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Institute of Food and Agricultural Sciences

HS797

Vegetable Disease Recognition and Management - Florida Greenhouse Vegetable Production Handbook, Vol 3[1]

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The major emphasis of a plant disease control program for greenhouse vegetable production is on prevention. It is far more expedient to prevent the introduction of a plant pathogen than it is to control it once it is present. The major reason for this is that few fungicides have been or are likely to be labeled for use on vegetables in the greenhouse. Four main factors discourage fungicide manufacturers from pursuing vegetable labels: 1) greenhouse vegetable acreage is insignificant when compared to field production of the same vegetables (nationwide), hence there is no profit incentive for the manufacturers, 2) worker exposure and subsequent manufacturer liability is much higher for fungicides cleared for use indoors compared to the field, 3) pesticide formulations are more apt to be phytotoxic within the protected environment of the greenhouse than in the field, and 4) pesticide residues are apt to be higher in greenhouse vegetables than in field produce due to the absence of the eroding forces of the environment (e.g., UV light, rain, etc.). With many manufacturers hesitant to expend the registration cost for product use in such high liability and low profit sites, it is imperative for growers to prevent disease problems from occurring.

Disease prevention, like any other component of production, is hard work. As with all work tasks, it can be done either superficially or intensively. It is safe to say that the level of effort put into disease prevention will correlate with the level of yield obtained. An intensive and comprehensive disease prevention program is outlined below. This program makes the assumption that growers know what diseases they are trying to prevent. If this is not the case, then growers should contact the nearest County Extension agent and find out what diseases are likely on a particular vegetable crop. Growers in the area may also be helpful in outlining potential disease problems. On entering into production, growers should remember to record production information and disease outbreaks. If there is a question as to the identity of a disease, growers should contact the County agent for assistance. The Florida Extension

1. This document is HS797 and a part of SP48, a chapter of the Florida Greenhouse Vegetable Production Handbook- Volume 3, one of a series of the Horticultural Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Date first printed: December, 1990. Date revised: December 2001. Please visit the EDIS Web site at **http://edis.ifas.ufl.edu**.

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Plant Disease Clinic network is a tax-supported, minimal-charge diagnostic service available to all citizens of Florida who need disease determinations for any type of plant material. The County agent can assist the growers in accessing this service.

Preplant Sanitation for Disease Control

House Preparation. At the conclusion of the previous crop, workers should remove as much of the previous crop debris as possible. This debris must not be discarded in a dump pile adjacent to the production site because plant pathogens can overseason in plant debris. All houses should be cleaned of all fallen plant debris and surfaces cleaned free of soil, media, etc. Production systems that have had incidence of root and stem diseases should be rigorously sanitized. Hydroponic systems (sumps, plumbing lines, and 4-inch growing pipes) need to be thoroughly scrubbed with a suitable disinfestant. All production houses will benefit from the action of passive solarization during the noncropping period in summer. Structures can be sealed completely after wetting media, surfaces etc. The temperatures generated should exceed 130F and will assist in the eradication of pathogens and other pests in the production area.

Houses should be inspected for possible entry points of unsterile soil or insect vectors of plant viruses. All air intakes should be covered with insect-proof screens and soil-proof screens. Land adjacent to the production houses should be maintained by frequent mowing. Appropriate weed control is needed if weed populations include such vegetable weed relatives as ground cherry, nightshade, etc.

Media Preparation. Incidence of root or stem diseases should be carefully recorded if bag or media-filled trough systems are used. Infested bags should be discarded at the end of the season or immediately after plant death. Infested media in troughs should either be discarded or sterilized in place. If media is discarded, new media should be mixed upon disinfested concrete slabs to avoid exterior soil contamination. Trough structures should be thoroughly disinfested prior to being refilled. All troughs should be sterilized between crops depending on the house design, available sterilant products, and license status of the grower. In-ground (soil) production of vegetables in the greenhouse also requires sterilization between cropping seasons.

