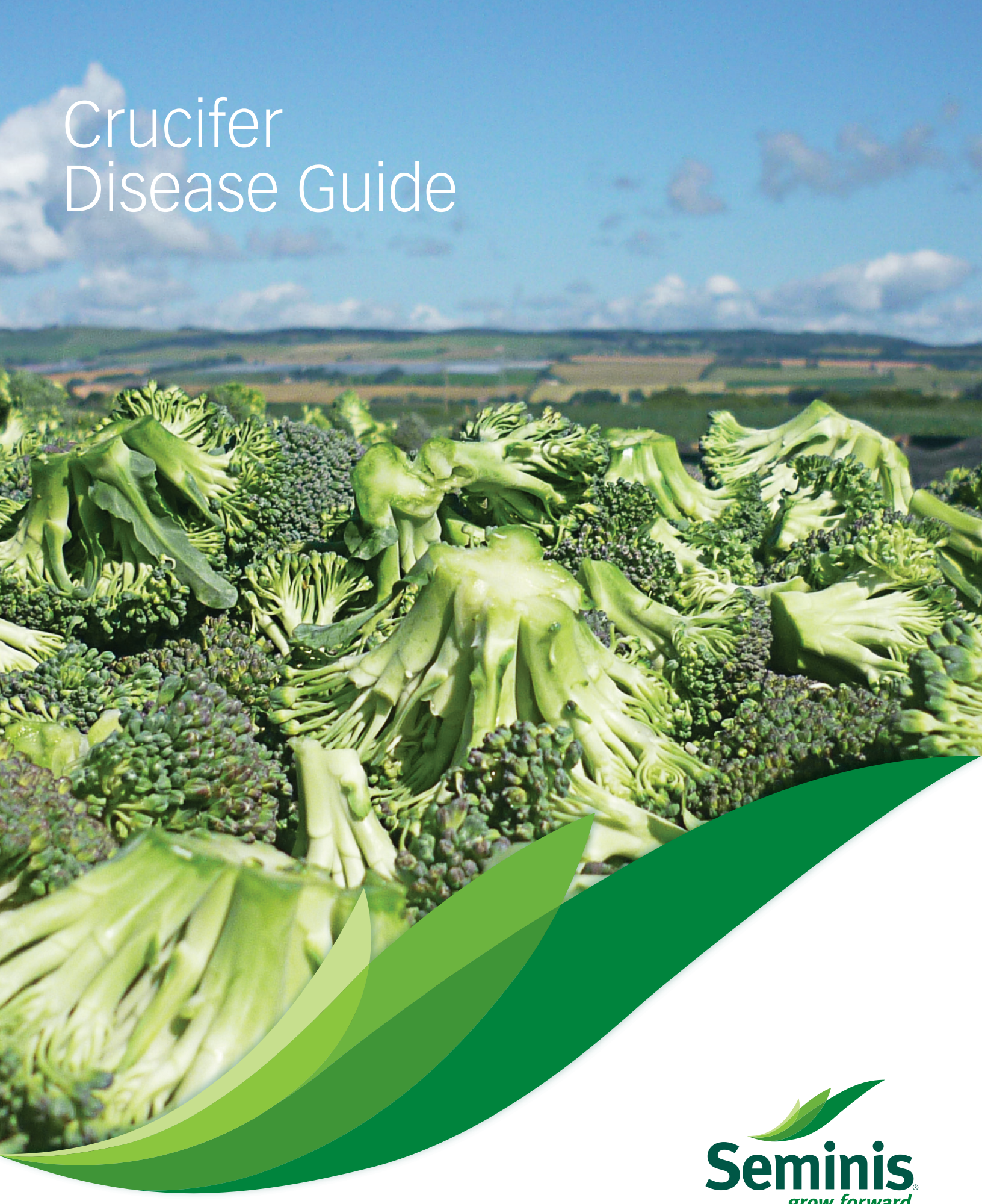
Crucifer Disease Guide



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grow forward

Crucifer
Disease Guide

A PRACTICAL GUIDE FOR SEEDSMEN, GROWERS AND AGRICULTURAL ADVISORS

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Preface

This guide provides general descriptions and pictures of the more common crucifer diseases and disorders worldwide. For each disease and disorder, the reader will find the common name, the cause, where it occurs, symptoms, conditions necessary for development and control measures.

The photographs were chosen to illustrate characteristic symptoms of each disease and disorder. It is important to note, however, that the variety grown, cultural practices, environmental conditions, and the pathogen population all influence the appearance and severity of a disease or disorder and, thus, the control measures.

The primary audience for this guide includes crucifer producers and those who service these crucifer producers. This service group would include agricultural advisors, private consultants, farm managers, agronomists and representatives of food processors, chemical companies and seed companies. We hope this book can be used in the field as a quick guide to information about some common crucifer diseases and their control. However, it should be noted that positive diagnosis of crucifer problems by using only this book is not recommended, nor encouraged, and this guide should not to be substituted for the professional opinion of a producer, grower, agronomist, pathologist or similar professional dealing with this specific crop. Even the most experienced plant pathologist uses both laboratory and greenhouse techniques to confirm suspicions from the field. Moreover, this guide by no means covers every crucifer disease. Rather, an attempt has been made to present those diseases which are prevalent worldwide.

A glossary of words used in the text can be found at the end of the book, along with a list of references for further disease information.

Always read and follow label directions for any herbicide, fungicide, insecticide or any other chemical used for treatment or control.

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Bacterial Diseases

INFECTIOUS DISEASES AND PESTS

Bacterial Leaf Spot

Causal Agent:
Pseudomonas syringae*. pv. *maculicola

Distribution:
Worldwide

Symptoms:
The disease occurs mainly on cauliflower, though broccoli, cabbage, Brussels sprouts and turnips can also be affected. Symptoms consist of leaf spots that begin as small, water-soaked pinpoint lesions. Later, these lesions become dark brown or purple with translucent haloes. Individual spots are slightly sunken and up to 3 mm (1/8 in.) in size. Often, spots will coalesce to form an irregular angular lesion, giving a puckered, ragged appearance to the leaf. With severely affected plants, leaves may become chlorotic and senesce. The bacterium causes small, gray-to-brown spots on the cauliflower curd, which can affect both surface and underlying tissues. Peppery spot symptoms may also occur on stems, petioles and seed pods.

Conditions for Disease Development:
This bacterium can survive in soil and in crop debris for at least one year. The organism can also be seedborne. It is spread by splashing rain or irrigation water. Insects may also spread this disease. Bacterial leaf spot is most severe during cool, wet weather.

Control:
Use seed free of *Pseudomonas syringae* pv. *maculicola* and sow into seed beds free from the organism. If the disease occurred previously in the seed bed, the soil should be sterilized before planting. Rotate to a non-host seed bed for at least one year following a cruciferous crop.

