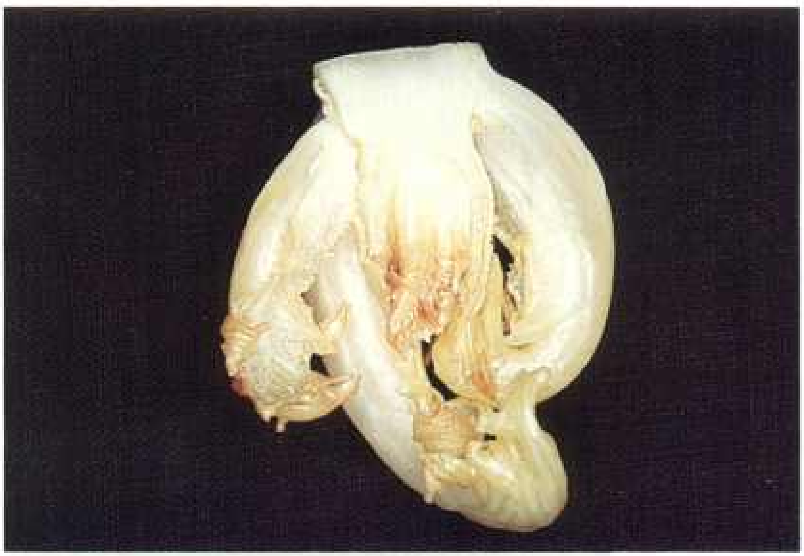


14 Watery soft rot of witloof chicory; normal head above.

15 Internal rib necrosis on 'Climax' head lettuce.

16 Rusty-brown discoloration of 'Climax' head lettuce.

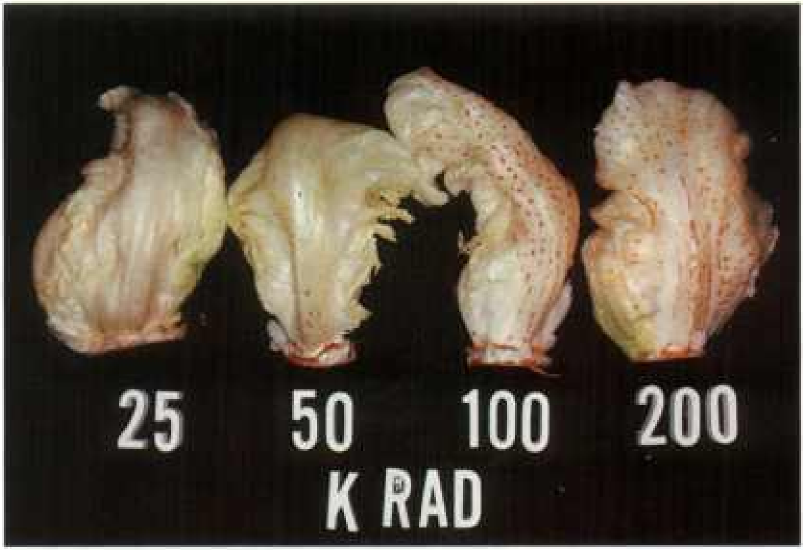
17 Brown stain, caused by excess carbon dioxide, on inner leaf of head lettuce.