Water Source. Where persistent root/stem disease problems have occurred, a possible source of pathogens may be irrigation water. In Florida, shallow wells, ponds, ditches, or canals often support significant levels of plant pathogenic bacteria and fungi that can be introduced into a clean production system through irrigation. Water from deep wells (60 to 75 ft.) and city water are usually free of this risk of pathogen intrusion. Also sump location should be checked, since surrounding land should be pitched away so there is no possibility of back flushing soil into the sump during heavy rains.

Tool and Surface Cleanup. Tools used for pruning, media transport, pollinating etc., should be disinfested between cropping seasons. Soil fungi can survive in dried soil on tools between seasons just as certain viral and bacterial pathogens can survive on hand tools between crops. Areas destined to contact tools or transplants should also be treated with a disinfestant.

Transplant Production. Many growers prefer to produce their own transplants. Transplant production should utilize only new seed and flats, and new sterile media. Transplant quality is extremely important. Dropping one transplant onto unsterile soil can contaminate this plant with propagules of Pythium spp. (or other soilborne pathogens) that will result in a rapid and devasting root rot in a nutrient film system. Transplants should be produced in a separate greenhouse from ongoing crop production to minimize worker contact with these plants. Isolation of transplants will reduce the likelihood of disease spread from production areas. There are vegetable cultivars that are resistant to some strains of pathogens responsible for common diseases.

Production Sanitation for Disease Control

A number of recommended sanitation steps have been adopted by successful growers. Some of the more common ones are listed below:

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1. Addition of an 'air lock' type entrance to each production house so that workers, wind-carried insects, soil etc., do not enter the production area directly from the outside (Fig. 1)

Figure 1. Airlock entrance room for sanitation control and work room.

2. Use of foot baths to prevent unsterile soil from being carried into the production space (Fig. 2).

Figure 2. Foot bath used to restrict entrance of plant pathogens.

3. Restricted access by visitors to production and transplant houses. No one knows for sure where visitors have been prior to visiting your farm.

4. Raising transplants at a height of at least 1 foot above the ground to minimize dust or splashing soil contamination of plants.

5. Prohibition of cigar, cigarette, snuff, and chewing tobacco use by workers involved in production areas, so as to minimize contamination by viruses present in tobacco.

6. Rigid hand-scrubbing rules for personnel involved in pruning, pollinating, tying, or harvesting activities.

7. Filters on all air intakes to restrict air-blown soil and vector-insect entry (Fig. 3).

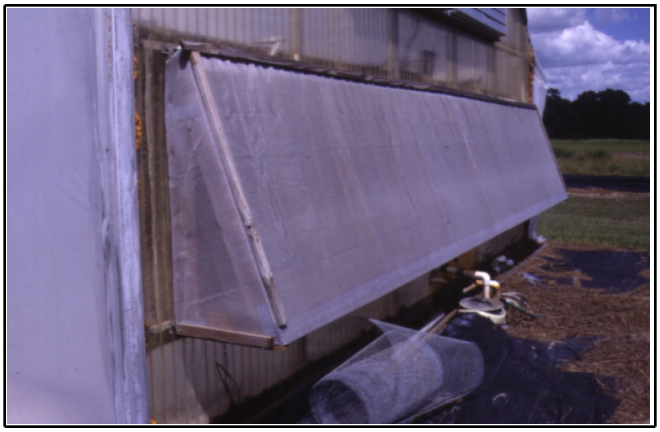

Figure 3. Screens on air intake surfaces to exclude insects that might carry virus.

8. Rigid vegetation control around the periphery of houses to avoid insect and pathogen buildup on weeds.

9. Periodic tool, walkway, and bench surface treatment with disinfestants.

Disease Diagnosis and Integrated Management

Production areas should be examined for the initial symptoms of disease during routine crop maintenance activities. The earlier a disease is found and identified, the more effective removal of infected plant parts will be to stop or slow disease progress. The more common diseases affecting greenhouse vegetables in Florida are described in the following

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text. A more extensive list of field diseases of these crops can be found in the Florida Plant Disease Control Guide. For help in disease identification, growers are urged to consult the nearest county Extension agent, patronize the Florida Extension Plant Disease Clinic network, or use some other private, commercial laboratory that specializes in disease diagnosis.