Bacterial Soft Rot

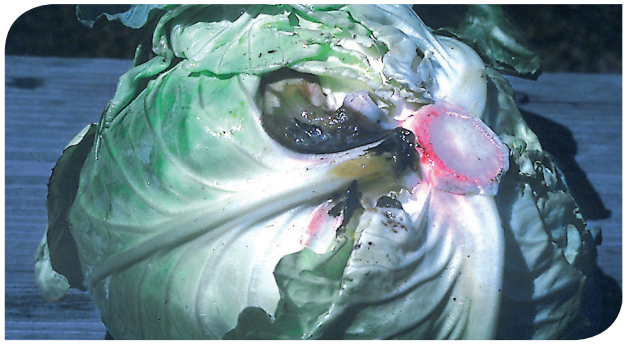
Causal Agent:
Pectobacterium* spp. (synonym: *Erwinia* spp.), *Pseudomonas marginalis* pv. *marginalis

Distribution:
Worldwide

Symptoms:
Symptoms first appear on leaves as small, water-soaked lesions that quickly enlarge. Affected tissue turns brown and becomes soft and mushy with an accompanying foul odor. Eventually, leaves, stems and roots may decay entirely. This disease may be found in the field on cabbage, Chinese cabbage, rutabaga and turnips, but post-harvest soft rot during shipping or storage accounts for the majority of losses from this pathogen.

Conditions for Disease Development:
Soft rot bacteria survive in soil and decaying plant material, and infect plants through wounds, stomata or hydathodes. Cultivation, harvesting, handling, freezing or insect injuries are often points of initial infection. The pathogen is generally spread by irrigation water, rain, several species of maggot flies and other insects. Disease development is usually favored by warm [25-30°C (77-86°F)], humid conditions or following periods of wet weather that lead to free moisture on plant tissues. *Erwinia* spp. and *Pseudomonas* spp. may also act as secondary pathogens, following other diseases such as black rot or black leg.

Control:
To minimize soft rot losses, control insects, try to avoid mechanical injury during harvest, packing and shipping, and do not pack produce when wet. Additionally, store and ship produce at temperatures near 4°C (39°F).



Black Rot

Causal Agent:
Xanthomonas campestris* pv. *campestris

Distribution:
Worldwide

Symptoms:
Symptoms manifest as localized wilting at leaf margins. Wilted tissue becomes chlorotic and progresses to form the characteristic V-shaped lesion associated with this disease. Within chlorotic tissue, leaf veins turn black, giving the disease its name – black rot. At advanced stages, affected tissue becomes brown and necrotic. Black leaf veins may extend from the affected leaf into the main stalk where the darkened vascular system may be visible. As the disease progresses into the vascular system, lesions resulting from systemic invasion may appear along leaf midribs and between leaf veins. Systemically infected plants may be stunted and develop more severe symptoms on one side of the plant. In affected cabbage, heads are smaller and outer leaves may senesce. The disease can progress on cabbage during storage, making the heads unmarketable. Under cool conditions, symptoms may be confused with those caused by *Pseudomonas syringae* pv. *maculicola* (Peppery leaf spot) or *Xanthomonas campestris* pv. *armoraciae* (Xanthomonas leaf spot).

Conditions for Disease Development:
The black rot organism can survive in crop residue for up to two years. The bacterium can also infect cruciferous weeds, such as pepper grass (*Lepidium virginicum*), wild radish (*Raphanus raphanistrum*), black mustard (*Brassica nigra*), wart cress (*Coronopus didymus*), wild turnip (*Brassica campestris*) and others. These weeds, as well as nearby crucifer crops, can serve as reservoirs for the bacterium, which may subsequently spread to healthy crops. Though hydathode infection is most common, stomatal entry may occur when plants are subjected to heavy rains or irrigation. The organism can also enter through natural wounds in the root system during periods of soil saturation. With warm temperatures of 27-30°C (81-86°F), symptoms may appear in 10 to 12 days. However, under cool conditions, an infected plant may not show symptoms. Spread of the disease in the field generally occurs by wind-blown rain, irrigation water, cultivation, insects or animals. The bacterium can be seedborne, which may result in seedling infection. Secondary infection from black rot-infected seedlings may occur in nurseries or seed beds and the disease generally spreads rapidly during transplant/growing operations.

Control:
Use high-quality seed free of *X. campestris* pv. *campestris.* Implement a three-year rotation to non-cruciferous crops. Seed beds should be geographically isolated from commercial crucifer crops. Do not mow or clip transplants. Plant crops in well-drained soils and use irrigation practices that minimize leaf wetness. Keep fields free of cruciferous weeds. Disinfect seed beds and equipment with steam or germicidal sprays before use. Control insects to minimize spread of the pathogen.

Black Rot

Scab

Causal Agent:
Streptomyces scabies

Distribution:
Worldwide

Symptoms:
This disease is most commonly on radishes, but also infects turnips and rutabaga. As the root swells, small (1mm; 1/32 in.) white lesions develop on the root surface. A ridge of light-colored tissue forms at the margin, while the center of the lesion darkens, giving it a crater-like appearance. Secondary infections of lesions by other organisms may cause discoloration and softening of the root.

Conditions for Disease Development:
The bacterium survives host-free for many years in alkaline to neutral soils. Dry soil and poorly fertilized soils favor disease development.

Control:
Implement long crop rotations to non-hosts. Eradicate fleshy, rooted weeds, such as pigweed (*Amaranthus* sp.). Avoid the use of soil amendments that increase soil pH. Apply acid-producing fertilizers. Irrigate during periods of warm, dry weather to help reduce infection.

Xanthomonas Leaf Spot

Causal Agent:
Xanthomonas campestris* pv. *armoraciae

Distribution:
United States, Australia and Japan

Symptoms:
Cabbage, cauliflower, broccoli, radishes and turnips are susceptible to this disease. Symptoms first appear as depressed, translucent flecks on leaves. These flecks develop into circular or angular lesions up to 5 mm (1/10 in.) across that are yellowish-white to brown or black in color and are surrounded by translucent haloes. Centers of lesions often break down, giving the leaf a shot-hole appearance. Symptoms are generally restricted to the tissue between the veins, although, dark streaks are often present along the veins. Lesions on leaf margins often result in tipburn-like symptoms, which later give a tattered appearance to the leaf.

Conditions for Disease Development:
The organism can be soil- or seed-borne. Infected plant debris is also a source of inoculum. The organism invades via stomata and requires long periods of free moisture on the leaf surface to infect. Prolonged periods of dew formation, or rain, favor disease development. The disease often appears during the cooler temperatures of fall or winter, although, the organism will infect and cause symptoms over a wide range of temperatures.

Control:
Use seed-free of *Xanthomonas campestris* pv. *armoraciae.* Plant crops in well-drained soils and use irrigation practices that minimize leaf wetness. Rotate to a non-host crop for at least three years following a cruciferous crop.

Fungal Diseases

INFECTIOUS DISEASES AND PESTS

Alternaria Diseases

Causal Agent:
Alternaria brassicae, A. brassicicola, A. raphani

Distribution:
Worldwide

Symptoms:
These *Alternaria* species cause leaf spots that appear on older tissue and often begin as small, circular lesions. These lesions expand and develop concentric rings with chlorotic haloes. Lesion centers may break apart, giving a shot-hole appearance to the leaf or, if conditions are favorable, become covered with a sooty black mass of spores. These fungi may also infect seedlings with symptoms appearing as black streaks on cotyledons and hypocotyls, which may result in damping-off. *Alternaria* spp. may also infect the base of cabbage heads and cause browning of cauliflower and broccoli heads, rendering the heads unmarketable. Flower clusters may also become infected during seed production, affecting seed quality.

