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# ONION
## DISEASE GUIDE

*A PRACTICAL GUIDE FOR SEEDSMEN, GROWERS AND AGRICULTURAL ADVISORS*


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# PREFACE

This guide provides descriptions and photographs of the more commonly found diseases and disorders of onion and leek worldwide. For each disease and disorder, the reader will find the common name, causal agent, distribution, symptoms, conditions for disease development and control measures. The photographs illustrate characteristic symptoms of the diseases and disorders included in this guide. It is important to note however, that many factors can influence the appearance and severity of symptoms.

The primary audience for this guide includes onion and leek producers, agricultural advisors, farm managers, agronomists, food processors, chemical companies and seed companies. This guide should be used in the field as a quick reference for information about common diseases and disorders and their control. However, diagnosis of these diseases and disorders using only this guide is not recommended. Even the most experienced plant pathologist relies upon laboratory and greenhouse techniques to confirm suspicions from the field. Moreover, this guide is by no means inclusive of every onion or leek disease. Rather, we present those diseases that are prevalent worldwide. With one exception, insect pests were not included in this publication. Thrips injury was included to compare the unique foliar damage caused by thrips feeding to that caused by infectious diseases and other non-infectious disorders.

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

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### NON-INFECTIOUS DISORDERS



### MISCELLANEOUS

# BACTERIAL
## DISEASES

# BACTERIAL BLIGHT OF LEEK

## SYMPTOMS:

The disease first appears as dark-green, longitudinal, water-soaked lesions that form at leaf tips and edges. As they elongate, lesions turn orange to brown with surrounding chlorosis and may extend as a narrow strip from leaf tip to the sheath. When a lesion extends into the sheath, the affected leaf turns light-green, curls, splits and eventually wilts and dies. Severely affected plants are misshapen, undersized and cannot be harvested.

## CONDITIONS FOR DISEASE DEVELOPMENT:

Infested seed and infected leek debris from a previous crop are both sources of primary inoculum. The bacterium may infect but remain latent in the plant until environmental conditions favor development of disease. Generally, warm temperatures and high humidity encourage symptom expression and disease spread.

## CONTROL:

Sow only clean seed. During the growing season, limit overhead irrigation and avoid mowing the crop when plants are wet with dew or rain. Removing infected plants and plant debris throughout the season and rotating to a non-host help mitigate the risk of disease. Apply soil amendments as needed to increase soil pH to at least 5.5 to reduce the chance of infection.

*Elongate orange to brown lesions with surrounding chlorosis.*

Causal Agent:
*Pseudomonas syringae* pv. *porri*

Distribution:
Canada, Europe, New Zealand and USA

# BACTERIAL LEAF STREAK AND BULB ROT

## SYMPTOMS:

The first symptoms observed are oval, water-soaked leaf lesions, tip-burn and leaf streaking of varying lengths. Initially, leaf streaks are green but eventually darken to black. As infections become more severe and spread down the leaf, entire leaves collapse and dry. Leaf distortion and twisting may also occur. Bulb infection is characterized by dark spots on outer scales and reddish brown discoloration of inner scales. Symptoms often develop in a ring-like pattern due to restriction of the rot by the scales.

*Early disease symptoms showing leaf streaking caused by Pseudomonas viridiflava.*

## CONDITIONS FOR DISEASE DEVELOPMENT:

This disease occurs particularly in winter and spring when temperatures are cool. Epidemics are associated with prolonged periods of rain, which favor progression of the disease. Excess fertilizer stimulates disease development. It is thought that frost damage may predispose onion plants to infection.

*Darkening and collapse of the entire leaf.*

*Disease progression from leaf streaking (right) to plant death (left).*

## CONTROL:

Applications of fixed copper compounds or streptomycin inhibit spread of this disease although bacterial strains resistant to copper may occur. Excessive fertilizer applications may increase foliar symptoms and should be avoided. Reduce postharvest rot by harvesting onions at the proper maturity stage, by reducing wounding and bruising during harvest and by proper curing of bulbs with forced hot air.

*Bulb cross-section showing reddish-brown discoloration of infected inner scales.*

Causal Agent:
*Pseudomonas viridiflava*

Distribution:
USA (Colorado, Florida, Georgia and Texas) and Venezuela

# BACTERIAL SOFT ROT

## SYMPTOMS:

Bacterial soft rot is mainly a problem on mature bulbs. Affected scales first appear water-soaked and pale yellow to light brown when infected by *Dickeya chrysanthemi* or bleached gray to white when infected with *Pectobacterium carotovorum* subsp. *carotovorum*. As the soft rot progresses, invaded fleshy scales become soft and sticky with the interior of the bulb breaking-down. A watery, foul-smelling thick liquid can be squeezed from the neck of diseased bulbs.

## CONDITIONS FOR DISEASE DEVELOPMENT:

Bacterial soft rot is most common on onions in storage or transit; however, this disease can develop on onions in the field before harvest, after heavy rains and when leaves are drying. The main sources of inoculum are contaminated soil and crop residues. The bacteria is spread by splashing rain, irrigation water and insects. Entry into bulbs is only through wounds such as those caused by transplanting, mechanical injuries or sunscald. Also, onion maggots can carry soft rot bacteria and introduce them while feeding. This disease is favored by warm, humid conditions with an optimum temperature range of 20-30°C (68-86°F). However, during storage or transit soft rot can develop when temperatures are above 3°C (37°F).

## CONTROL:

Avoid overhead irrigation where possible, and control insect pests such as the onion maggot. Disease spread and infection may be reduced by copper-based bactericides. Allow onion tops to mature before harvesting and avoid damaging bulbs during harvest. Store onion bulbs only after they have been properly dried, and provide the appropriate temperature and humidity with good ventilation to prevent moisture condensation from forming on the bulbs.

*Foliar collapse of an infected plant.*

*Early season soft rotting of a bulb.*

*Soft rot developing late in the season in two bulbs.*

Causal Agents:
*Dickeya chrysanthem i* (syn. *Erwinia chrysanthemi*),
*Pectobacterium carotovorum* subsp. *carotovorum* (syn. *E. carotovora* subsp. *carotovora*)

Distribution:
Mexico and USA (*D. chrysanthemi*), Worldwide (*P. carotovorum* subsp. *carotovorum*)

# CENTER ROT

## SYMPTOMS:

Symptoms first appear as whitish to tan lesions with water-soaked margins, often on interior leaves. Foliar lesions can rapidly coalesce, progressing to wilt and dieback of affected leaves. The pathogen moves from the leaves into the neck and bulb causing yellowish to light-brown discoloration. With severe infections, all leaves can be affected giving a bleached appearance to plants. Secondary bacterial infections rot interior bulb tissue and produce a foul odor. Under conditions favorable to the disease, yield losses may approach 100 percent.

## CONDITIONS FOR DISEASE DEVELOPMENT:

Both pathogens are seedborne and can survive on a few reported alternate hosts (corn, cotton, melon, pineapple, rice and sugar cane). They may also survive epiphytically on weeds and crop debris. Spread can occur by wind, splashing water and thrips. Infection is favored by moderate to warm temperatures and rainfall during bulb initiation.

## CONTROL:

Seed produced in high risk areas should be tested for *Pantoea ananatis* and *Pantoea agglomerans* before sowing. Some onion varieties are known to be more susceptible to this disease than others. Avoid planting these varieties where disease pressure is high. Control weeds, volunteer onions and thrips. Consider drip rather than sprinkler irrigation if possible, and avoid working in fields when foliage is wet. Avoid excessive nitrogen fertilization. If applied preventively, copper-based bactericides may provide control under low to moderate disease pressure. Initiate sprays two weeks before bulbing and continue every 5-7 days thereafter. Deep cultivate after harvest to promote decomposition of crop debris. Where this disease occurs, a minimum three-year rotation to non-hosts is recommended.

*Wilt and dieback of onion leaves infected with Pantoea ananatis.*

*Bacterial decay of interior bulb tissue associated with center rot.*

Causal Agent:
*Pantoea ananatis* (syn. *Erwinia ananatis*), *P. agglomerans* (syn. *E. herbicola*)

Distribution:
Peru, Poland, South Africa and USA (Colorado, Georgia, Michigan and New York)

# ENTEROBACTER BULB DECAY

## SYMPTOMS:

The exterior of the bulb remains asymptomatic while the inner scales show a brown to black discoloration and decay.

## CONDITIONS FOR DISEASE DEVELOPMENT:

This disease was observed in mature bulbs in the field after a period where air temperatures had reached 40-45°C (104-113°F). The bacterium is common in many environments and is considered to be an opportunistic pathogen on onions.

## CONTROL:

No control measures have been reported.

*Bulb longitudinal-section showing infected internal scales.*

*Bulb cross-section showing infected internal scales.*

Causal Agent:
*Enterobacter cloacae*

Distribution:
Poland and USA (California, Colorado, New York, Utah and Washington)

# SLIPPERY SKIN

## SYMPTOMS:

Field symptoms often appear as one or two wilted leaves in the center of the leaf cluster. These leaves eventually turn pale yellow and dieback from the tip while older and younger leaves maintain a healthy green appearance. During the early stages of this disease, the bulbs may appear healthy except for a softening of the neck tissue. In a longitudinal section, one or more inner scales will look watery or cooked. The disease progresses from the top of the infected scale to the base where it can then spread to other scales, rather than by spreading crosswise from scale to scale. Eventually, all the internal tissue will rot. Finally, the internal scales dry and the bulb shrivels. Squeezing the base of infected plants causes the rotted inner portion of the bulbs to slide out through the neck, hence the name slippery skin.

## CONDITIONS FOR DISEASE DEVELOPMENT:

This bacterium requires moisture for infection and grows in the temperature range of 5-41°C (41-106°F). Severe disease can occur during periods of high rainfall combined with strong winds or hail. Heavy irrigation and persistent dews are also conducive to this disease. This bacterium is soil-borne and can be readily water-splashed to the foliage and necks where it can enter through wounds. As the plant matures it increases in susceptibility with the mature plant being highly susceptible. In warm weather, approximately 30°C (86°F), infected bulbs can decay within 10 days. However, in storage decay moves slowly, often requiring 1-3 months for a bulb to decay completely.

## CONTROL:

Harvest onions when bulbs have reached full maturity. Do not store bulbs until they have been properly dried. Minimizing stem and bulb injury and avoiding overhead irrigation when the crop is approaching maturity can reduce losses from this disease. Bulbs should be stored at 0-2°C (32-36°F) with adequate ventilation to prevent condensation from forming on the bulbs.

*Bulb cross-section showing collapse and shriveling of internal scales.*

Causal Agent:
*Burkholderia gladioli* pv. *alliicola* (syn. *Pseudomonas gladioli* pv. *alliicola*)

Distribution:
Worldwide

# SOUR SKIN

## SYMPTOMS:

Field symptoms often appear as one or two leaves that have turned a light brown color. A watery rot develops at the base of the leaves and proceeds into the neck, allowing the leaves to be easily pulled from the bulb. As the disease progresses the outer bulb scales are infected. However, the outer most bulb scales and inner bulb scales may not become infected, which distinguishes sour skin from slippery skin where inner bulb scales are infected first. Infected scales develop a slimy pale yellow to light brown decay and may separate from adjacent scales allowing the firm center scales to slide out when the bulb is squeezed. Infected bulbs often have an acrid, vinegar-like odor due to secondary invaders, especially yeasts, colonizing decaying bulbs.