18 Heart leaf injury on head lettuce caused by excess carbon dioxide.

19 Field freezing causing blistering of epidermis on head lettuce.

20 Field freezing causing water-soaking of midribs and lamina.

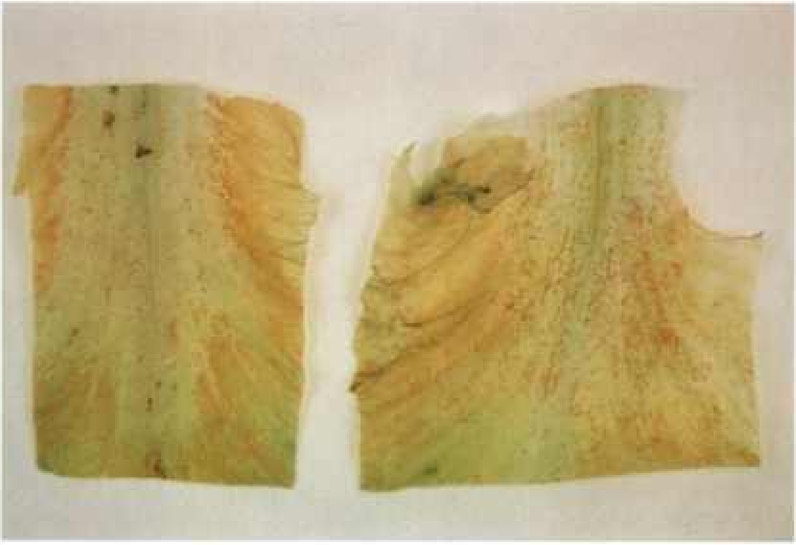


21 Gamma irradiation injury visible as spotting on inner leaves.


22 Marginal senescence on head lettuce.

23 Marginal browning of endive leaves.

24 Low oxygen injury on wrapper leaves of head lettuce.

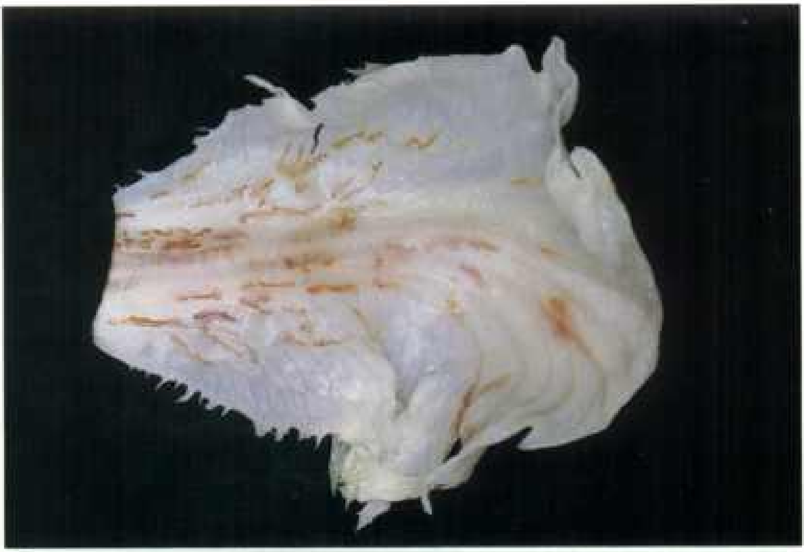


25 Ozone injury on outer leaves of head lettuce.

26 Pink rib.

27 Rib discoloration on inner leaf surface.

28 Russet spotting on head lettuce.



29 Russet spotting on leaf of head lettuce.

30 Tipburn on outer leaf of head lettuce.

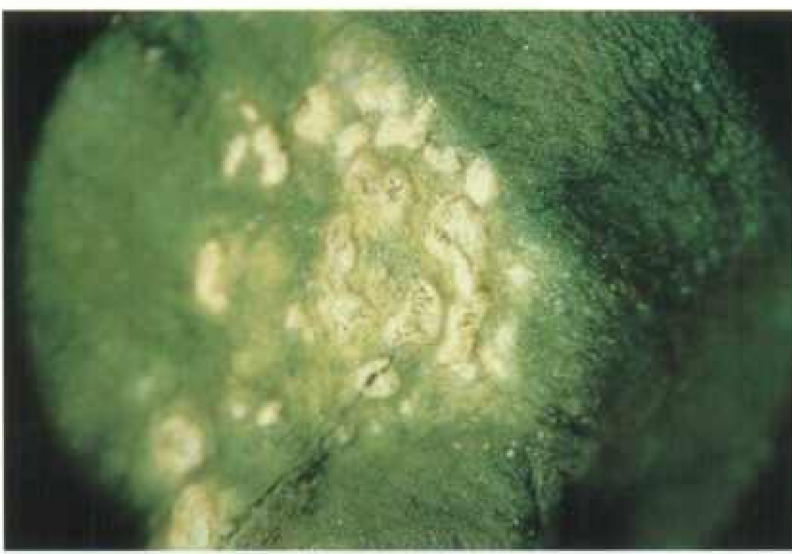
31 Tipburn on inner leaf of head lettuce.