Conditions for Disease Development:
Cruciferous crop residues are commonly the primary source of inoculum. Cruciferous weeds may also harbor these fungi. *Alternaria* species may be seedborne. Conidia of Alternaria spp. are disseminated by wind and water. Disease development is favored by free moisture on plant surfaces and temperatures between 20-27°C (68-81°F).

Control:
Use high-quality seed free of these three *Alternaria* species. Incorporate cruciferous residues, practice crop rotation and apply foliar fungicides to help manage this disease.

Black Leg

Causal Agent:
***Leptosphaeria maculans* (anamorph: *Phoma lingam*)**

Distribution:
Worldwide

Symptoms:
Symptoms manifest as oval, sunken, light-brown cankers with purple-to-black margins near the base of stems. Cankers enlarge and girdle stems, causing plant collapse. Lesions may also develop on cotyledons and hypocotyls of young seedlings and appear on leaves as pale, irregular spots. Leaf spots gradually enlarge, becoming circular with gray centers. Under favorable conditions, small black fruiting structures (pycnidia) develop in stem cankers and leaf spots. Severely infected plants are stunted and often wilt. The leaves remain attached and the plant turns a dull blue-red color. The root system may be destroyed, although new roots may form above the stem cankers, allowing the plant to remain alive. When infected cabbage heads are stored, the infection can spread to the base of leaves where brown to black spots develop. On root crops, a dark, dry rot can occur in storage.

Conditions for Disease Development:
The fungus can survive in crop debris and cruciferous weeds. Infected seed, however, may also be a source of primary inoculum. In seed beds, infected seedlings generally develop symptoms in two to three weeks. Irrigation water can spread the spores of the fungus to surrounding healthy seedlings. Secondary infection may also occur when the young plants are dipped in water prior to transplant. The disease may also spread by splashing rain, workers and equipment.

Control:
Use *Leptosphaeria maculans*-free seed. Eradicate cruciferous weeds, remove or deep plow plant debris and practice a three-to-four year rotation to non-host. Fumigate, solarize or flood infested fields to help reduce field inoculum levels.

Black Root

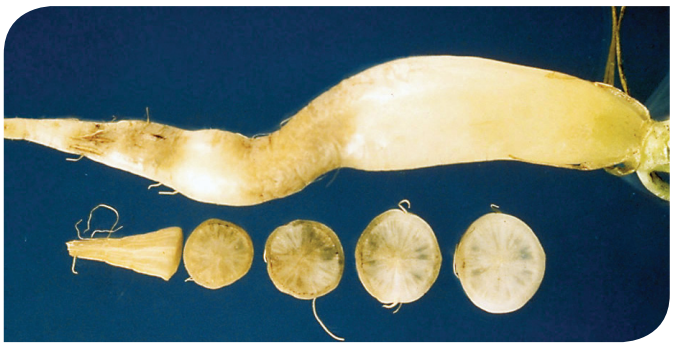
Causal Agent:
Aphanomyces raphani

Distribution:
Worldwide

Symptoms:
Root lesions develop where secondary roots emerge from the tap root. These bluish-gray to black lesions girdle the root, but infected tissue remains firm. Icicle-types of radishes may be severely affected by this disease, with yield losses approaching 100 percent. If infection occurs beneath the salable portion of a globe-type of radish, a crop may be harvested with minimal loss.

Conditions for Disease Development:
Aphanomyces raphani can survive for more than one year as oospores in crop residues and soil. The fungus is generally not seedborne, but may be carried in debris associated with seed. Abundant soil moisture is required for zoospores to swim to and infect host tissues. Warm temperatures [20-27°C (68-80°F)] favor infection and subsequent disease development.

Control:
Use high-quality seed free from crop residues. Implement good field sanitation practices, manage irrigation water, practice three-to-four year crop rotations to non-host and apply chemical soil treatments to control black root.



Bottom Rot

Causal Agent:
Rhizoctonia solani

Distribution:
Worldwide

Symptoms:
Infection generally occurs in cabbage after head formation as the fungus enters leaves and stems that are in contact with infested soil. Symptoms first appear as tan-to-brown, well defined lesions. *Rhizoctonia solani* then invades the center of the head, with complete rot often occurring within 10 days. Leaves may wilt and senesce after the head is colonized.

Conditions for Disease Development:
Disease development is favored by damp to wet soil, wet foliage and temperatures ranging from 20-28°C (68-82°F).

Control:
Maintain plant health and provide adequate fertilizer. Avoid excessive soil moisture, and plant on raised beds to help ensure adequate drainage. Rotate to a non-host crop to help manage this disease.

Cercospora Leaf Spot

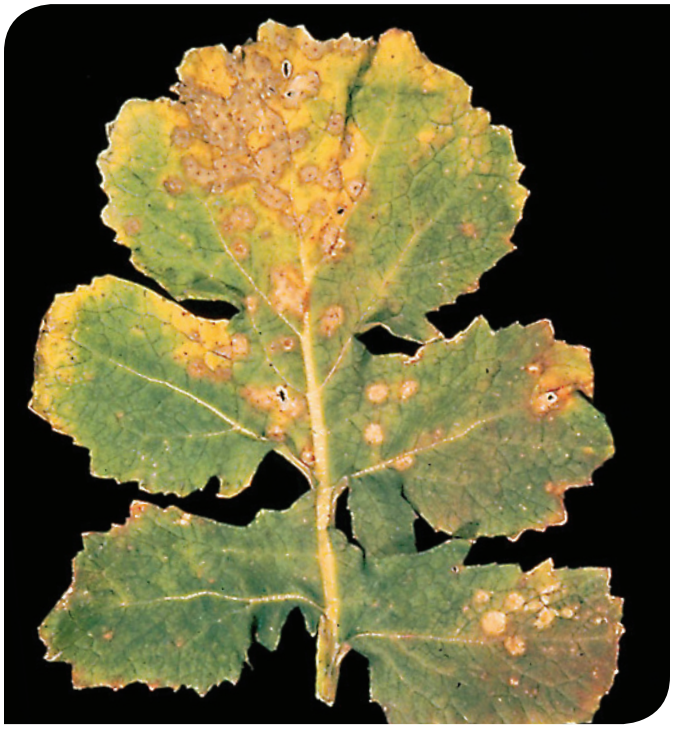
Causal Agent:
Cercospora brassicicola

Distribution:
Generally tropical and subtropical regions

Symptoms:
Leaf spots vary in color from pale green to white and are bordered by brown tissue and general chlorosis. Lesion may be circular or angular in appearance. Severely affected plants may defoliate.

Conditions for Disease Development:
The fungus can be seedborne, but more commonly survives in volunteer plants and weeds. Spores are spread by wind, rain and irrigation water, or mechanically by equipment and people. High relative humidity and temperatures between 13-18°C (55-64°F) generally encourage disease development.

Control:
Eradicate cruciferous weeds and volunteers. Apply fungicides early and often to achieve adequate disease control.