## CONDITIONS FOR DISEASE DEVELOPMENT:

*Burkholderia cepacia* is commonly spread by heavy rains, overhead irrigation and flooding which splash the bacteria onto young or wounded foliage. Infection typically occurs through wounds including those made when onions are cut at harvest. Infection can also occur when water lands on upright leaves and flows into leaf blade axils carrying the bacterium with it. Sour skin is favored by rainstorms and warm weather, and develops rapidly at temperatures above 30°C (86°F).

Causal Agent:
*Burkholderia cepacia*
(syn. *Pseudomonas cepacia*)

Distribution:
Worldwide

## CONTROL:

The use of furrow irrigation, instead of overhead and recycled irrigation water, will reduce losses from this disease. Do not damage foliage prior to harvest or bulbs during harvest since *B. cepacia* enters the plant primarily through wounds. Onion crops should be harvested at maturity and the bulbs dried quickly. Storing onions at cool temperatures 0°C (32°F) with adequate ventilation to prevent condensation on the bulbs will reduce storage losses resulting from this disease.

*Cross-section through bulb showing separation of scales.*

*Light brown discoloration of infected inner leaves.*

*Yellowing of infected inner leaves.*

*Cross-section through bulb showing water-soaking of infected scales.*

*Longitudinal-section through bulb showing yellow brown discoloration of infected outer scales.*

# XANTHOMONAS LEAF BLIGHT

## SYMPTOMS:

Symptoms first appear as white to tan flecks, light-colored spots and/or lenticular lesions surrounded by water-soaking. Lesions rapidly enlarge, turning tan to brown with extensive water-soaking. As the disease progresses, lesions coalesce into dry necrotic areas of tip dieback. Typically, blighting of outer, older leaves leads to plant stunting and undersized bulbs. When conditions are favorable for disease, all leaves may become completely blighted and plant death may follow. Symptoms in leek, shallot, chives, and garlic are similar to those in onion but are less severe. Short-day onion varieties may develop symptoms at any stage of crop development, and long-day onion varieties usually develop symptoms during or after bulb-initiation.

## CONDITIONS FOR DISEASE DEVELOPMENT:

Disease is favored by temperatures above 26°C (80°F). Frequent rains and high humidity promote disease development. Severe outbreaks are often associated with heavy rain, hail and wind-blown sand that damages foliage. Symptoms usually appear 7-10 days later. Spread of the pathogen within and between fields occurs with both overhead and furrow irrigation and movement of residual onion debris by field equipment. *Xanthomonas axonopodis* pv. *allii* is also seed-transmitted. Frequent rains and overhead irrigation can initiate an epidemic from contaminated seed in semi-arid environments. The bacterium survives on contaminated seed, in infested crop debris and as an epiphyte or pathogen on volunteer onions, legumes and weeds.

## CONTROL:

Use only clean seed or transplants. Rotate to non-hosts for at least two years. Do not plant onion or garlic after dry beans, soybeans or alfalfa which may harbor this pathogen. Control volunteer onions and weeds in and around fields. During the growing season avoid overhead irrigation and excessive nitrogen fertilization. Copper bactericides alone or in combination with recommended fungicides can be effective in semi-arid regions when applied prior to the onset of symptoms. Incorporate crop debris into soil promptly after harvest

*Tip dieback in an infected onion field.*

*Lenticular lesions on an onion leaf.*

## Causal Agent:

*Xanthomonas axonopodis* pv. *allii*

## Distribution:

Brazil, the Caribbean, Japan, Reunion Island (France), South Africa, USA and Venezuela

# FUNGAL
## DISEASES

# BASAL ROT

## SYMPTOMS:

The first above ground symptoms are yellowing, curling and necrosis at the tip of leaf blades. With time, whole leaf blades show symptoms and eventually wither and decay. Infected roots are dark brown, flattened, transparent and sometimes hollow. When affected bulbs are cut vertically, they show a watery, brown discoloration of the outermost layer of the stem plate, which may progress up through the storage leaves. White mycelium of the fungus may colonize the stem plate and, eventually, roots may rot completely. Infected plants can be pulled easily because of their stunted, decayed root system. Infected bulbs may show no decay at harvest but may rot in storage.

## CONDITIONS FOR DISEASE DEVELOPMENT:

Optimum temperature for disease development is 27°C (80°F) and infection is limited when temperatures are below 15°C (59°F). Onion plants can be infected directly by the pathogen at any stage, but injury to the roots, the basal plate or bulbs by onion maggots or other insects appears to increase the incidence of this disease. The fungus can persist in soil as resting spores called chlamydospores for several years. Spread of this fungus often occurs by movement of infested soil on equipment, in irrigation water or on infected onion sets.

## CONTROL:

Growing varieties with tolerance to basal rot can reduce losses from this disease. Long term rotation with non-host crops for four years or longer may also help to reduce losses. Dipping seedlings in fungicide before transplanting can also reduce disease severity. Additionally, control of soil insects and foliage diseases, the use of healthy onion sets and avoidance of fertilizer injury all help to reduce basal rot losses.

*Foliar symptoms showing withering and necrosis of leaves.*

*Foliar symptoms and extensive root loss on infected seedlings.*

*White mycelial growth on the basal plate.*

*Bulb and basal plate rot.*

*Basal plate rot.*

Causal Agent:
*Fusarium oxysporum* f. sp. *cepae*

Distribution:
Worldwide

# BLACK MOLD

## SYMPTOMS:

Black mold generally develops at the neck of the bulbs on injured or necrotic leaf tissue. However, it can develop on injured or diseased roots, or on bruised or split outer scales along the side of bulbs. Infected bulbs may develop a black discoloration at the neck. Clusters of black spores generally form along veins and on or between the outer papery scales of bulbs. Infected tissue first has a water-soaked appearance and over time will dry and shrivel. No external symptoms may be visible on some infected bulbs. Soft rot bacteria can follow infection by this fungus.

## CONDITIONS FOR DISEASE DEVELOPMENT:

Spores of this fungus are very common in the air and soil. Black mold is most common when temperatures are higher than 30°C (86°F) in the field or 24°C (75°F) in storage. Free moisture for six hours or longer on the onion surface is necessary for infection to occur.

## CONTROL:

Fungicide applications to seeds, seedlings and bulbs may be helpful. Storage conditions should be cool and dry, and bruising of bulbs should be avoided.

*Black fungal spores are visible under the outer papery scales of the bulb.*

*Exposed black fungal spores under the outer papery scales.*

*Bulb longitudinal-section showing extensive infection of the scales (right).*

*Bulb longitudinal-section showing initial infection of scales at the bulb neck.*

Causal Agent:
*Aspergillus niger*

Distribution:
Worldwide

# BLACK STALK ROT

## SYMPTOMS:

Early symptoms of black stalk rot and purple blotch may be confused because they are similar in appearance. However, black stalk rot will eventually cover the infection site with a dense carpet of black spores. The affected areas generally progress along the length of leaves and flower stalks. Initially yellow then tan, these lesions later darken when spore production is at its highest. Seed stalks may become girdled and break before the seed matures. Surface infection of bulbs results in a black sooty appearance.

*Black spore production on a scape.*

## CONDITIONS FOR DISEASE DEVELOPMENT:

This fungus can infect and survive over a wide range of environmental conditions, causing the most severe damage in warm, humid climates. It generally attacks old, diseased, weakened host tissue and will often follow downy mildew.

## CONTROL:

The crop should be kept free from downy mildew, leaf blight and other diseases. Although chemical sprays can be effective, cultural control may also be achieved with proper plant spacing, fertilizer applications and irrigation to ensure the healthiest plant possible. Controlling insects such as thrips, which may injure the plant and provide access for the fungus, can be beneficial. Also, bulbs should not be bruised when harvested and should be properly dried before storage.

Causal Agent:
*Stemphylium botryosum* (teleomorph: *Pleospora tarda*)

Distribution:
Worldwide

# BLUE MOLD ROT

## SYMPTOMS:

First symptoms include pale yellowish lesions and watery soft spots. These affected areas are soon covered with characteristic blue-green spores. Fleshy scales may show water-soaking and a light tan or gray color when affected bulbs are cut open. As decay continues, bulbs may become soft and tough or may develop a watery rot. A musty odor is usually present.

## CONDITIONS FOR DISEASE DEVELOPMENT:

*Penicillium* spp. can be found in soil, on plant and animal debris or on senescing tissues. Infection of bulbs is usually through tissues damaged by bruising, freezing injury or sunscald. The pathogen grows well at 21-25°C (70-77°F) and under moist conditions.

## CONTROL:

A minimum of bruising and wounding of bulbs during harvest and prompt drying of harvested bulbs is recommended. Low temperature, approximately 5°C (41°F), and relative humidity are recommended for storage. Fungicide treatment of bulbs can be effective in controlling this disease.

*Lesion development on the side of a bulb.*

*Blue-green fungal sporulation develops within a lesion.*

Causal Agent:
*Penicillium* species

Distribution:
Worldwide

# BOTRYTIS BROWN STAIN

## SYMPTOMS:

This fungus generally is not capable of infecting healthy leaf tissue, but it can infect the outer scales of storage onions. Spores of the fungus germinate on onion leaves and produce enzymes that result in superficial flecking. When the fungus grows into the bulb scales, it causes a brown stain on the neck and outer scales. The leaf fleck and bulb stain are usually not regarded as economic problems.

## CONDITIONS FOR DISEASE DEVELOPMENT:

Leaf fleck may occur during periods of moist weather with moderate temperatures, 21°C (69°F). Brown stain may decrease during storage because of environmental conditions that do not favor disease development.

## CONTROL:

The fungus can survive as sclerotia in cull piles, therefore destroying cull piles will reduce this inoculum source. A fungicide spray program to control leaf blight and downy mildew should provide adequate control of brown stain. However, control measures are generally not required for the leaf flecking. Bulb scales that are discolored normally dry out during storage and fall off during handling, leaving the remainder of the bulb salable.

*Brown stain on the neck and outer bulb scales.*

*Superficial leaf flecking.*

Causal Agent:
*Botrytis cinerea*

Distribution:
North America and Europe

# BOTRYTIS LEAF BLIGHT

## SYMPTOMS:

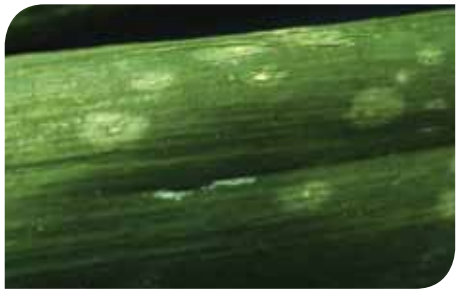
The fungus primarily attacks the leaves. The first symptoms begin as small white spots that are surrounded by a greenish halo. Centers of spots often are tan, making it difficult to distinguish between leaf blight and damage from insect feeding, mechanical damage or herbicide injury. Lesions expand with age and when numerous, may cause leaf tips to dieback. Eventually, leaf death results and severely affected onion fields develop a blighted appearance. Bulbs from infected plants may be small because growth is reduced by leaf loss.

## CONDITIONS FOR DISEASE DEVELOPMENT:

The fungus may over-winter in infected plant material or may survive in the soil as small, dark brown sclerotia. During moist periods with moderate temperatures, fungal spores are dispersed from sclerotia, infected leaves and debris to initiate infection. This disease can spread rapidly when environmental conditions are favorable for development.