32 Gray mold rot on rhubarb.

33 Bacterial soft rot on crown of spinach plant.

34 Downy mildew lesions on spinach leaf.

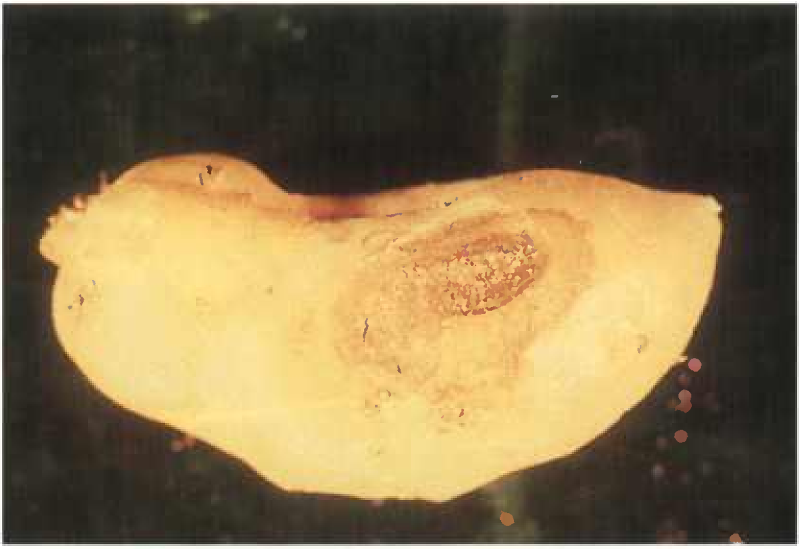
35 Downy mildew on upper and lower spinach leaf surface.



36 White rust pustules on spinach leaf.

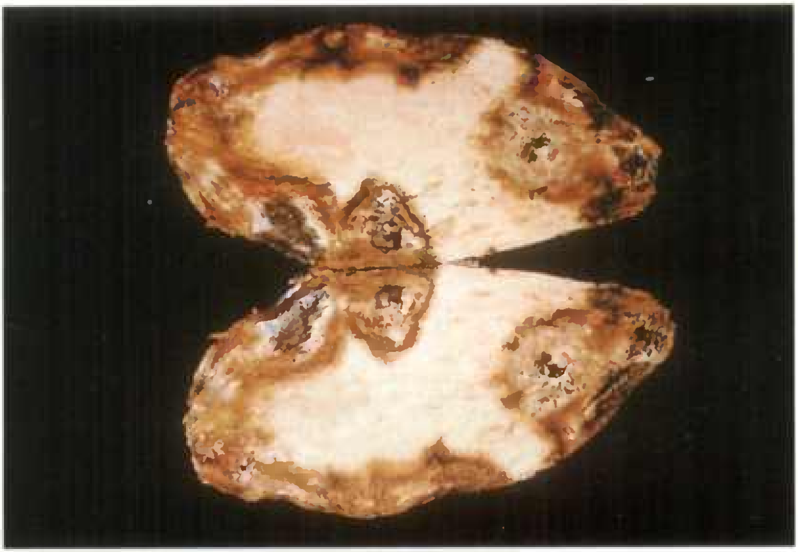

37 White rust on spinach leaves.


38 Bacterial soft rot of sweetpotato roots.



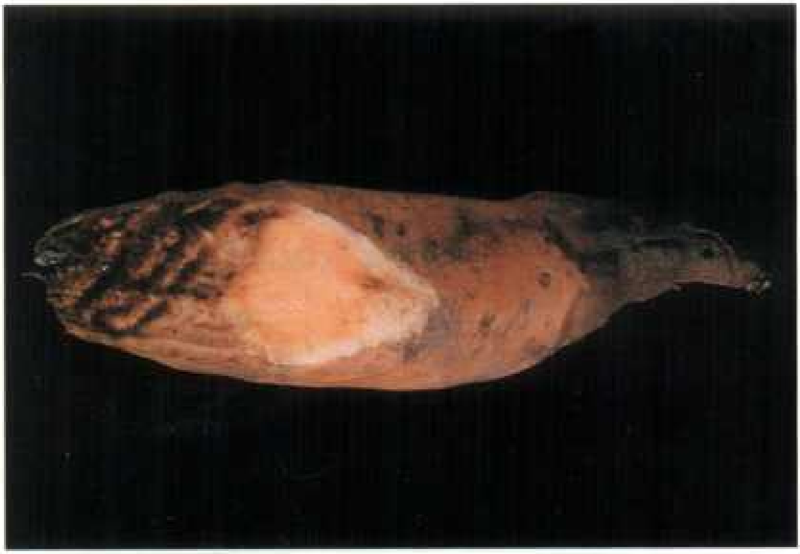
39 Bacterial soft rot lesion on sweetpotato.