Clubroot

Causal Agent:
***Plasmodiophora brassicae* (Many races have been identified)**

Distribution:
Worldwide

Symptoms:
This soilborne fungus infects nearly all cultivated crucifers. The disease can be difficult to detect as affected plants wilt on hot days but may recover after sundown. *Plasmodiophora brassicae* enters through root hairs, and root cells stimulated by the pathogen multiply rapidly in size and number, forming club-like galls on roots. Deformed roots no longer function normally and are susceptible to rot by secondary soilborne organisms. Young plants affected by this disease often die. Older plants grow to maturity, but are unable to produce a marketable product.

Conditions for Disease Development:
Infected roots serve as the major source of inoculum and release zoospores, which infect root tissue. Zoospore-contaminated irrigation water, equipment and people may spread this disease. Propagation of the pathogen may occur if asymptomatic, infected seedlings are transplanted into clean fields. Acidic soils and temperatures ranging from 12-27°C (54-81°F) allow for rapid disease development.

Control:
Eradicate cruciferous weeds and volunteers. Cultivate to promote breakdown of crop residues. Implement five-to-seven year crop rotations to non-hosts, lime soil to a pH of 7.3 or greater, and fumigate soil or sow into *Plasmodiophora brassicae*-free soil medium.

Damping-Off & Wirestem

Causal Agent:
Pythium* spp., *Fusarium* spp., *Rhizoctonia solani

Distribution:
Worldwide

Symptoms:
Pre-emergence damping-off is generally caused by the invasion of the host by the fungus prior to plant emergence from soil. This is due to conditions that inhibit or slow seed germination, while allowing the pathogen to grow. Post-emergence damping-off occurs on young seedlings at or near the soil line, although, *Pythium* spp. may infect at the roots or root hairs. The host tissue appears water-soaked and constricted, eventually leading to seedling collapse. Damping-off becomes less of a problem as the host plants mature. A hypocotyl or stem infection of older plants by *Rhizoctonia solani* may produce a canker. Infected stems may be somewhat smaller in diameter than normal, but tough and wiry; hence, the name "wirestem." This disease is most problematic on slow-growing and deep-seeded plants.

Conditions for Disease Development:
These fungi may be present in the soil for a long time, but will not generally affect plants until the right environmental conditions, such as wet soils and cool temperatures, are met. Disease damage is generally greater in soil with infected, non-decomposed plant debris.

Control:
Fumigate, manage irrigation water and rotate to non-hosts to help reduce inoculum levels. Sow fungicide-treated seed to help control these pathogens.

Downy Mildew

Causal Agent:
Hyaloperonospora parasitica
(synonym: *Peronospora parasitica*)

Distribution:
Worldwide

Symptoms:
This disease manifests as yellow, purple or brown irregular-shaped areas on upper leaf surfaces, which correspond to white to gray, "downy" fungal spore masses on abaxial leaf surfaces. Under heavy disease pressure, sporangia develop on the upper leaf surfaces, as well, which may lead to seedling death. Early infections by this obligate pathogen may invade the vascular system, turning it black. Cauliflower curds, broccoli florets, radish roots and cabbage heads may all be unmarketable if infected.

Conditions for Disease Development:
Heavy fog, light rains, prolonged leaf wetness and night temperatures between 8-16°C (46-61°F), with day temperatures below 24°C (75°), generally favor disease development.

Control:
Eradicate cruciferous weeds and volunteers. Furrow or drip irrigate, and transplant at densities that promote good aeration and reduced humidity. Apply fungicides early and often to achieve adequate disease control.

Phytophthora Root Rot

Causal Agent:
Phytophthora megasperma

Distribution:
Worldwide

Symptoms:
All cruciferous crops and many cruciferous weeds are affected by this disease. Plants first develop symptoms as temperatures fall and soil moisture increases. Leaf margins discolor red to purple beginning at the leaf tips and progressing to the stem, resulting in leaf dieback. Stem lesions appear gray when compared to healthy tissue. Infected plants generally wilt and often die.

Conditions for Disease Development:
This pathogen overwinters as oospores inside root tissue of diseased plants. Oospores give rise to zoospores, which are motile and infect roots of susceptible plants. Wet, poorly drained soils and temperatures between 13-25°C (55-77°F) generally favor this disease.

Control:
Cultivate to prevent compaction of soils and help promote good soil drainage. Avoid planting into a field with a history of Phytophthora root rot and implement three-year crop rotations to non-susceptible crops. Apply chemical soil treatments to help manage this disease.

Powdery Mildew

Causal Agent:
Erysiphe cruciferarum

Distribution:
Worldwide

Symptoms:
Symptoms begin as star-shaped, white lesions on the upper surface of the foliage. Lesions gradually coalesce, and leaf surfaces appear dusted with white powder. Infection on cabbage or cauliflower can reduce head or curd size. On Brussels sprouts, the disease moves onto the stems where sporulation is accompanied by a purplish discoloration of host tissues. Sprout buds may be heavily infected, resulting in an unmarketable product.

Conditions for Disease Development:
This obligate pathogen overwinters as cleistothecia on dead host tissue or as mycelium in living tissue. Weed species serve as alternate hosts in the off-season and commonly serves as an inoculum source for subsequent disease cycles. Disease development is generally favored by dew and moderate temperatures [15-20°C (59-68°F)] and conidia are easily spread by wind or by harvesting the crop. Water stress within the host also favors infection.

Control:
Apply preventive fungicidal sprays and eradicate cruciferous weeds and volunteers to control this disease.

Ring Spot

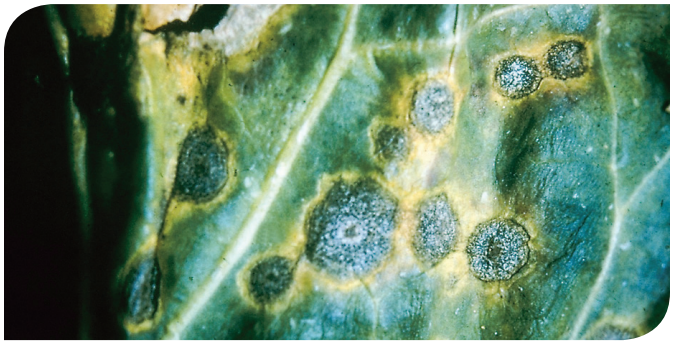
Causal Agent:
***Mycosphaerella brassicicola* (anamorph: *Astromella brassicae*)**

Distribution:
Worldwide in cool, moist climates

Symptoms:
Lesions manifest as water-soaked areas surrounded by chlorotic haloes, which are visible on both leaf surfaces and stems. On leaves, lesions can expand in size to 2.5cm (1 in.) in diameter. Fruiting bodies often form concentric rings within lesions. Lesions may coalesce, giving leaves a yellow, tattered appearance. On stems, lesions are often rectangular to oval. The disease may also cause a storage rot of cabbage, leaving it shriveled and leathery.

Conditions for Disease Development:
Infected debris serves as the primary inoculum source. The fungal spores (ascospores) are spread by wind, and infection occurs through the stomata. Cool [15-21°C (59-70°F)], moist weather generally favors disease development.

Control:
Remove and destroy crop refuse. Locate seed beds away from existing cruciferous crops. Apply preventive fungicide sprays to help control this disease.