## CONTROL:

A good preventive fungicide spray program is important. Disease forecasting systems have been developed for some areas and these are very useful for determining the optimum timing for sprays. Destroying onion or debris cull piles will help reduce sources of inoculum. Orienting plant rows and spacing to maximize air movement helps reduce the time that leaves are wet and results in less disease incidence and severity. Cultural practices such as deep plowing and crop rotation will help reduce numbers of sclerotia in the soil.



*White spots surrounded by a greenish halo.*

*White spots surrounded by a greenish halo.*

*Tan colored leaf spots.*

*Black sclerotia develop on an infected bulb.*

Causal Agent:
*Botrytis squamosa*

Distribution:
North America and Europe

# DAMPING-OFF

## SYMPTOMS:

***Fusarium* species -** The fungus may cause both pre- and post-emergence damping-off. Roots are invaded and eventually turn dark red or black as they decay. Seedlings are unthrifty and stunted, eventually turn yellow, wilt and die.

***Pythium* species -** Symptoms on young seedlings are similar to those caused by *Rhizoctonia*. A water-soaked lesion develops on lower stems and a watery rot occurs on the roots. The roots may turn black as they decay. The fungus can also attack seeds and cause a watery decay. Older plants that are infected are stunted and yellowing and wilting of leaves may occur during severe infections.

***Rhizoctonia solani* -** Seeds may rot before germinating and seedlings may decay before emergence. A brown rot develops on roots and lower stems at or below the soil line, and infected seedlings quickly wilt and collapse.

## CONDITIONS FOR DISEASE DEVELOPMENT:

The fungi that cause damping-off are usually common in an onion production field. These fungi generally survive for long periods in soil and may persist in plant debris or on roots of weeds. Damping-off tends to be most severe under conditions of high soil moisture and compaction. Moderate temperatures, especially when onion crops are grown in succession, favor this disease. In greenhouses, damping-off can be more common when improperly pasteurized soil or previously used seedling trays are used for planting. Water splash can move infested soil from diseased to healthy plants and spread this disease.

## CONTROL:

Crop rotation with cereal crops and soil fumigation or solarization may help reduce damping-off in fields. Improving soil drainage by using raised beds, and regulating soil moisture by avoiding excessive irrigation help to reduce disease. Good sanitation in greenhouses, including using sterilized planting trays and proper soil pasteurization, reduces damping-off. Onions are most susceptible between the flag leaf and first true leaf stage, especially under low light intensity. Therefore, reduced watering can lessen disease losses during this stage. Some fungicide seed treatments or soil drenches can help prevent serious damping-off.

*Damping-off caused by Fusarium species.*

*Damping-off caused by Fusarium species.*

*Root rot caused by Pythium species.*

Causal Agent:
*Fusarium* species, *Pythium* species, *Rhizoctonia solani* (teleomorph: *Thanatephorus cucumeris*)

Distribution:
Worldwide

# DOWNY MILDEW

## SYMPTOMS:

Typically the first symptom observed is the brownish-purple velvet-like sporulation of the pathogen on healthy green leaves. As the disease progresses lesions which are slightly paler than the normal leaf color, enlarge and may girdle the leaf. These lesions progress to a pale yellow followed by brown necrosis resulting in collapse of the leaf tissue. Infected seed stalks tend to remain pale yellow and, as with the foliage, are often invaded by other fungi, typically *Stemphylium* or *Alternaria* species. Field infections usually begin in small patches and progress rapidly throughout the field. Bulbs can be infected and may either rot in storage, or if planted, give rise to pale green foliage.

## CONDITIONS FOR DISEASE DEVELOPMENT:

The fungus survives in volunteer onion plants, onion sets, plant debris or in the soil. The fungal spores are disseminated onto plants by winds and splashing rain during cool wet weather, which is essential for disease development. Rain, dew or high humidity (>95%) is required for fungal spore germination and infection. The fungus grows internally and continues to produce spores as long as the weather remains cool and wet.

*Pale yellow lesions on scapes.*

## Causal Agent:

*Peronospora destructor*

## Distribution:

Disease occurs worldwide in temperate and cool growing regions.

## CONTROL:

A regular fungicide spray program based on climatic conditions can reduce crop losses. Avoid planting onion sets that are contaminated with the fungus. Eliminate plant debris and cull piles. Plant rows in the direction of the prevailing winds and use furrow irrigation rather than sprinkler irrigation. A 3-4 year rotation out of onions in areas where the disease is present can help reduce losses.

*Sporulation on an infected leaf.*

*Extensive foliar damage in the field.*

*Peronospora destructor infection may be followed by invading secondary organisms, often leading to plant collapse.*

*Symptom development on an affected scape.*

*Peronospora destructor sporulation on leaves.*

*Brownish-purple sporulation on healthy green leaves.*

# LEAF BLOTCH

## SYMPTOMS:

Leaf infection results in elongated lesions that develop parallel to leaf veins. At first, lesions appear as chlorotic areas but later turn brown. Weak, senescent tissue is more likely to be colonized by this fungus than healthy foliage and stalks. *Cladosporium allii-cepa* produces an abundance of brown to olive-brown spores giving affected tissues a dark, velvety appearance. As the disease progresses onion plants begin to die.

*Elongated leaf lesion.*

## CONDITIONS FOR DISEASE DEVELOPMENT:

Usually, this fungus is considered a weak pathogen infecting plants already weakened by wounds, adverse growing conditions or disease. The disease is spread by air-borne spores that land on the foliage and scales. Infection occurs over a wide range of temperatures and when humidity is high. However, free water can reduce conidial germination.

*Olive-brown fungal sporulation on a leaf.*

## CONTROL:

A healthy, vigorously growing plant rarely is infected by this fungus so proper fertilization, plant spacing and irrigation can prevent high disease incidence. In addition, disposing of onion debris by removal or plowing reduces fungal inoculum and disease incidence. Chemical sprays applied at regular intervals can effectively control leaf blotch.

Causal Agent:
*Cladosporium allii-cepa*

Distribution:
British Isles and Canada

# NECK ROT

## SYMPTOMS:

The growing crop seldom shows symptoms until harvest. However, this disease can be very destructive on stored onions. The fungus can invade the young healthy leaf tissue, but it usually infects the neck directly or through wounded tissue. This tissue becomes soft and spongy as the fungus continues to grow into the bulb. Affected parts of the bulb are brown and water-soaked, and the diseased tissue eventually collapses and becomes spongy. A white to gray mycelial growth eventually develops between the bulb scales and masses of small black sclerotia may develop on the outer scales around the neck. In addition to neck rot, *Botrytis allii* has been implicated in causing a soil-line rot. Other *Botrytis* species can also cause this disease. The fungus penetrates the outer scales of the bulb initiating a rot that is exacerbated by secondary invaders.

## CONDITIONS FOR DISEASE DEVELOPMENT:

Under prolonged wet conditions the fungus can sporulate on dead and decaying tissue in the field as well as from sclerotia. Wind readily disseminates these conidia to other plants where they can infect the neck of the plant through wounds or cuts. Disease spread is most rapid during moderate temperatures with high humidity, rainfall or overhead irrigation. The condition of plants at harvest is important since infection can be more severe if necks are still succulent. Also, storing uncured onions at temperatures and humidity that are too high can promote disease development and spread. Soil-line rot is often more severe when onions are transplanted and during cool, moist weather.

## Causal Agent:

*Botrytis allii* (teleomorph: *Botryotinia allii*)

## Distribution

Worldwide

## CONTROL:

Use varieties that are adapted to the growing area to ensure that the plants mature by harvest. Avoid excessive late season fertilizing, which may delay maturity. Adjust plant spacing and row orientation to obtain the best air movement through the plants. Avoid injury to the onion neck and damage to the bulbs, especially at harvest. Field applications of fungicides prior to harvest may reduce disease severity. Destroy onion cull and debris piles that may serve as a source of inoculum. Deep plow fields with a history of the disease to bury the sclerotia and rotate out of onions in these fields for several years. Be sure bulbs are cured and remove damaged bulbs before storage. Do not allow moisture condensation to form on the bulbs and use cool temperatures and moderate humidity for bulb storage.

*Bulb longitudinal-section showing early symptoms of neck rot.*

*Bulb longitudinal-section showing advanced symptoms of neck rot.*

*Soil-line neck rot development on a bulb.*

*Botrytis allii mycelia and sclerotia on a bulb.*

# PHYTOPHTHORA NECK AND BULB ROT

## SYMPTOMS:

Onion plants from small seedlings to the mature bulb stage may be affected. Initial above-ground symptoms include pale green leaves followed by yellowing and drying from the tips. Soon thereafter, the necks become soft and tops fall over, especially in younger plants. Internal symptoms include a watery soft rot of the neck interior that progresses into grey water-soaked tissue with a leathery texture below ground in young plants and into bulbs of more mature plants. Sunken white to grey leaf lesions occur, but are rare and generally do not extend into the neck region. Roots become necrotic only during later stages of disease development.

*Pale green to yellow leaves drying from the tips.*

*Tip dieback, watery soft rot of the neck interior and grey water-soaked leathery interior bulb scales.*

*Watery soft rot of neck interior and grey water-soaked leathery interior bulb scales.*

## CONDITIONS FOR DISEASE DEVELOPMENT:

Warm, wet conditions are conducive to disease development. Disease incidence is much greater in low spots in the field or areas near center irrigation pivots that remain wet for prolonged periods. Use of irrigation water from ponds receiving agricultural run-off water is a potential source of inoculum.

## CONTROL:

Resistant varieties are available. Avoid wet areas in the field and recirculation of field run-off water for irrigation. Fungicide applications in-furrow at time of transplant or as a plant drench after transplanting may reduce losses from this disease.

Causal Agent:
*Phytophthora nicotianae* (syn. *P. nicotianae* var. *parasitica* and *P. parasitica*)

Distribution:
Brazil and Taiwan

# PINK ROOT

## SYMPTOMS:

The term “pink root” reflects the most obvious symptom of this disease. Infected roots show a light pink color that become deeper pink or red with time and finally purple-brown as the roots shrivel and disintegrate. New roots may continue to form and then be killed by the fungus. Plants with severe infections appear to suffer from nutrient deficiencies or drought, and the leaves turn white, yellow or brown starting at the tips and eventually die. Leaf number and size are reduced and the plants are easily uprooted. Plants infected early in the season start bulbing prematurely and show more damage than those infected later. Note that the older roots of resistant cultivars will also display the pink color due to fungal infection as the roots senesce. However, resistant cultivars suffer very little loss of yield in the presence of the pathogen. Bulbs from infected plants are usually undersized and of reduced market value.

## CONDITIONS FOR DISEASE DEVELOPMENT:

The fungus is generally considered ubiquitous and can survive in the soil, in diseased roots and the debris of susceptible crops for several years. The fungus can be spread through soil movement and in surface water. This disease can develop at all soil moisture levels that allow onion growth. This pathogen will attack healthy crops in warm onion growing regions. Optimum temperatures for growth of the pathogen and disease development are 24-28°C (75-82°F). Little disease will develop when temperatures drop below 16°C (60°F).

## CONTROL:

Resistance to the pathogen varies among cultivars, thus resistant cultivars should be planted when possible. Resistance may be overcome if soil temperatures of 28°C (82°F) or higher occur. Planting so the bulk of the root growth occurs prior to reaching soil temperatures that favor disease development can minimize severe losses from this disease. Long term rotation (4-6 years) with non-host crops, such as cereals, helps reduce losses. Also, soil solarization or fumigation can help to reduce pink root and increase marketable bulbs.