40 Sweetpotato black rot, external symptoms.



41 Sweetpotato black rot, internal symptoms.

42 Sweetpotato charcoal rot.

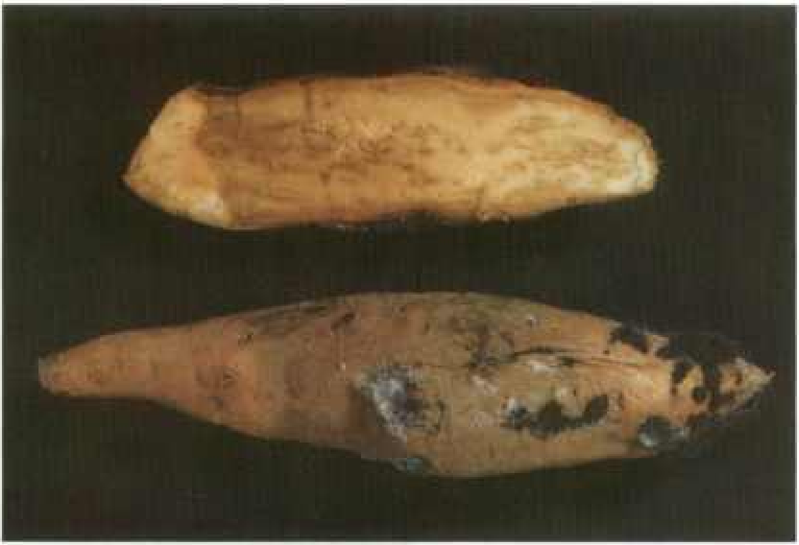


43 Sweetpotato dry rot.

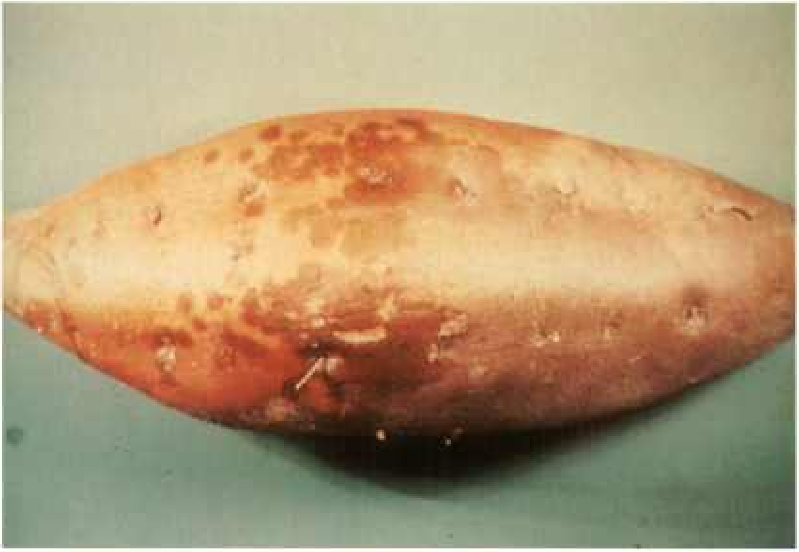
44 Sweetpotato fusarium surface rot.