Sclerotinia Stem Rot and Watery Soft Rot

Causal Agent:
Sclerotinia sclerotiorum

Distribution:
Worldwide, except in the warmest areas of the tropics

Symptoms:
In moist weather, stem infections spread rapidly downward to decay the roots and expand upward wilting leaves, resulting in plant collapse. A white, cottony growth and black, seed-sized sclerotia may be visible on or embedded in the affected tissues. When dry weather follows infection, brown cankers form on stems without progressing further. This disease may also cause losses during storage and transportation.

Conditions for Disease Development:
Sclerotia of this fungus are long-lived, allowing it to persist in soil for many years. Disease development is generally favored by abundant soil moisture and temperatures ranging from 10-25°C (50-77°F). Sclerotia that come in contact with the stem or foliage may directly infect host tissue. However, the ascospores of *Sclerotinia sclerotiorum* require a supply of nutrients to infect. Pollen and flower parts from the host crop or adjacent weeds, such as common ragweed (*Ambrosia artemisiifolia*), serve as a nutrient source and permit the fungus to develop specialized structures which then penetrate the crucifer host. Crucifers, especially cabbage, that come in contact with colonized plant tissue may then become infected.

Control:
Implement good sanitation practices and long rotations to non-host crops. Cultivate to help promote good soil drainage. Flood fields for a long period of time during warm weather to destroy sclerotia. Manage weeds and apply fungicide sprays to control this disease.

Verticillium Wilt

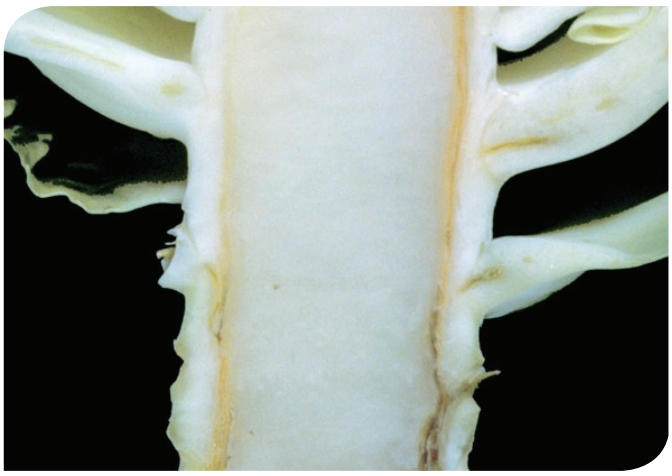
Causal Agent:
Verticillium dahliae

Distribution:
Worldwide

Symptoms:
This disease is most commonly seen on cauliflower and Chinese cabbage. V-shaped lesions with yellow borders form along leaf margins of lower leaves. Vascular tissue develops a dark brown discoloration, which can extend from the roots into the stem. Symptoms may be easily confused with those of black rot.

Conditions for Disease Development:
This fungus survives in soil, and continuous cropping can lead to the buildup of inoculum levels. Cool weather and moist soil generally favor disease development.

Control:
Implement long rotations to non-susceptible crops or fumigate soil.



White Leaf Spot

Causal Agent:
***Pseudocercosporella capsellae* (teleomorph: *Mycosphaerella capsellae*)**

Distribution:
Worldwide

Symptoms:
White leaf spot occurs on turnips, Chinese cabbage, Chinese mustard, cabbage and broccoli, and infrequently on cauliflower. Oval lesions with gray, brown or nearly white centers and dark margins form on cotyledons, leaves and petioles. When lesions are numerous, affected foliage may turn yellow and senesce.

Conditions for Disease Development:
This fungus may be seed-borne and overwinters in volunteer plants or perennial weeds. The ascospores are spread by wind and rain. Disease development is generally favored when air temperatures are cool [13-18°C (55-64°F)] and moisture is abundant.

Control:
Eradicate cruciferous weeds and volunteers. Cultivate to help promote good soil drainage, and implement crop rotation to non-host species.

White Rust

Causal Agent:
Albugo candida **(Many races have been identified)**

Distribution:
Worldwide

Symptoms:
White rust affects every known cruciferous crop. However, this disease is most common on radishes, horseradish, mustard and turnips. Symptoms manifest as chlorotic or necrotic spots on upper leaf surfaces. Later pustules form on abaxial leaf surfaces, small stems and floral parts. Pustules rupture the host epidermis and expose a white, chalky dust of sporangia in small, zonate areas. Occasionally affected portions of leaves are swollen and distorted. On radishes, *A. candida* causes clubroot-like swellings on the roots. On flower stalks, distorted stems and flowers result in a staghead appearance.

Conditions for Disease Development:
Oospores serve as primary inoculum for this disease and can survive for many years in soil or as a contaminant of seeds. Infection is generally favored by cool [13-18°C (55-64°F)], wet weather in the form of prolonged dews or fog. Sporangia are produced in the pustules and are spread by wind, rain or insects to neighboring plants.

Control:
Use *Albugo candida*-free seed. Incorporate crop debris and eradicate cruciferous weeds. Where practical, implement long rations to non-host species. Apply fungicides to help control this disease.

Yellows

Causal Agent:
Fusarium oxysporum f. sp. conglutinans
(Two races have been identified),
F. oxysporum f. sp. raphani

Distribution:
Worldwide

Symptoms:
Affected foliage turns dull and chlorotic. Some leaves appear distorted due to uneven growth. Leaves may die prematurely and senesce, starting at the base of the plant. This pathogen invades the vascular system of host plants, turning the vascular tissue brown or yellow. Plants which do not die are often stunted and have one-sided yellowing of the leaves or stem.

Conditions for Disease Development:
This fungus survives in the soil and produces spores which can persist in the soil for many years. The fungus enters the plant through the roots and moves into the vascular system. Host susceptibility and the environment affect disease development. The disease is generally favored by warm temperatures. At temperatures below 20°C (68°F), disease development is greatly reduced.

Control:
Resistant varieties help provide the most effective control of this disease.

Virus Diseases

INFECTIOUS DISEASES AND PESTS

Cauliflower Mosaic

Causal Agent:
Cauliflower mosaic virus **(CaMV)**

Distribution:
Worldwide, especially in temperate areas of the United States and Europe

Symptoms:
Only members of the crucifer family are susceptible to CaMV. Systemic symptoms consist of a clearing or chlorosis along leaf veins (vein clearing). This is often seen first at the base of a leaf. Later, symptoms appear as dark green areas along veins (vein banding) and necrotic spotting of the leaf. Chinese cabbage is particularly susceptible to CaMV. In addition to vein clearing, a striking mosaic may develop with light and dark green areas on leaves. Plants can be stunted. Internal necrotic spotting in stored cabbage has been attributed to CaMV infection.

Conditions for Disease Development:
The primary inoculum source of CaMV is infected brassica crops or cruciferous weeds. The virus is transmitted to the crop by many species of aphids, such as the cabbage aphid, the false cabbage aphid and the green peach aphid. Aphids can acquire and transmit CaMV within one minute of feeding on an infected plant. Temperatures between 16-20°C (61-68°F) favor symptom expression in plants. CaMV is often found as a mixed infection with Turnip mosaic virus, resulting in more severe symptoms than when either virus is present alone.