*Leaf tip dieback is apparent on the infected plants in the foreground.*

*Infected roots turn reddish-purple in color.*

*Pink root-resistant bulb (left) and susceptible bulb (right).*

*Seedlings with severe root infection.*

Causal Agent:
*Phoma terrestris* (syn. *Pyrenochaeta terrestris*)

Distribution:
Worldwide

# POWDERY MILDEW

## SYMPTOMS:

Circular to oblong chlorotic lesions 5-20 mm (0.2-0.8 in.) in diameter develop on older leaves and rarely on younger leaves prior to bulb initiation. Sporulation gives lesions a gray to white powdery appearance. Chlorosis and eventually necrosis may develop around areas of sporulation. Lesions may coalesce to cover large areas of the leaf surface. This disease appears to be most common on varieties with glossy leaves, which are associated with thin cuticular waxes.

## CONDITIONS FOR DISEASE DEVELOPMENT:

*Leveillula taurica* overwinters in crop residue and many alternate hosts. Conidia are spread primarily by wind. Environmental conditions that favor infection include relatively warm temperatures and low relative humidity.

## CONTROL:

Following harvest, removal of crop residue, deep tillage and rotation to a non-host crop for at least one year will help eliminate the pathogen. Fungicide sprays to control this disease are available. Avoid excessive nitrogen fertilization and moisture stress.

*White fungal sporulation on several leaves.*

Causal Agent:
*Leveillula taurica* (anamorph: *Oidiopsis sicula*)

Distribution:
Brazil, Israel, Italy, Turkey and USA (California, Idaho, Utah and Washington)

# PURPLE BLOTCH

## SYMPTOMS:

Older leaves tend to be more susceptible than younger leaves. Symptoms begin as water-soaked lesions that usually have a white center. Edges of lesions become brown to purple and the leaf turns yellow above and below the lesions. With time, dark brown to black concentric rings form throughout the lesions. These are areas of sporulation of the fungus. As the disease progresses, lesions may girdle the leaf causing it to collapse and die. Similar symptoms occur on seed stalks and infected stalks can collapse resulting in shriveled seed development. When bulb infection occurs, it is normally through the neck. If the fungus invades the bulb, the infected area is initially bright yellow, but eventually turns a characteristic red wine color.

## CONDITIONS FOR DISEASE DEVELOPMENT:

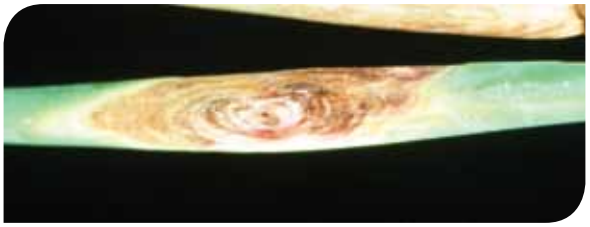
The fungus over-winters as mycelium in leaf debris and cull piles. Spores are formed during humid nights and leaf wetness periods greater than 12 hours. As the morning dew dries, spores become air-borne and are disseminated to susceptible onion tissue. 1-4 days are needed for symptoms to develop after infection. Disease development is greatest during prolonged periods of leaf wetness.

## CONTROL:

A fungicide spray program with broad spectrum protective fungicides applied prior to infection can provide good protection. Minimizing leaf wetness by using surface rather than sprinkler irrigation, good field drainage and correct plant spacing can reduce disease development. A rotation out of *Allium* to unrelated crops for several years can reduce disease as well.

*Brownish-purple leaf lesion.*

*Brownish-purple foliar lesions.*



*Expanding brownish-purple lesion showing concentric rings of sporulation.*

Causal Agent:
*Alternaria porri*

Distribution:
Worldwide

# RUST

## SYMPTOMS:

The disease first appears as small, circular, white to tan lesions along leaf veins. Lesions develop into orange to red circular or elongate uredial pustules that are often surrounded by chlorosis. Chlorotic leaf spots may also occur without further symptom development. When disease pressure is severe, leaves turn yellow and die prematurely. Dark brown teliospores may form in the pustules later in the season.

*Early infection in leek showing small white to tan lesions.*

*Uredial pustules with surrounding chlorosis on leek.*

## CONDITIONS FOR DISEASE DEVELOPMENT:

The fungus can survive as urediospores or teliospores. Wild *Allium* species serve as a source of inoculum from which urediospores are disseminated by wind over long distances. Infection is favored by cool to mild temperatures and high relative humidity (97 percent). Stressed plants are more severely affected by this disease than are healthy plants.

*Rust lesions with orange pustules.*

## CONTROL:

Routine application of fungicides adequately controls this pathogen when disease pressure is low. Disease incidence is reduced by cultural practices such as crop rotation, low planting densities, destruction of wild *Allium* species and cultivation for good soil drainage. Where appropriate, isolation of leek from onion crops may also reduce disease.

*Black granular pustules develop late in the growing season.*

*Foliar chlorosis and dieback in leek with severe Puccinia allii infection.*

Causal Agent:
*Puccinia allii* (synonym: *P. porri*)

Distribution:
Disease occurs worldwide in temperate and cool growing regions.

# SMUDGE

## SYMPTOMS:

The disease occurs late in the season as the crop matures and continues to develop on bulbs in storage. The fruiting bodies of the fungus turn from dark green to black as they mature, and form concentric rings around the neck and on the surface of dry outer bulb scales. If the humidity is high, the disease may spread to the inner scales, causing small, yellow lesions. If the disease continues to develop, the bulb may shrivel and sprout prematurely. Under warm, wet conditions this fungus can cause damping-off and leaf spotting.

*Concentric rings of fungal fruiting bodies form on the surface of bulb scales.*

## CONDITIONS FOR DISEASE DEVELOPMENT:

The fungus can over-winter in the soil and can be introduced on infected bulbs. Warm moist conditions favor conidial production and wind and rain splash spread the conidia. These conidia infect mature bulb scales and cause disease when free moisture and optimum temperatures [20-26°C (68-78°F)] for infection occur.

## CONTROL:

Yellow and red skinned varieties can be used in areas where disease pressure is high. The use of healthy transplants as well as crop rotation for several years out of white onions can reduce disease severity. Harvesting onions during dry weather and curing them quickly at the proper temperature and moisture can reduce disease incidence. Fungicide programs similar to those used to control neck rot and downy mildew can be effective against smudge.

Causal Agent:
*Colletotrichum circinans*

Distribution:
Worldwide

# SMUT

## SYMPTOMS:

Infected seedlings often die within six weeks of emergence. Dark areas can be seen first on cotyledons soon after their emergence from soil. On older plants raised, blister-like lesions can occur near the base of the scales, and large lesions cause leaves to curve downward. Streaks may develop within the leaves, leaf sheaths and bulbs. Mature lesions contain a black, powdery mass of spores. Infected plants are stunted as infection progresses inward from leaf to leaf.

## CONDITIONS FOR DISEASE DEVELOPMENT:

The fungus can over-winter as resting spores in the soil for several years. Spread of the fungus occurs through infected onion sets, transplants and when spores are transported by wind, equipment and water. Onion seedlings are susceptible to infection from just after germination until they reach the first true leaf stage. As each new leaf emerges it goes through a growth phase where it is susceptible to infection. After that growth phase, infection does not occur. Optimum temperatures for spore germination and growth are 13-22°C (56-72°F) while both are decreased above 25°C (77°F).

## CONTROL:

Chemical seed treatments can protect seedlings through the susceptible stage. In addition, any cultural practice that is favorable for rapid growth can shorten the susceptible stage of the onions. Healthy onion sets and transplants that are planted into infested soil may escape infection. A crop rotation out of onions for three or more years also reduces disease.

*Early symptoms of smut infection manifest as black streaks on leaves.*

*Infected seedlings showing dark streaks that contain masses of fungal spores.*

*Infected seedlings are stunted (one healthy seedling on the left and three infected seedlings on the right).*

Causal Agent:
*Urocystis colchici, U. cepulae* (syn. *U. magica*)

Distribution:
Worldwide

# SOUTHERN BLIGHT

## SYMPTOMS:

The fungus infects the outer scales of bulbs resulting in the development of white spot-like lesions. The infected bulb and neck tissues become soft and a watery rot develops. A white fungal growth often develops over the surface of the bulb scales, and mustard seed-sized light brown sclerotia form on the infected tissue, as well as in nearby soil and debris.

*Leaf dieback on infected plants in the field.*

## CONDITIONS FOR DISEASE DEVELOPMENT:

The pathogen has a wide host range and infects as many as 500 plant species besides onion. The fungus can survive for many years as sclerotia in the soil or for shorter periods in infected plant debris. It may spread from plant to plant in the root zone or through the movement of soil and water. Disease is most severe in warm [25-30°C (77-85°F)], moist soils that are high in organic matter. Fungal growth rapidly decreases below 15°C (59°F), resulting in little disease development.

*Mustard seed-sized light brown sclerotia on infected seedlings.*

## CONTROL:

Deep plowing of crop residue to bury sclerotia, soil fumigation or soil solarization may all help to reduce disease on subsequent crops. Crop rotation to cereals and grasses may help to reduce inoculum levels in soil. Post-harvest fungicide treatment of bulbs, as well as, storing bulbs at 10°C (50°F) or lower may help to limit storage losses.

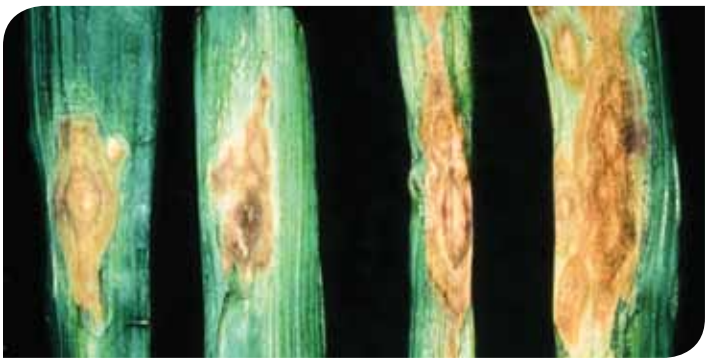
Causal Agent:
*Sclerotium rolfsii* (teleomorph *Athelia rolfsii*)

Distribution:
Worldwide

# STEMPHYLIUM LEAF BLIGHT

## SYMPTOMS:

Initial infections on the leaves and leaf sheaths are small, light yellow to brown, and water-soaked. As the lesions expand they coalesce causing extensive blighting of the leaves. Typically, lesions are found in higher numbers on the side of leaves facing the prevailing wind. The centers of lesions turn brown to tan, then dark olive brown and finally black as the fungus sporulates. Sometimes fruiting bodies called perithecia may appear in infected tissue as small, black, pinhead-like raised bodies. Symptoms of stemphylium leaf blight are very similar to those of purple blotch, which often results in misidentification.



*Dark brown to black sporulation on leaves.*

*Dark brown to black sporulation on senescing leaves.*

## CONDITIONS FOR DISEASE DEVELOPMENT:

Extended periods of leaf wetness from dew formation, rainfall or overhead irrigation during bulb formation and development can result in severe leaf blighting. Bulb size can be greatly reduced due to loss of foliage. Infection is usually limited to leaves and does not extend down to the scales of the bulb.

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## CONTROL:

Chemical control with fungicides is effective in reducing disease development. Long term rotation with unrelated crops may reduce losses. Also, good field drainage and reduced plant density may lessen disease severity.