Cucumber

1. Damping-off. A young plant disease complex caused by a variety of soil fungi that includes *Pythium* spp. and *Rhizoctonia solani*. Damping-off can occur in transplant production or after setting plants into the production house. Typically, infected plants develop a soil-line lesion that causes the plant to topple over. The stem lesion may be shrunken and dry or waterand softrotted.

Control. Seed should be sown in preplanting media within clean trays or flats. Most commercially obtained seed is pre-treated with a fungicide like captan or thiram to prevent damping-off. Transplants should be grown physically apart from any crop production so there is no chance for pathogen movement from the old crop to the new crop. Growers should avoid excessive watering (favors *Pythium* spp.) or overdoses of fertilizer that may lead to plant root or shoot damage. Senescent or damaged tissue is more susceptible to certain foliar pathogens like *Botrytis cinerea*.

2. Pythium Root Rot. This disease is caused primarily by *Pythium aphanidermatum*, the same fungus that causes cottony leak on field-grown cucumbers. Cucumbers that are grown in hydroponic systems can become rapidly and uniformly infected with this fungus through the passive movement of the fungus through the nutrient solution. The pathogen is a water fungus that can be introduced through infected transplants, soil contamination of the nutrient solution, or directly via infested water. Since the pathogen is a water fungus, it spreads effectively through the recirculation system. In fact, the aqueous environment stimulates fungus reproduction and dispersal of a motile asexual spore stage. In addition, systems with poor aeration or high salt stress on root systems may predispose root systems to disease.

Typical symptoms start as a reduction in plant vigor, development of a progressive mid-day wilt, and the decay of the root system. Individual roots develop discolored areas that are soft-rotted such that the outer root layer (cortex) slips off between the fingers when pulled. Young plants may reach a stage of terminal wilt within two weeks while older plants may last longer depending on the fruit load.

Control. Growers must use only pathogen-free transplants. Nutrient film systems normally experience more disease severity than individual bag systems. Before setting plants into nutrient film systems, the system must be thoroughly cleaned after the last crop. A number of disinfestants are available for this purpose. The system should be inspected for possible points of entry of unsterile soil or poor quality water that may introduce *Pythium* spp. Observations indicate that nutrient film systems that pulse the solutions over the plant roots rather than have a constant immersion offer higher oxygenation and more tolerance to this disease. No fungicides are legal for this disease in the crop production greenhouse.

3. Sclerotinia Stem Rot. This disease is infrequent in greenhouses except in areas where vegetables in the field (e.g., crucifers, potatoes, tomatoes, and various weeds) become infected. This pathogen can infect fruit, leaves, and stems. It can be commonly observed as white, fluffy mycelia. Lesions that form can girdle stems or petioles killing distal plant parts. This pathogen (*sclerotinia sclerotiorum*) produces overseasoning, vegetative structures called sclerotia in or on infected tissue. These sclerotia are black, irregular in shape, and may reach 1 cm in length.

Normally, infection of greenhouse plants results from airborne sexual spores (ascospores) that are liberated from germinated sclerotia in infested fields in the area. These spores enter the greenhouse through air intakes, land on plant surfaces, and cause disease. In some cases, sclerotia will survive on the soil surface in production houses without permanent flooring, resulting in more serious disease.

Control. Since secondary spread of this fungus by airborne or waterspores is not a likelihood, sanitation is a very effective control option. It would

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be a good practice to prune out plant portions or entire plants where infection is evident. Growers should burn or destroy these portions since the sclerotia formed on or in this tissue will persist for years in composts, dump piles, etc.