Control:
Eradicate cruciferous weeds and volunteers, and incorporate crop debris immediately after harvest. Isolate transplant beds from commercial crucifer crops.

Radish Mosaic

Causal Agent:
Radish mosaic virus **(RaMV)**

Distribution:
Japan, Europe and the U.S. state of California

Symptoms:
This virus infects almost all crucifers. Symptoms include mosaic, ringspots, leaf distortion, veinal necrosis and systemic necrosis. Infected radish plants may show leaf enations. In cauliflower and cabbage, symptoms appear as chlorotic and necrotic lesions along with a mosaic.

Conditions for Disease Development:
RaMV is transmitted by various beetles. The virus is present in both crop plants and weeds, which serve as reservoirs for spread of the disease.

Control:
Control insect vectors to help manage this disease.

Turnip Mosaic

Causal Agent:
Turnip mosaic virus **(TuMV)**

Distribution:
Worldwide, especially in temperate regions

Symptoms:
Leaves of cabbage, cauliflower and broccoli infected by the cabbage black ringspot strain of TuMV have 2-5 cm (¾-5 in.) of circular, light green lesions, which can best be seen on the abaxial leaf surface. Later, these lesions turn necrotic and may coalesce, resulting in large necrotic areas, which lead to defoliation. In cabbage, the outer leaves may develop necrotic spots which can occur throughout the head. In Chinese cabbage, symptoms manifest as vein necrosis and necrotic spotting of head leaves, and are often on one side of the plant. In turnips, radishes and mustard, leaf distortion, blisters, mosaic and stunting are commonly seen symptoms with any strain of the virus.

Conditions for Disease Development:
Turnip mosaic virus is generally transmitted mechanically and in a non-persistent manner by more than 80 species of aphid. Cruciferous weeds are hosts for both the virus and aphid vectors. Generally, virus symptoms are more severe at temperatures between 20-28°C (68-82°F). Simultaneous infections of TuMV and Cauliflower mosaic virus result in severe stunting and vein clearing in cool weather. During warm weather, mottling and stunting are more common.

Control:
Implement an insecticide spray program to help control vectors. Eradicate cruciferous weeds and volunteers. Incorporate plant residues immediately after harvest. Isolate transplant beds from crucifer crop fields.

Turnip Yellow Mosaic

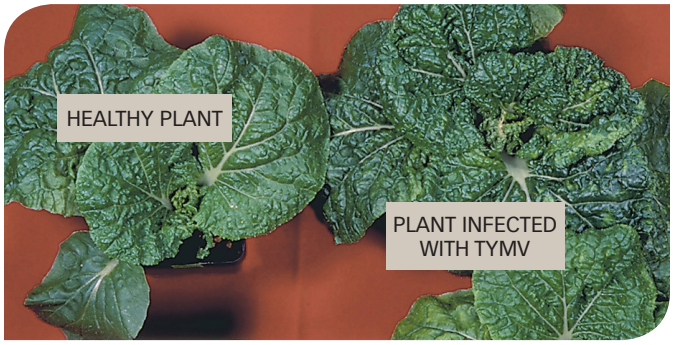
Causal Agent:
Turnip yellow mosaic virus **(TYMV)**

Distribution:
Western Europe

Symptoms:
This virus only infects crucifers. In cauliflower, symptoms begin as vein clearing, but subsequently develop into permanent yellow patches on older leaves. Symptoms on Chinese cabbage develop into bright yellow and dark green mosaic patterns. During cool weather, infected plants remain stunted. Symptoms are mild in other brassicas.

Conditions for Disease Development:
This virus overwinters in cruciferous weeds. Turnip yellow mosaic virus is generally transmitted by chewing insects such as flea beetles, mustard beetles, grasshoppers and earwigs. Temperatures near 25°C (77°F) are optimal for symptom development.

Control:
Use insecticides to help control insect populations. Eradicate cruciferous weeds and volunteers.



Nematode Diseases

INFECTIOUS DISEASES AND PESTS

Cabbage Cyst

Causal Agent:
***Heterodera cruciferae* (Cabbage Cyst Nematode),**
***H. schachtii* (Sugar Beet Cyst Nematode)**

Distribution:
Worldwide

Symptoms:
Heterodera cruciferae only infects crucifers, while *H. schachtii* infects crucifers and sugar beets. Foliar symptoms are dependent on plant age, season and temperature. Generally, plants first appear small and nutrient deficient. As the disease progresses, leaves may wilt or curl, especially during hot weather. Invaded roots branch profusely, while the taproot remains small. Plants that survive produce loose, small heads and discolored roots. Invasion of infected roots by fungi is common. A characteristic sign of this pathogen is the appearance of lemon-shaped cysts on the root surface, which are white, tan or reddish in color. Plants often die prematurely.

Conditions for Disease Development:
These nematodes overwinter as cysts and hatch soon after transplant, releasing juveniles that penetrate host root tissues. Loamy soils favor disease development, and irrigation water or rainfall allows these nematodes to swim or float to susceptible roots. The nematodes are also spread through contaminated soil, infected seedlings, tools and machinery.

Control:
Sow resistant varieties and rotate to non-hosts for a period of three to five years in order to help reduce nematode populations. Fumigate soil, apply nematicides, incorporate crop residues immediately after harvest, and eradicate weeds and volunteers to help control this disease.

Root Knot

Causal Agent:
***Meloidogyne* spp.**

Distribution:
Worldwide

Symptoms:
Symptoms of this disease are similar to those of clubroot, but clubroot-affected plants produce larger, more continuous swellings on the older portion of their roots. Root-knot nematodes on crucifers induce prolific root branching and galling above the point of infection. Invasion of infected roots by fungi may occur. Above-ground symptoms include stunting, chlorosis and wilting. Though infected plants may survive a growing season, the resulting crop is generally small and may be unmarketable.

Conditions for Disease Development:
These nematodes survive in infected root debris. Juveniles are attracted to root exudates of host plants and feed on root tissue. The most severe damage can occur in sandy soil with moderate moisture, but these nematodes are not limited to these conditions. Infection can occur at temperatures ranging from 10-35°C (50-95°F). Freezing temperatures kill all life-cycle stages of *Meloidogyne* species.

Control:
Soil fumigation, flooding or fallow farming help control populations of root knot nematodes.

Noninfectious Disorders

Black Speck

Causal Agent:
Physiological Disorder

Distribution:
United Kingdom, United States

Symptoms:
Black speck is a non-parasitic disorder of mature cabbage and Chinese cabbage. Lesions are discrete, dark brown or black, and up to 2 mm (1/16 in.) in diameter. Lesion margins are short and often have a narrow, yellow halo. Larger lesions of up to 1 cm (3/8 in.) in diameter may also occur. Lesions may coalesce, resulting in large, dead areas of leaf tissue. Minute specks occur on heart leaves. Symptoms may not occur until cabbage is stored at cool temperatures.

Conditions for Disease Development:
This disorder appears to be more severe on tender, lush crops and on crops grown during warm weather. Cool conditions during storage favor development of this disorder.

Control:
Not known.