Causal Agent:
*Stemphylium vesicarium*

Distribution:
India and USA, however, the pathogen may occur in other onion growing regions of the world.

# TWISTER

## SYMPTOMS:

Typically under field conditions leaves turn chlorotic, curl and twist resulting in an elongated neck and slender bulbs. Roots tend to be stunted and the plants may die. Small, white sunken lesions with dark, conidia-bearing structures may be present on leaves. When lesions are present, masses of pinkish orange conidia may develop. Up to 100% crop loss can occur when environmental conditions favor this disease.

## CONDITIONS FOR DISEASE DEVELOPMENT:

This soilborne fungus has a wide host range and survives in infected debris and on alternate hosts. Propagules are spread by rain, wind, irrigation water and insects. High humidity and temperatures between 23-30°C (73-86°F) favor leaf infection.

## CONTROL:

Hybrids with resistance are available. Cultivation practices reduce soilborne inoculum and fungicide applications also provide effective control.

*Young onion plant showing typical symptoms of twister caused by Colletotrichum gloeosporioides.*

*White sunken lesions with dark, conidia-bearing structures.*

Causal Agent:
*Colletotrichum gloeosporioides*

Distribution:
Worldwide, although only of significance in tropical and sub-tropical regions.

# WHITE ROT

## SYMPTOMS:

This disease can be one of the most damaging on onions with the first symptoms including yellowing, wilting and dropping of the older leaves. As the fungus invades the root system and basal plate it causes a rot, which eventually results in the collapse of the foliage. A soft rot gradually develops in the bulb and a thick white mycelial growth develops on the base of the bulb. Numerous sclerotia form on the diseased tissues. This disease usually appears on groups of plants in the field that are often widely spaced. However, large groups of plants may die suddenly when the fungus is abundant in the soil and conditions are favorable for disease.

## CONDITIONS FOR DISEASE DEVELOPMENT:

This disease is most severe in cool soils when soil moisture is favorable for root growth. The fungus can survive as sclerotia in the soil for many years and it can over-winter in infected onion debris and in diseased onion sets. Within rows this disease can spread laterally from root system to root system. The fungus is spread by movement of infested soil, infected onion sets and transplants.

## CONTROL:

White rot is difficult to control. Use healthy sets of plants and avoid introducing infested soil and water into the field. If the disease is just beginning in the field, removing and disposing of infected plants will help reduce the amount of the fungus in the soil. Spot treatments of soil with fumigants or fungicides may provide some control when the disease is limited in the field. Flooding, soil solarization and the use of natural and synthetic sclerotia germination stimulants have been shown to reduce sclerotia populations in the soil, and therefore may reduce losses from this disease.

*Localized plant death in the field.*

*Many small black sclerotia on an infected bulb.*

*White mycelia and small black sclerotia on mature bulbs.*

*White mycelia and small black sclerotia on bunching onions.*

Causal Agent:
*Sclerotium cepivorum*

Distribution:
Worldwide

# WHITE TIP

## SYMPTOMS:

Initial infection mainly occurs at the leaf tip and less frequently between the leaf tip and mid-leaf. Disease first appears as water-soaked spots that expand into lesions. Lesion margins remain water-soaked as affected tissue wilts and dries to the bleached white appearance for which this disease is named. When environmental conditions favor disease development, secondary lesions elongate to the base of the leaf. Crop losses are generally due to reduced plant weight in leek and storage rot of onion bulbs. Total crop loss may occur under severe disease pressure.

## CONDITIONS FOR DISEASE DEVELOPMENT:

*Phytophthora porri* oospores can survive for years in soil. High humidity and rainfall combined with low temperatures [15°C (59°F)] favor disease development. This disease tends to be more severe in fields with poor drainage. Once the disease is established, wind-borne and water-splashed sporangia and zoospores are easily spread.

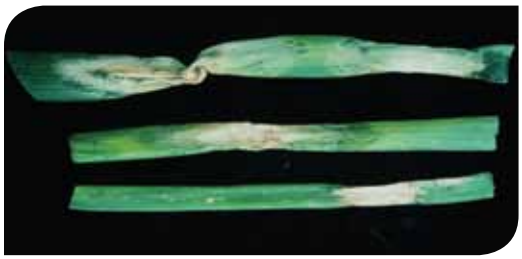
## CONTROL:

Avoid sprinkler irrigation. Rotation to non-host crops helps to reduce soil inoculum levels and losses from this disease. Some fungicides may be efficacious during early stages of infection.

*Severe disease development in the field.*

*Advanced leaf tip dieback.*

*Advanced leaf tip dieback.*



*Leaf lesions showing tissue collapse.*

Causal Agent:
*Phytophthora porri*

Distribution:
Worldwide

# YEAST SOFT ROT

## SYMPTOMS:

Symptoms are similar to those caused by soft rot bacteria. Diseased bulbs develop a soft, watery rot that tends to be confined to either the inner or outer fleshy scales and does not readily spread from scale to scale. When squeezed, fluid may exude from the neck of bulbs. Often, a large part of a bulb shows water-soaking and soft rotting.

## CONDITIONS FOR DISEASE DEVELOPMENT:

This fungus can survive in infected bulbs in cull piles or in onion field debris. It may be spread by fruit flies and other insects, and infection is thought to occur through wounds or natural openings in neck tissues. Temperatures between 20-30°C (68-85°F) favor development of this disease.

## CONTROL:

Bulbs should be harvested and handled carefully to reduce bruising and should be transported and stored at cool temperatures.

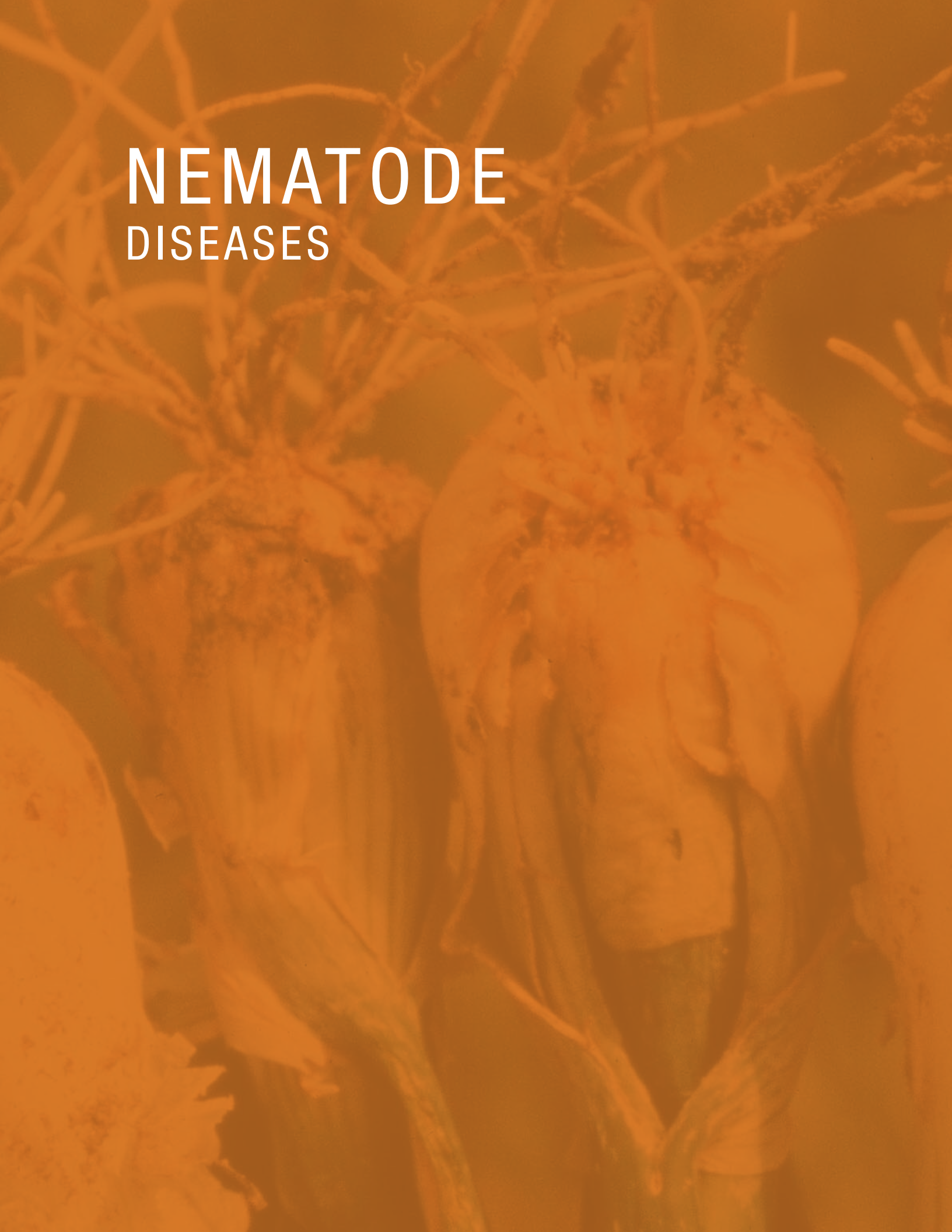
*Water-soaking of the inner bulb scales.*

*Extensive collapse and soft rotting of the inner bulb scales.*

Causal Agent:
*Kluyveromyces marxianus* var. *marxianus*

Distribution:
USA (Oregon and Washington)

# NEMATODE
## DISEASES



# LESION NEMATODE

## SYMPTOMS:

Infected plants are stunted and develop very few fine roots. Small, round to elongated lesions develop on roots. These lesions may be a cloudy yellow color initially, turning darker brown as the disease develops. Depending on disease severity, infected plants will grow poorly, produce low yields and show symptoms of water and nutrient deficiencies.

## CONDITIONS FOR DISEASE DEVELOPMENT:

Moderate soil moisture and temperatures from 20-30°C (68-86°F) favor growth and development of the lesion nematode. In certain areas a soil pH of 5.5-5.8 favors nematode development. Other factors such as soil type and organic amendments also affect development of the lesion nematode.

## CONTROL:

Soil fumigation and nematicide treatments offer the best control of the lesion nematode. Rotation with resistant crops such as oats or a summer fallow in hot, dry growing areas may reduce nematode populations.

*Root lesions caused by Pratylenchus penetrans.*

*Note nematodes feeding on root tip.*

Causal Agent:
*Pratylenchus penetrans*

Distribution:
Worldwide

# ROOT-KNOT NEMATODE

## SYMPTOMS:

Small, swollen galls 1-2 mm (0.06 in.) in diameter can be found on the roots when infected plants are carefully lifted from the ground and freed from soil particles without damaging the roots. Depending on the species causing infection, the shape of the galls can be round or spindly, and with or without short root branches that rise from the upper part of galls. It is often possible to see white to dark brown egg masses on the surface of the roots. Above ground symptoms may include stunting and yellowing that resembles water and nutrient deficiency and poor or irregular plant stands.

## CONDITIONS FOR DISEASE DEVELOPMENT:

Damage is more severe in sandy and muck soils than in clay soils. Temperatures for infection range from 10-35°C (50-95°F). However, *Meloidogyne* spp. are inactive above 40°C (104°F) or below 5°C (41°F). The nematodes are moved within and between fields by irrigation water or cultivation equipment, and can be introduced into fields in vegetative material such as bulbs and transplants.