45 Sweetpotato fusarium end and surface rot.

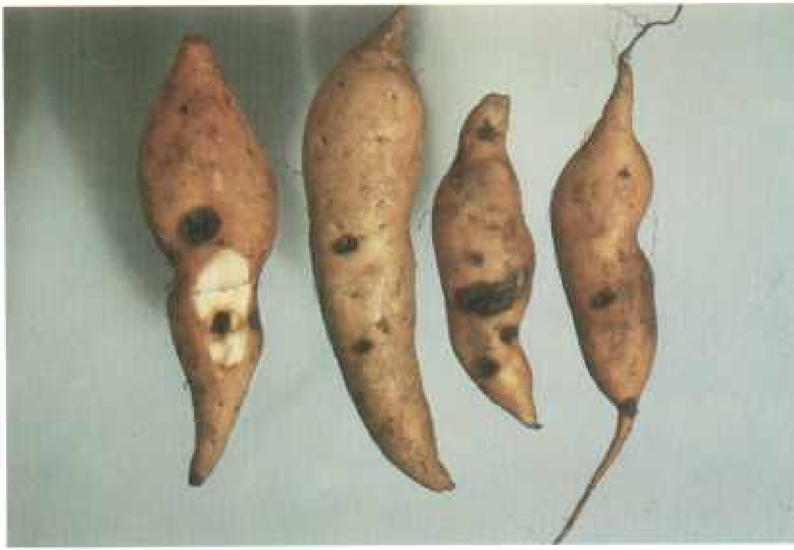

46 Sweetpotato Java black rot.



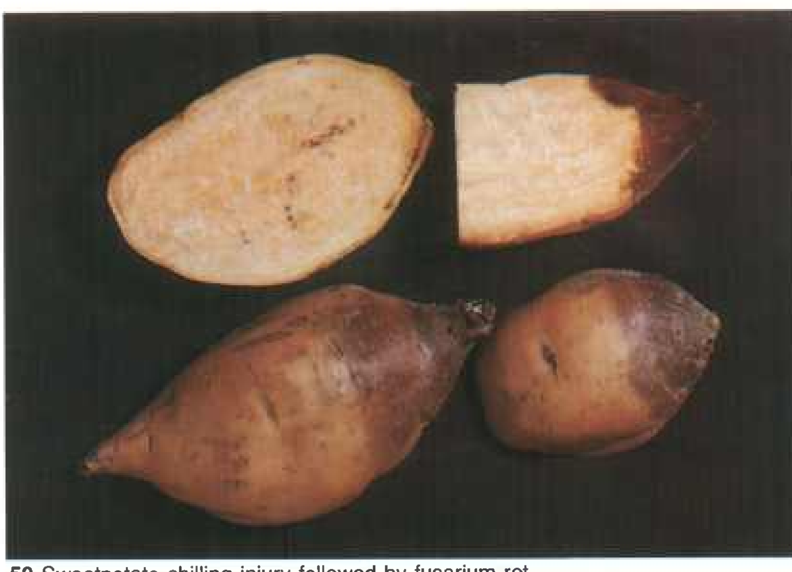
47 Sweetpotato rhizopus soft rot.



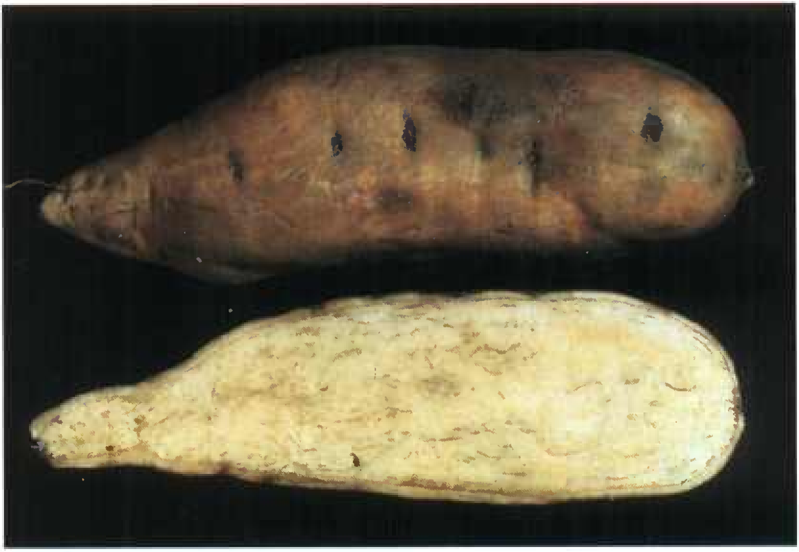
48 Sweetpotato scurf.



49 Sweetpotato soil rot (pox).



50 Sweetpotato chilling injury followed by fusarium rot.



51 Sweetpotato field freezing.

52 Sweetpotato pithy breakdown.


53 Sweetpotato internal cork.

Conversion Table

°C	°F	°C	°F
– 1.1	30	26.7	80
0	32	29.4	85
1.7	35	32.2	90
4.4	40	35.0	95
7.2	45	37.8	100
10.0	50	40.5	105
12.8	55	43.3	110
15.6	60	46.1	115
18.3	65	48.9	120
21.1	70	51.8	125
23.9	75		

Conversion:

$°F = °C \times 9/5 + 32$

$°C = °F - 32 \times 5/9$