Brown Bead

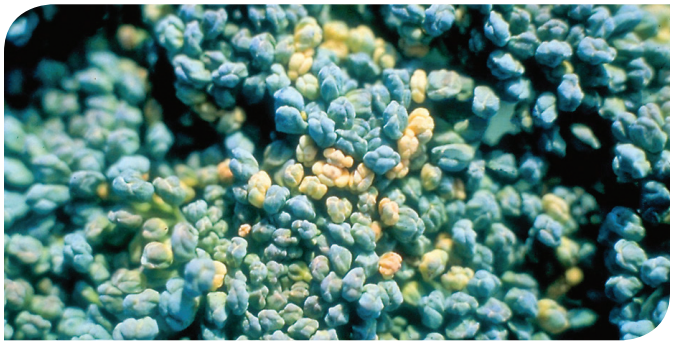
Causal Agent:
Physiological Disorder

Distribution:
Primarily on broccoli in the United States

Symptoms:
This disorder is most commonly seen when broccoli heads reach maturity. Sepals of individual buds turn from green to yellow to brown. As the necrotic buds die, they often dry up and senesce. This opens an avenue for soft rotting bacteria (*Pectobacterium* spp. and *Pseudomonas* spp.) to enter the host and cause further damage.

Conditions for Disease Development:
Brown bead is often seen when a period of high soil moisture is followed by a period of high temperatures and rapid plant growth, especially at the time of bud development. Widely varying relative humidities play a role in the expression of brown bead. Lack of boron may also be a contributing factor to this disorder.

Control:
Not known.



Edema

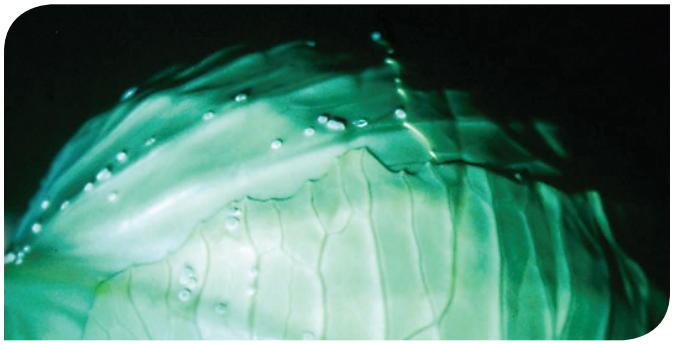
Causal Agent:
Physiological Disorder

Distribution:
Worldwide

Symptoms:
Symptoms may develop on any part of the plant, but are most common on the undersurface of leaves. Small, wart-like bumps form that may coalesce into ridges. Epidermal cells of the wart-like areas may rupture. Leaf blotching may also occur.

Conditions for Disease Development:
The disorder generally occurs when the soil is warm and wet, and the air temperature is cool. For example, this may occur on a cool night after several warm, humid days. Prolonged periods of high humidity favor edema.

Control:
For greenhouse crops, place heating pipes away from soil beds and close ventilators at night. Manage irrigation to help ensure proper soil moisture.



Hollow Stem

Causal Agent:
Physiological Disorder

Distribution:
Worldwide

Symptoms:
Hollow stem occurs in cauliflower, broccoli and cabbage. The thick, fleshy center of the stem core splits due to an uneven growth rate and an elongated cavity forms. The cavity may extend to either end of the plant to produce an opening to the outside environment. When this occurs, infections by fungi and bacteria are common.

Conditions for Disease Development:
Irregular or sudden rapid growth, high temperatures, high nitrogen levels and low plant populations favor development of hollow stem. A boron-deficient growing condition may also encourage this disorder.

Control:
Avoid excessive soil fertility. Increase planting density for broccoli to help decrease plant growth rates and reduce the incidence of hollow stem.

Nutritional Deficiencies

Causal Agent:
Physiological Disorder

Distribution:
Worldwide

Symptoms:
The most common nutrient deficiencies in crucifers are:

Molybdenum - Causes whiptail and blindness (no apical growing point) of broccoli and cauliflower. Leaves are extremely malformed, being narrow with curled, ruffled edges. Curd development is poor.

Boron - Symptoms occur as cabbage and cauliflower approach maturity. The pith becomes cracked and brown. In cauliflower, the curd may become brown. Radish roots become distorted and an internal brown discoloration occurs. Scabby surface cankers may appear on radishes.

Magnesium - Chlorosis occurs on interveinal areas of lower leaves. Necrotic spots may occur in the chlorotic tissue. Growth is reduced.

Conditions for Disease Development:
Acid or alkaline soils may lead to nutrient deficiencies due to the immobilization of nutrients. Some soils are naturally low in specific nutrients. The excessive, or unbalanced, use of fertilizer may also cause some nutrients to become unavailable to the plants.

Control:
Use a balanced fertilizer program appropriate to the soil and the crop. Alter soil pH or apply foliar fertilizers to help correct some deficiencies.

Tipburn

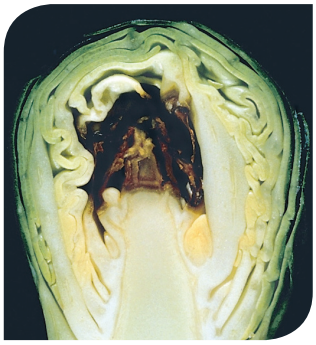
Causal Agent:
Physiological Disorder

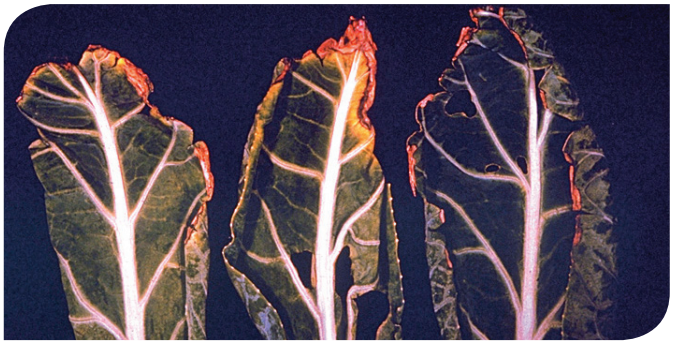
Distribution:
Worldwide

Symptoms:
Symptoms manifest as brown to black necrotic tissue at leaf tips. Leaves surrounding the growing point are particularly susceptible to this disorder. Tipburn is readily seen when exposed plant structures, such as leaves and curds, are affected. However, damage to the heads of Brussels sprouts, cabbage and Chinese cabbage may go undetected until they are cut open. In severe cases of tipburn, the head is soft and the plant is dwarfed.

Conditions for Disease Development:
Tipburn is related to calcium deficiency in developing tissues. Fast growth and high relative humidity favor symptom development. Developing leaves, which are already low in calcium, are severely stressed for calcium during times of rapid growth. Transpiration and translocation are slowed when relative humidity is high, thus calcium transport is inhibited.

Control:
Grow tolerant varieties. Avoid excessive fertilization, and increase available calcium in the soil through soil amendments. Apply foliar nutrient solutions of calcium salts. Manage irrigation to help regulate plant growth.





Abaxial Directed away from the axis or stem; the lower leaf surface.