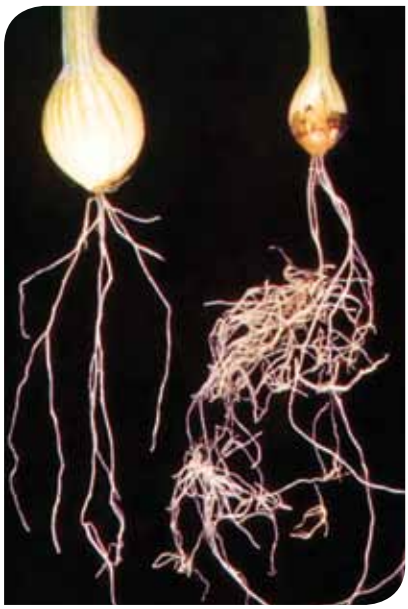
## CONTROL:

Soil fumigation, crop rotation to a non-host or a long fallow period helps to reduce populations of root-knot nematodes.

Causal Agent:
*Meloidogyne* spp.

Distribution:
Worldwide

*Root galls caused by Meloidogyne hapla.*



*Extensive branching of an infected root system. Healthy plant (left) and infected plant (right).*

*Stunting of infected plants in the field caused by Meloidogyne hapla.*

*Seedling root symptoms caused by Meloidogyne chitwoodi.*

# STEM AND BULB NEMATODE

## SYMPTOMS:

Infected young seedlings are stunted, pale and have swollen areas along the cotyledons. Leaves can develop yellowish-brown spots, can be short and thickened and stem swelling (bloating) can occur. As the disease progresses, the foliage collapses and the stems and necks of bulbs soften. The bulb scales become soft and light gray. Infected bulbs are light in weight, may be malformed or produce sprouts and double bulbs. Fungal and bacterial secondary infections are common and often give off a foul odor.

## CONDITIONS FOR DISEASE DEVELOPMENT:

New infections often come from nematode infested onion sets. Once the nematodes enter the seedlings they reproduce and migrate within or on the surface of plants. They can be spread by moving infested soil and debris, by rain and irrigation water and by farming equipment. Infected weeds and discarded onions often become the source of nematodes for the next crop. A soil temperature of 21°C (70°F) is optimum for nematode movement and symptom development, while free moisture favors nematode longevity and activity.

Causal Agent:
*Ditylenchus dipsaci*

Distribution:
Worldwide

## CONTROL:

To avoid introducing the nematode, check onion sets to verify they are disease free prior to planting. If the nematode is present in the soil, fumigation can give good control. Complete removal and destruction of cull piles, volunteer onions and host weeds are important for reducing this disease. Also, a four year crop rotation to non-hosts such as spinach, carrots, beets, crucifers, lettuce or grains has proven effective.

*Field symptoms, infected (left) and healthy (right).*

*Longitudinal section of a bulb showing infected basal plate.*

*Stem and bulb bloating.*

*Young plants infected by Ditylenchus dipsaci.*

# STUBBY-ROOT NEMATODE

## SYMPTOMS:

Plants are stunted, turn yellow or may be killed when infection occurs at the seedling stage. Infected root systems develop numerous stubby branches, often in clusters, as a result of nematodes feeding on root tips. Distinctive lesions are not visible; however, discoloration and necrosis will occur on infected roots due to secondary infections by other organisms. The stubby-root nematode is a strictly external feeder and therefore will not be embedded in root tissue like the root-knot nematode.

*Field symptoms.*

## CONDITIONS FOR DISEASE DEVELOPMENT:

The stubby-root nematode is active at soil temperatures between 20°C (68°F) and 35°C (95°F). Sandy and sandy loam soils favor its reproduction.

*Stubby-root symptoms, infected (left) and healthy (right).*

## CONTROL:

Treatment of infested soil with fumigants and nematicides reduces nematode populations. Flooding followed by soil drying can also decrease the population density. Long term rotation to resistant crops may give some control.

Causal Agent:
*Paratrichodorus allius*, *P. minor*

Distribution:
Worldwide


PARASITIC
PLANT

# DODDER

## SYMPTOMS:

Dodder is a parasitic plant that forms a yellow or orange thread-like vine that winds around the above ground parts of affected plants. These shoots produce pegs that penetrate into the plant to absorb nutrients. The vine spreads to adjacent plants as it continues to grow.

## CONDITIONS FOR DISEASE DEVELOPMENT:

Dodder has a wide host range, including many weed and crop species. It produces tiny flowers in clusters that contain thousands of small seeds. A few seeds will germinate the first year, but the remaining seeds lie dormant for many years before germinating. In the field, dodder emerges and twines around onion seedlings.

## CONTROL:

Dodder may survive as debris or seeds on or in the ground. It can also be introduced into fields via equipment and in irrigation water. Therefore, early removal of dodder along with infected plants is the best method of control. Burning crop residues and cleaning equipment thoroughly before moving it from dodder-infested fields to dodder-free fields help to control this parasitic plant. Herbicides and rotation to cereal crops may also provide control.

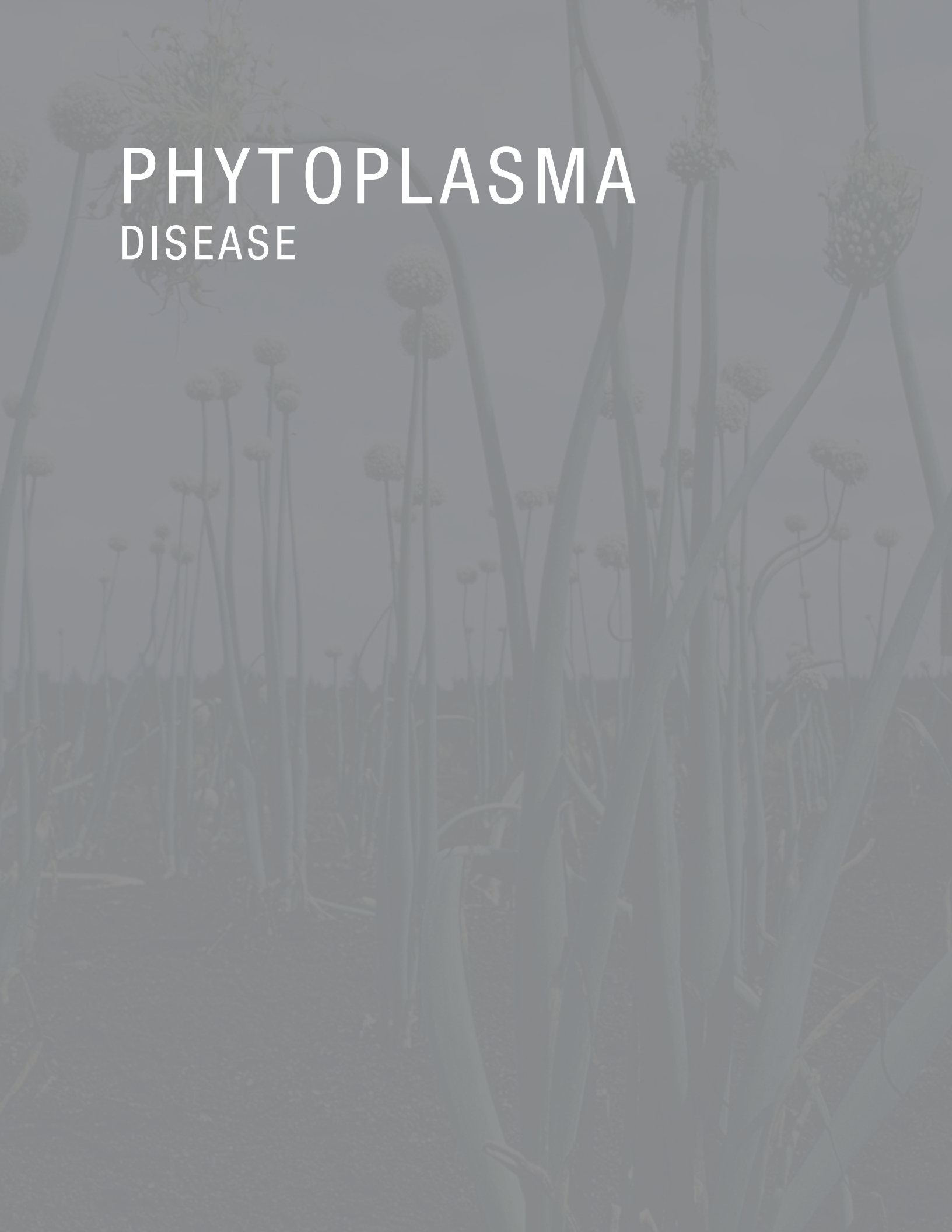
*Field infestation.*

*Dodder wrapped around onion leaves and scapes.*

*Flowering dodder.*

Causal Agent:
*Cuscuta* spp.

Distribution:
Worldwide



# PHYTOPLASMA
## DISEASE

# ASTER YELLOWS

## SYMPTOMS:

In bulb crops foliar symptoms begin as yellow and green streaks at the base of young leaves. Affected leaves will flatten and occasionally twist and intertwine. Eventually, entire leaves become yellow. In seed crops the umbel will have a star-burst appearance with elongated pedicels and distorted flowers. Occasionally, small bulbs will form in the flowers instead of seed.

*Foliar symptoms showing yellow and green streaks.*

## CONDITIONS FOR DISEASE DEVELOPMENT:

The aster yellows phytoplasma is transmitted during feeding by the aster leafhopper, *Macrosteles quadrilineatus*. Conditions that favor succulent plant growth may result in more leafhoppers being attracted to these plants and increase the incidence of this disease.

*Affected umbel showing elongated pedicels.*

*Severely affected umbel showing "star-burst" appearance.*

## CONTROL:

This phytoplasma can over-winter in adult leafhoppers, grains, weeds and ornamentals and therefore, a good weed and leafhopper control program can be effective in reducing the incidence of this disease. Isolating onion seed crops from other host crops and weed sources may also be effective.

*Aster yellows affected seed crop showing umbel distortion.*

Causal Agent:
The Aster Yellows Phytoplasma
(syn. The Onion Yellows Phytoplasma)

Vector:
The aster leafhopper (*Macrosteles quadrilineatus*), many other species of leafhoppers

Distribution:
Europe, Japan and North America

# VIRUS
## DISEASES

# IRIS YELLOW SPOT

## SYMPTOMS:

Infections remain localized and occur where thrips feed, resulting in an uneven distribution of the disease within the plant. Iris yellow spot virus (IYSV) can only be detected in or adjacent to lesions. Infected leaves are generally dull in appearance. Initially, lesions can be irregular to diamond-shaped and chlorotic to bleached white in color. Distinctive, defined borders may or may not develop as lesions elongate. Leaves dieback as lesions enlarge and coalesce. Lesions may completely girdle the scape and cause lodging before seeds mature. Infected onion plants usually produce undersized, asymptomatic bulbs. Infected leek plants are stunted.

## CONDITIONS FOR DISEASE DEVELOPMENT:

Onion thrips (*Thrips tabaci*) transmit IYSV in a persistent manner. Disease severity is positively correlated with thrips populations in the field. This virus is not seed transmitted. Over-wintering onions, volunteers from prior productions, infected transplants and alternate hosts can all serve as sources of both vector and virus. Bulb to plant transmission of IYSV has not been demonstrated in bulbs collected from infected plants.

## CONTROL:

All onion and leek varieties are susceptible to IYSV; however some varieties appear less susceptible than others. Many pesticides are available to help manage and control weeds, alternate hosts and the thrips vector. In addition, culled onions from packing operations should immediately be removed from the vicinity of all onion productions to provide further control of the thrips vector.