4. Botrytis Blight - *Botrytis cinerea* infects all plant parts above ground during favorable weather. Disease can be expected when nighttime temperatures fall below 60F with relative humidity at 90% or higher. The *Botrytis* fungus infects many plants in Florida and the abundant spores are easily carried into greenhouses. Once infection has occurred, the fungus becomes internalized and can proliferate in spite of adverse temperature or relative humidity conditions. Stem lesions commonly develop that girdle individual plants. Leaftips and edges and young fruit often wither and the grayish-tan growth of the reproductive stage of the fungus develops. Wind currents, vibrations during tying, or condensation splash can all effectively spread the spores of this fungus throughout the greenhouse.

Control. Temperature and humidity (<90%) must be controlled to disfavor the fungus. Houses must be vented to lower humidity. Growers should prune off lower canopy to improve drying and air circulation. Workers should avoid pruning operations during overcast periods when new wounds may easily be colonized by *Botrytis*. Tissue should be pruned back close to the stem to avoid stubs that are easily colonized by this pathogen. Infected plant tissue should be sanitized for control.

5. Cucumber Mosaic Virus. This virus is primarily aphidinto cucumber plants in the greenhouse. The various aphid vectors do not retain this virus for more than a period of hours, such that disease spread is dependent on persistent weed host reservoirs of this virus in the area. Infection on young plants will develop within a week of aphid transmission while taking about two weeks on older plants. Temperature also affects symptom development, with symptoms developing faster between 79 to 89F than between 61 to 75F. Once established, the spread of this disease by mechanical means is possible but slow.

Symptoms include the appearance of mosaic patterns on new leaves; these leaves turn yellow with some withering along leaf margins. Leaf size is reduced, new leaves remain wrinkled, and fruit set is reduced or stopped. The virus also produces a random pattern of chlorotic blotches or ring spots on infected leaves. Infection that occurs on mature plants is often difficult to assess except on the newest growth since symptom development on older canopy is slow to develop.

Control. Growers must rogue out all symptomatic plants as soon as possible to reduce risk of spread. Adequate weed control must be maintained around the production area to eliminate possible weed reservoirs of this virus. Aphid populations should be minimized to restrict secondary spread of this virus within the greenhouse.

6. Downy Mildew. This disease is caused by the fungus *Pseudoperonospora cubensis*. Spores of the fungus are airborne and establish under conditions of leaf wetness on greenhouse plants. This pathogen can infect within a temperature range of 50 to 80F but the optimal temperature is between 61 to 72F. Three factors determine downy mildew infection; dew period, temperature, and concentration of asexual spores on the leaf surface. Under a constant spore concentration, disease can proceed from a 2-hour dew period at 68F, a 6-hour dew period at 59 to 68F, a 12-hour dew period at 50 to 68F, or a 24-hour dew period at 41 to 68F.

Early symptoms include a mosaic pattern of sorts as pale-green areas develop on leaves. These lesions are angular in shape and vein-delimited and during moist weather, the lower surface exhibits the purplish growth of fungus reproduction. Entire leaves can become blighted and significant canopy can be lost.

Control. Growers should minimize condensation development in the greenhouse that can provide leaf wetness for infection. Adjacent areas should be kept free of wild or cultivated cucurbits that may act as reservoirs for this fungus. Resistance and tolerance to this pathogen is available in some cultivars. No fungicide control measures are available for greenhouse use.

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7. Gummy stem blight - This disease is caused by the fungus *Phyllosticta citrullina (Mycosphaerella citrullina*) and the organism can be seed-borne and can survive in crop debris. The disease usually begins at the crown of the plant or along the stem where lesions are brown, turning white with age, and often exude a copper-colored sap. The organism soon attacks the leaves where lesions are irregular in shape and dark brown with faint zonation. The organism eventually attacks the cucumber fruit sometimes with only a blackened lesion on the blossom end. Often the lesion will be on the interior of the blossom end barely detectable from the outside. In severe disease outbreaks, the fruits are subject to a rapid rotting, even while still on the vine.