Adaxial Directed toward the axis or stem; the upper leaf surface.

Anamorph The asexual form in the life cycle of a fungus. Asexual spores (conidia) are usually produced.

Ascospore Sexually derived fungal spore within a sack-like structure (ascus).

Bacterium (pl. bacteria) A microscopic, single-celled organism.

Blight Sudden and severe necrosis of the above-ground portions of a plant.

Canker Localized, necrotic areas on roots or stems. Tissue may be sunken and/or cracked.

Causal agent The organism or agent (bacterium, fungus, nematode, virus, etc.) That incites a given disease.

Chlorosis (adj. chlorotic) The failure of chlorophyll development caused by disease or a nutritional disorder; the fading of green plant color to light green, yellow or white.

Coalesce Merging of individual lesions.

Concentric More than one circle in a lesion with a common center.

Conidium (pl. conidia) An asexually-formed fungal spore.

Cotyledon The first foliar structure to emerge from a seed.

Crucifer A member of the plant family brassicae that includes broccoli, brussels sprouts, cabbage, cauliflower, kohlrabi, radishes, rutabaga and turnips.

Cyst In fungi, the resting structure formed by a zoospore. In nematodes, the egg-containing carcass or oxidized cuticle of a dead adult female of the genera *globodera* and *heterodera*.

Damping-off A rotting of seedlings at or below soil level.

Debris Remnant plant material.

Defoliation The loss of leaves.

Distal Located far from the point of attachment.

Edema A watery swelling of plant organs or parts; often caused by overwatering in cloudy, humid weather when evaporation (transpiration) is reduced.

Enation A tissue malformation often appearing as a ridge or a leaf-like growth and originating along leaf veins.

Epidermis The outer layer of cells occurring on plants.

Forma Specialis (f. sp.)	Special form; a biotype (or group of biotypes) of a species of pathogen that differs from others in the ability to infect selected genera or species of infected plants.
Fumigation	Sterilization by chemical volaltilization.
Fungicide	A chemical used to control fungi.
Fungus (pl. fungi)	A microscopic organism with thread-like cells which grows on living and/or dead plants.
Gall	Swelling of roots, stems or leaves caused by abnormal growth of tissue.
Girdle	The encircling of a root or stem by a pathogen that results in disruption of the phloem.
Herbicide	Chemical Substance Used To Control Weeds.
High Resistance	The ability of a plant variety to highly restrict the activities of a specific pathogen or insect pest and/or to restrict the symptoms and signs of a disease, when compared to susceptible varieties. Varieties with high resistance may exhibit some symptoms when a specified pathogen or pest pressure is severe. New and/or atypical strains of the specific pathogen or pest may overcome the resistance.
Host	A plant from which a parasite obtains nutrition.
Hydathode	A leaf structure that eliminates unused salts, sugars and water from a plant through a pore at the leaf margin.
Hypocotyl	The lower stem of a plant between the cotyledons and the roots.
Infection	The process in which an organism attacks a plant.
Infested	Containing a great number of insects, mites, nematodes, etc., as applied to an area or field. Also applied to a plant surface or soil contaminated with bacteria, fungi, etc.
Inoculum	A pathogen or its parts that can cause disease.
Insecticide	A substance used to control insects.
Intermediate resistance	The ability of a plant variety to restrict the growth and development of a specific pathogen or insect pest, but may exhibit a greater range of symptoms compared to varieties with high resistance. Intermediate resistant plant varieties will still show less severe symptoms or damage than susceptible plant varieties when grown under similar environmental conditions and/or pest or pathogen pressure.
Interveinal	The area of leaf tissue bordered by veins.
Juvenile	An immature nematode.
Lesion	A well-defined, but localized, diseased area on a plant.

Mosaic Variegated patterns of light and dark areas on a plant often caused by viruses.

Mottle Irregular light and dark areas on leaves or fruit surfaces symptomatic of viral diseases.

Mycelium (pl. Mycelia) The mass of thin, microscopic, hair-like structures that forms the vegetative part of a fungus.

Necrosis (adj. necrotic) The death of plant cells or tissues, usually accompanied by black or brown darkening.

Nematode Tiny worms that can live in plants, animals, soil or water.

Oospore A sexual spore produced by the union of two morphologically different gametangia (oogonium and antheridium).

Pathogen An organism or agent that is capable of causing disease.

Pathovar (pv.) A type of subspecies; strain or group of strains of a bacterial species differentiated by pathogenicity on one or more hosts (species or cultivars).

Pedicel The stalk of a flower or fruit.

Persistent Referring to circulatory viruses that remain infectious within their insect vectors for long periods without inducing lysis and are transmitted via salivary fluids.

Petiole The stalk of a leaf.

Phloem The food conducting tissue of a plant.

Pustule A small blister-like elevation of the epidermis that forms as fungal spores develop and emerge.

Pycnidium (pl. pycnidia) A spherical or flask-shaped asexual fruiting structure of a fungus.

Race A subspecific group of pathogens with distinct pathological or physiological properties.

Reservoir Infected plants that can serve as a source of inoculum for further infection of other plants.

Saturation Being completely filled with liquid, generally water.

Sclerotium (pl. sclerotia) A compact mass of hyphae capable of surviving unfavorable environmental conditions.

Seedborne Pathogen Infectious agent associated with seed and having the potential of causing a disease of a seedling or a plant.

Senesce To decline or degenerate as with maturation or a physiological aging process; often hastened by environmental stress, disease or insect attack; growing old.

Silique The specialized seed pod of a crucifier.

Soilborne Denoting a soil source or origin of pathogens; the property of a microorganism living and surviving in the soil.

Sporangium (pl. sporangia) A spore case of fungi; commonly a sac-like or flask-like fungus structure of which the contents are converted by cleavage into an indefinite number of endogenous asexual spores.

Spore A reproductive structure of fungi and some bacteria.

Sporulate To form or produce spores.

Stoma (pl. stomata) A pore in a leaf surface.

Strain A general term referring to (a) an isolate; descendent of a pure culture pathogen, (b) a race; one of a group of similar isolates or (c) one of a group of virus isolates that have common antigens.

Stunted Describing a plant reduced in size and vigor due to unfavorable conditions; may be due to a wide range of pathogens or abiotic agents.

Susceptibility The inability of a plant variety to restrict the growth and development of a specified pest or pathogen.

Systemic Spreading internally throughout a plant.

Teleomorph The sexual form of a fungus.

Tolerance The ability of a plant variety to endure abiotic stress without serious consequences for growth, appearance and yield.

Translocation The transfer of nutrients or a virus through the plant.

Transpiration The loss of water vapor via stomata.

Vascular The conductive system of a plant combining the xylem and phloem.

Vector An agent able to transmit a pathogen.

Virus A sub-microscopic obligate disease causing agent.

Volunteer A cultivated plant growing from self-sown or accidentally dropped seed or vegetative matter.

Water-Soaked Diseased plant tissue that appears wet and dark and may be depressed and translucent.

Xylem The water-conducting tissue of a plant.

Zonate Distinguished from adjacent parts by a distinctive feature (such as concentric rings).

Zoospore An asexually produced fungal spore bearing flagella and capable of active movement in water.

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Notes

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