*Developing IYSV lesion.*

*Uneven distribution of IYSV lesions on scapes.*

*Irregular to diamond-shaped lesions on leaves.*

*Numerous IYSV lesions resulting from intense thrips feeding activity.*

Causal Agent:
*Iris yellow spot virus* (IYSV)

Vector:
Onion thrips (*Thrips tabaci*)

Distribution:
Worldwide

# LEEK YELLOW STRIPE

## SYMPTOMS:

Symptom expression can vary by type. In green leeks, leaves of infected plants develop longitudinal yellow stripes and plants appear yellow. In grey leeks, symptoms appear milder and stripes are grey-green. Generally, stripes are more prominent in older leaves. Leaf cuticles of infected plants are thinner than those of healthy plants, and the leaf surface is often rippled in appearance. Infected plants are stunted, lack vigor and may be more prone to frost injury than healthy plants.

## CONDITIONS FOR DISEASE DEVELOPMENT:

While principally a pathogen of leek, onion and garlic are also hosts of this virus. Because leeks are vegetatively propagated, leek yellow stripe may be spread through pruning and handling infected plants and bulbils. The virus is transmitted by many aphid species in a non-persistent manner. Cool temperatures and low light favor disease development. Early infections affect plants more severely than those that occur late in the growing season. Infected plants may recover under higher temperatures that favor growth of the host.

Causal Agent:
*Leek yellow stripe virus* (LYSV)

Vector:
Many species of aphids

Distribution:
Worldwide

## CONTROL:

Cultural practices that promote vigorous plant growth can help to reduce losses from this disease. Mechanical transmission is best managed by following proper sanitation practices during vegetative propagation. Rogue infected plants and control aphids to reduce incidence of LYSV. This virus is not seed transmitted.

*Longitudinal streaking in mature plants.*

*Longitudinal streaking in mature plants.*

*Note rippled areas of infected leaves.*

# ONION YELLOW DWARF

## SYMPTOMS:

Infected leaves have symptoms ranging from yellow streaks to complete yellowing. Leaves tend to flatten, crinkle, twist and bend over. Plants may be wilted and dwarfed and bulbs usually remain solid but do not reach their full size. In seed crops, plants produce smaller flower clusters and fewer florets.

*Foliar symptoms showing flattening and twisting of the leaves.*

## CONDITIONS FOR DISEASE DEVELOPMENT:

The virus is carried by infected seed bulbs, onion sets and volunteer onions. Many aphid species can transmit this virus from infected to healthy plants. Plants that are infected at a young stage may form small bulbs or fail to form bulbs, whereas plants infected during mid-season may produce slightly undersized bulbs.

*Foliar symptoms showing leaf streaking.*

*Foliar symptoms showing yellow streaking of the leaves.*

## CONTROL:

Some onion varieties are tolerant and can help reduce losses from this disease. The use of true seed for onion production results in virus-free plants since the virus is not seed-borne. The use of virus-free bulbs and sets, and producing crops in an area where the virus is absent are also effective. Roguing out infected plants helps to reduce the incidence of this virus.

Causal Agent:
*Onion yellow dwarf virus*

Vector:
Many species of aphids

Distribution:
Worldwide

# NON-INFECTIOUS DISORDERS

# BULB SPLITTING

## SYMPTOMS:

The first symptom observed is the splitting of the basal plate. Secondary growth of the affected bulb often occurs as one to several small bulbs protruding from the split basal plate.

## CONDITIONS FOR DISEASE DEVELOPMENT:

Uneven irrigation of onion fields increases the incidence of this disorder. Fields that are over-irrigated, allowed to dry completely and then over-irrigated again often have many split bulbs. This condition is more prevalent in areas of the field were stands are thin or uneven. These openings can provide an entrance for secondary microorganisms, which cause bulb decay. Bulb mites (*Rhizoglyphus* species) are frequently associated with bulb splitting. However, they have yet to be implicated as the causal agent.

## CONTROL:

Attention to seedbed prep, planting and the use of high quality seed will result in uniform stands, which will reduce this disorder. The maintenance of uniform irrigation and fertilization practices to prevent phases of rapid and slow growth of onion bulbs can reduce the incidence of this disease.

*Small bulbs protruding from a split basal plate.*

*Small bulbs protruding from split basal plates.*

Causal Agent:
Physiological

Distribution:
Worldwide

# FREEZE DAMAGE

## SYMPTOMS:

Affected seedlings become yellow at or near the soil line when temperatures are below freezing for prolonged periods. Upon freezing and thawing the soft tissues lose their integrity and become translucent and watery in appearance and texture. Freeze damaged scales become a grayish yellow color. Often, individual scales are injured entirely but adjacent inner and outer scales may or may not show freeze damage. The innermost sections of an onion may escape damage. However, the bulb may still be unmarketable.

*Cross-section of a bulb showing water-soaking of freeze-damaged tissue.*

## CONDITIONS FOR DISEASE DEVELOPMENT:

Freezing of onions becomes a problem at temperatures below -2°C (28°F). When soil is repeatedly frozen and thawed the plants can be heaved to the surface of the soil where they die from root damage and desiccation. Bulbs in the ground are less likely to be freeze damaged than those on the soil surface.

*Longitudinal-section of a bulb showing water-soaking of freeze-damaged tissue.*

## CONTROL:

Onion bulbs vary greatly in their ability to tolerate freezing temperature. Onions least tolerant to freezing are usually those lowest in solids such as the Grano types.

Causal Agent:
Environmental

Distribution:
Worldwide

# GREENING

## SYMPTOMS:

Sunlight causes the formation of chlorophyll in the outer scales, which results in the scales turning green.

## CONDITIONS FOR DISEASE DEVELOPMENT:

Excessive or late season nitrogen applications can delay maturity and enhance the greening of onion bulbs. Greening can occur if onion bulbs are exposed to sunlight during the growing season or the bulbs are allowed to cure for extended periods under moderate light.

## CONTROL:

An early fertilization program that promotes foliar development can reduce losses from greening at bulb maturity. Avoid excessive and late season nitrogen application. Do not cure bulbs for extended periods in the field.

*Green outer bulb scales.*

*Green outer bulb scales.*

Causal Agent:
Sunlight

Distribution:
Worldwide

# HERBICIDE INJURY

## SYMPTOMS:

Contact herbicides typically will cause chlorotic or necrotic spots. Multiple spots can result in deformed leaves as well as leaf curling. Systemic herbicides, those that are translocated in the plant, tend to cause a yellowing of the foliage. They may also cause necrotic spots and leaf curling.

## CONDITIONS FOR DISEASE DEVELOPMENT:

Generally, foliar damage occurs when herbicides are applied at excessive rates, at the wrong stage of plant growth or during unfavorable weather conditions. Injury often occurs from herbicide drift when crops or weeds adjacent to onions are sprayed. Damage from drift is usually most severe at the edge of a field closest to where a herbicide was applied, with injury decreasing with increasing distance from the source.

## CONTROL:

Use herbicides as directed and apply during appropriate weather conditions. Plants will frequently recover from foliar damage if it is not too extensive.

*Leaf tissue yellowing caused by glyphosate.*

*Leaf lesions caused by paraquat.*

*Leaf lesions and leaf curling caused by bromoxynil and oxyfluorfen.*

*Leaf lesions caused by oxyfluorfen.*

Causal Agent:
Herbicides

Distribution:
Worldwide

# LEAF VARIEGATION (CHIMERA)

## SYMPTOMS:

Leaf tissue is variegated resulting in tissues that have a normal green color being directly adjacent to tissues that are varying shades of yellow to white in color. Variegated tissue patterns may be mosaic or linear. The yellow to white tissue is deficient in chlorophyll and can result in abnormal or stunted plant growth when severe.

## CONDITIONS FOR DISEASE DEVELOPMENT:

This is a genetic abnormality and its expression and occurrence is unaffected by environmental conditions. This condition generally occurs on only a small percentage of the plants in a field.

## CONTROL:

Plant seed that is known to be free of genetic abnormalities.

*Foliar symptoms showing yellow leaf streaking.*

Causal Agent:
Genetic mutation

Distribution:
Worldwide

# NUTRIENT DISORDERS

## SYMPTOMS:

The following symptoms are indicative of nutritional deficiencies, however, soil and foliar fertilizer analyses should be conducted to verify nutritional needs:

***Nitrogen:*** Deficiencies result in stunted plants with pale green to yellow leaves that dieback from the tips. Also, the foliage tends to be erect and the bulbs are smaller than normal and mature earlier. Excess nitrogen causes rapid plant growth and delays maturity. The bulbs tend to be softer and more susceptible to storage rots.

***Phosphorus:*** Deficiencies result in slow growth, delayed maturity and a high percentage of thick necked bulbs at harvest. Leaves become a dull green color and dieback from the tips without the yellowing associated with nitrogen and potassium deficiencies.

***Potassium:*** Deficiencies result in the foliage initially becoming darker green and the tips of the older leaves begin to wilt, especially on the upper surface. Eventually the leaves droop and take on a satiny progressing to paper-like appearance and develop chlorosis similar to that caused by nitrogen deficiencies.

***Magnesium:*** Deficiencies result in slow plant growth with the older leaves becoming uniformly yellow along their entire length.

***Zinc:*** Deficiencies result in stunted plant growth with noticeable twisting and faint interveinal chlorosis of the leaves. Onions are very sensitive to zinc deficiencies.

***Molybdenum:*** Deficiencies result in poor emergence and seedling death. As the plant grows, leaves will dieback from the tip with a noticeable soft transition zone between the healthy and necrotic tissue. Onions are very sensitive to molybdenum deficiencies.

***Manganese:*** Deficiencies result in slow growth, delayed maturity and a high percentage of thick necked bulbs at harvest. The older leaves develop interveinal chlorosis, which progresses to a tip-burn, and they may curl and eventually become necrotic. Onions are very sensitive to manganese deficiencies.

***Boron:*** Deficiencies result in distorted and stunted plant growth. Leaves become brittle and may turn a gray-green to a blue-green color. Young foliage may be a mottled yellow green while older leaves become chlorotic with tip dieback and sunken areas. Transverse yellow lines that develop into cracking can occur near the base of the leaves.

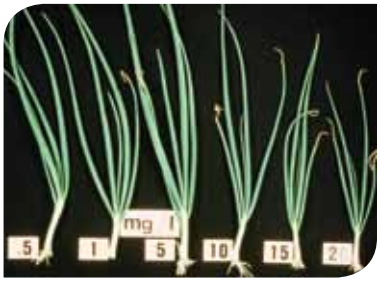
## CONDITIONS FOR DISEASE DEVELOPMENT:

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

## CONTROL:

Use a balanced fertilizer program. Soil and foliar nutrient analysis can give valuable information on nutritional deficiencies and excesses. Altering the soil pH and using foliar nutrient sprays can correct some deficiencies.

*Nitrogen deficient (left) and healthy (right).*




*Foliar response to increasing boron concentrations.*

Causal Agent:
Insufficient nutrients

Distribution:
Worldwide

# STORM DAMAGE

## SYMPTOMS:

Injury from wind, pelting rain or hail is usually visible only on the side of leaves that were facing prevailing winds during a storm. Spots develop that are typically 1-5 mm (0.06 – 0.2 in.) in diameter, white to yellow in color and round or irregular in shape. Although rain damage is rarely serious, hail damage may defoliate a crop. Storm damage may be confused with *Botrytis* leaf blight or herbicide injury and can also make plants more susceptible to fungal and bacterial pathogens.

*Foliar lesions caused by hail.*

## CONDITIONS FOR DISEASE DEVELOPMENT:

Raindrops, hailstones and soil particles blown by strong winds wound leaf, neck and flower stalk tissues.

*Foliar lesions caused by pelting rain.*

## CONTROL:

In areas that are subject to storms, seed cereal crops with onions to act as a wind break. Once the onion seedlings are established use selective herbicides to kill the cereal crop. Spray broad spectrum fungicides on storm damaged plants to reduce the risk of secondary infections.

Causal Agent:
Environmental

Distribution:
Worldwide

# SUNSCALD

## SYMPTOMS:

Sunscald is primarily a problem on young seedlings and mature bulbs. High soil temperatures damage seedling tissue at the soil line, resulting in shriveling and collapse of plants. On onion bulbs, affected tissue collapses and becomes bleached, soft and slippery. Affected areas dry and shrivel rapidly, and scales eventually become brown and necrotic. Soft rot organisms can invade and decay the bulbs if sun-scalded onions are not dried and cured rapidly.

*Affected tissue collapses and becomes bleached in appearance.*

## CONDITIONS FOR DISEASE DEVELOPMENT:

Direct sun can heat dark soils to temperatures as high as 65°C (149°F) resulting in tissue death at the soil line. Harvesting and curing onions in direct sunlight can result in sunscald on the bulbs.

*At the soil line affected tissue shrivels and collapses.*

## CONTROL:

Sow onion seed to avoid high soil temperatures when seedlings are succulent and most susceptible to sunscald. Onions can be cured in the field only after day-time high temperatures are below 29°C (85°F). If curing is done in the windrows, the tops of one set can be used to cover the bulbs of the previous set.

Causal Agent:
Direct sunlight and high temperatures

Distribution:
Worldwide

# THRIPS DAMAGE

## SYMPTOMS:

Thrips damage results from the piercing and rasping action of the cone-shaped mouth parts of the insect. At first, tiny, dark green spots appear on the leaf. These spots become white or silver with time and if widespread, can impart a silvery streaked appearance to the leaves, which will appear as a bright sheen in direct sunlight. Severely affected leaf tissues wither and collapse when plants are water stressed. Thrips are most commonly found between the newest growing leaves or in seed heads.

## CONDITIONS FOR DISEASE DEVELOPMENT:

Thrips over-winter in bulbs, as larvae or pupae in leaf litter or in the soil and on alternate hosts. The life cycle of these insects from egg to adult can be completed within two weeks. Thrips damage is greatest after periods of hot, dry weather. Cool, rainy weather reduces thrips populations and thrips damage.

## CONTROL:

Good crop management and sanitation generally keep thrips damage to a minimum. Healthy leaf tissue will endure thrips feeding better than stressed tissue. *Thrips tabaci* has a wide host range including numerous weed species; thus, weed control in and around an onion crop may reduce thrips levels. Also, cultivation and plowing to eliminate debris near the soil surface will reduce thrips populations. Insecticide control is feasible, however, several applications are usually required and resistance to insecticides has been reported.

*Thrips feeding on the leaf surface.*

*A high population of thrips feeding results in white-silvery spots and streaks on the foliage.*

Causal Agent:
*Thrips tabaci* (the onion thrips),
*Frankliniella occidentialis* (the western flower thrips) and numerous other species

Distribution:
Worldwide

# TRANSLUCENT SCALE

## SYMPTOMS:

Translucent scale typically appears after harvest and worsens after 3-4 months of bulb storage. The onion scales take on a grayish watery texture making them appear translucent. All scales can be affected, however, typically only the second and third fleshy scales exhibit symptoms. These symptoms are similar to freezing injury and can be distinguished from it only when it is known the bulbs were not subjected to cold temperatures. Also, frost damage occurs from the outside in, and opaque white tissues are often produced within frost damaged scales.

*Bulb cross-section showing the grayish watery texture of the scales.*

## CONDITIONS FOR DISEASE DEVELOPMENT:

Exposure to high relative humidity and high temperatures [32°C (90°F)] during the last several days of field curing onions can cause an increase in the incidence of this disorder. In addition, a delay of 2-4 weeks between field curing and cold storage of onions at 0°C (32°F) may also increase the incidence of this disorder.

## CONTROL:

Onion bulbs should be cured properly and stored at the appropriate temperature [0°C (32°F)] and relative humidity.

Synonym:
Physiological breakdown

Causal Agent:
Unknown

Distribution:
Worldwide

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# GLOSSARY

ABIOTIC: Of or pertaining to the absence of life, as in a disease not caused by living organisms.

ALTERNATE HOST: One of two species of host on which some pathogens, such as certain rust fungi, must develop to complete their life cycles; or, a species of host other than the principal host on which a parasite can survive.

AXIL: The upper angle between a lateral organ, such as a leafstalk, and the stem that bears it.

BACTERICIDE: A substance that kills bacteria.

BACTERIUM (PL. BACTERIA): A microscopic, single-celled organism lacking chlorophyll.

BASAL PLATE: The base of the stem where root growth is initiated.

BLIGHT: A sudden and severe necrosis of the above ground portions of a plant.

BULBIL: A small secondary bulb that forms in the angle between a leaf and stem or in place of flowers on certain plants.

CANKER: A localized, diseased area on roots or stems where tissue shrinks and cracks open.

CAUSAL AGENT: The organism or agent (bacterium, fungus, nematode, virus, etc.) that incites a given disease or injury.

CHLAMYDOSPORE: A thick-walled, asexual resting spore produced by some fungi.

CHLOROPHYLL: The green pigment used by plants in their food production process.

CHLOROSIS (ADJ. CHLOROTIC): The failure of chlorophyll development caused by disease or a nutritional disturbance; the fading of green plant color to light green, yellow or white.

COALESCE: To come together.

CONCENTRIC: Different size circles having a common center.

CONIDIUM (PL. CONIDIA): A fungal spore formed asexually.

COTYLEDON: The first foliar structure to emerge from a seed.

DAMPING-OFF: A rotting of seedlings at or below soil level.

DEBRIS: Remnant plant material.

DEFOLIATION: The loss of leaves.

DIEBACK: Progressive death of shoots, branches or roots, usually starting from the tip, as the result of biotic or abiotic factors.

DISTAL: Located far from the point of attachment.

DIURNAL: Occurring or active during the daytime.

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

ENDOGENOUS: Produced, living or undergoing development inside.

EPIDERMIS: The superficial layer of cells occurring on all plant parts.

EPIPHYTE: An organism (e.g. bacterium) growing on the surface of a plant, from which it gains physical and nutritional support, without causing disease.

FALLOW: Pertains to cropland not cultivated or not planted for one or more seasons.

FLORET: Small flower, usually part of a dense cluster.

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 or infected plants.

FUMIGATION: Sterilizing by fuming action.

FUNGICIDE: A substance that kills or inhibits the growth of fungi.

FUNGUS (PL. FUNGI): A microscopic organism with thread-like cells which lives on dead or living plants.

GALL: Swellings of roots, stems or leaves caused by abnormal growth of tissue.

GIRDLE: To encircle with dead tissue around a root or stem.

HERBICIDE: A 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 specified pathogen or pest pressure is severe. New and/or atypical strains of the specific pathogen or pest may overcome the resistance, sometimes completely.

HYPOCOTYL: The lower stem of a plant between the cotyledon and the roots.

INFECTION: The process by which an organism attacks a plant.

INFESTED: Containing great numbers 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 potentially infective agent available in soil, air or liquid that could be applied to a host either naturally or artificially to elicit a response.

INTERMEDIATE RESISTANCE: The ability of a plant variety to restrict the growth and development of the specified pest or pathogen, 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 tissue bordered by veins.

LENTICULAR: Shaped like a biconvex lens.

LESION: A well-defined but limited diseased area on a plant.

MOSAIC: The pattern of light and dark areas often caused by viruses.

MOTTLE: Irregular blotches of light and dark areas.

MYCELIUM (PL. MYCELIA): The mass of thin, microscopic, hair-like structures that forms the vegetative part of a fungus.

NECK: The part of an onion or leek plant just above the bulb. Consists of the lower portions of leaves and/or scape(s).

NECROSIS (ADJ. NECROTIC): The death of plant cells or tissue, usually accompanied by black or brown darkening.

NEMATICIDE: A substance that kills or inhibits nematodes.

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).

OPPORTUNISTIC: A pathogen that is naturally saprobic and often common, but on occasion able to cause disease in a host plant rendered susceptible by one or more predisposing factors.

PATHOGEN: An agent that incites disease.

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

PEDICEL: Small slender stalk; stalk bearing an individual flower, inflorescence or spore.

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

PHYSIOLOGICAL DISEASE: A disease (or disorder) produced by some unfavorable genetic, physical or environmental factor.

PHYTOPLASMA: An obligate, pleomorphic, single-celled organism lacking a cell wall.

PROPAGULE: Any part of an organism capable of initiating independent growth when separated from the parent body (e.g. fungal spore).

PUSTULE: The small blister-like elevation of epidermis formed as fungal spores develop and emerge.

RACE: A group of pathogens with distinct pathological or physiological properties.

RESERVOIR: Plants which are infected with a disease-causing organism and can serve as a source for further infection of other plants.

ROGUE: To remove and destroy undesired individual plants from a population.

SATURATION: Being completely filled with liquid, generally water.

SCALE: Fleshy basal leaf tissue that forms the layers of a bulb.

SCAPE: A peduncle, rising from the ground, naked or without leaves; a leafless flower stalk.

SCLEROTIUM (PL. SCLEROTIA): A hardened resting body produced by certain fungi.

SEEDBORNE PATHOGEN: An 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.

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 whose 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.

STRAIN: A general term referring to (a) an isolate; descendent of a pure culture of a 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 plants to restrict the activities of a specified pest or pathogen.

SYSTEMIC: Spreading internally throughout the plant

TELEOMORPH: The sexual form of a fungus. Sexual spores are produced after meiosis occurs.

TELIOSPORE: Thick-walled resting or over-wintering spore produced by the rusts (Uredinales) and smuts (Ustilaginales) in which karyogamy occurs; it germinates to form a promycelium (basidium) in which meiosis occurs.

TOLERANCE: The ability of plants to endure a specified pest, pathogen, environmental pressure or chemical stress. A tolerant variety will sustain less damage than a susceptible variety when grown under the same conditions.

TRANSLOCATION: The transfer of nutrients, chemicals or a virus through the plant.

TRANSLUCENT: Transmitting light but diffusing it enough to cause images to be blurred.

TRANSPIRATION: The loss of water vapor from the surface of leaves.

UMBEL: A type of inflorescence in which flowers are borne at the end of a common stalk forming a more or less flattened or rounded cluster; can be composed with subsets of umbels.

UREDINIOSPORE: Binucleate, dikaryotic (n+n), asexual, one-celled repeating or summer spore of rust fungi; borne in a uredinium.

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

VASCULAR: Referring to the conductive system of a plant composed of the xylem and phloem.

VECTOR: An organism able to transmit a pathogen.

VIRUS: Very small sub-microscopic disease-causing agent.

WATER-SOAKED: Tissue having the appearance of being soaked in water.

WINDROW: Leaves or other plant material swept or raked into rows to dry.

ZONATE: Distinguished from adjacent parts by a distinctive feature such as concentric rings.

ZOOSPORE: An asexually produced fungal spore bearing flagella and capable of locomotion in water.

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# NOTES

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