Control. The first line of defense is to plant disease-free seed and to make sure greenhouses are sanitized completely between cucumber crops. Strict sanitation must be practiced during the growing season, removing diseased leaves, plants, or fruits. Ventilation is important to keep plants dry, especially during wet weather. Horizontal air-flow fans should be used to move air about in the greenhouse and plants should be pruned properly to enhance air movement. There are no labeled fungicides with great effectiveness against this organism in Florida.

Lettuce

1. Damping-off. Seedling loss in lettuce can be caused by a variety of fungi including *Pythium* spp. and *Rhizoctonia solani*. Affected plants exhibit a soil line stem canker that produces seedling death. Seedling damage is rapid and usually results from the introduction of fungal propagules into the growth medium.

Control. Growers should sow seed in preplanting media within clean trays or flats. Transplants should be grown physically apart from any crop production so there is no chance for pathogen movement to the new crop. Growers must avoid excessive watering (favors *Pythium* spp.) or overdoses of fertilizer that may lead to plant root or shoot damage. Senescent or damaged tissue is more susceptible to certain foliar pathogens like *Botrytis cinerea*.

2. Botrytis Blight - *Botrytis cinerea* can infect lettuce under conditions similar to those surrounding cucumber or tomato infection. Although infection can occur between temperatures of 32 to 96F, the optimum temperature for rapid infection is between 69 to 75F. High relative humidity is required for infection, with percentages above 90% favoring fungus germination and infection. The fungus is readily airborne or waterwithin the environment. The fungus is hosted by a wide range of weed and crop species and can persist in plant debris in the field almost indefinitely.

This disease can occur on seedling lettuce, starting on leaves or stems and producing a damping-off. Infection on older plants can begin with leaf infection that proceeds downward through the petiole to the stem. Often, infection will begin with lower, senescent leaves or those damaged by salt burn or other pathogens. Infection moves quickly to the lower stem and causes a head decay from the center outward. Affected tissues develop a soft brown rot that is rapidly covered with an ashen-gray layer of fungal mycelium and spores.

Control. This disease can be prevented from occurring by controlling production conditions to avoid senescent leaf tissue. A fungicide program and correct production conditions that reduce condensation splash within the greenhouse should be instituted. Fans should be used to keep air circulating, especially at day's end to lower relative humidity below 90% and dry leaf tissue before the dark hours. Infected material should be sanitized carefully to remove the fungal inoculum from the greenhouse.

3. Pythium Root Rot. Various *Pythium* spp. can infect the roots of lettuce in the hydroponic production system in much the same way as with cucumber and tomato. The introduction of these fungi during transplant production, or directly into the nutrient film via infested soil or water can result in dramatic disease development. Affected plants develop a wilt symptom, that lengthens with each passing day until plant death. Plant color lightens while lower leaves will demonstrate marginal to interveinal chlorosis and necrosis prior to plant collapse. Roots lose their healthy, white color and develop a water-soaked, light tan appearance. The

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outer root layer (cortex) loses its integrity and can be stripped off between two fingers.

Control. Growers must use only pathogen-free transplants. Nutrient film systems normally experience more disease severity than bag culture systems. Before setting plants into nutrient film systems, growers should make sure system has been thoroughly cleaned since the last crop. A number of disinfestants are available for this purpose. The system should be inspected for possible points of entry of unsterile soil or poor quality water that may introduce *Pythium* spp. Observations indicate that nutrient film systems that pulse the solutions over the plant roots rather than have a constant immersion offer higher oxygenation and more tolerance to this disease. No fungicides are legal for this disease in the greenhouse.

Tomato

1. Aphid-borne Viruses - Several viruses like tobacco etch virus and cucumber mosaic are aphid-transmitted to the tomato plant during a brief feeding period by the insect. When virus susceptible weeds and crops exist in the area, aphids may acquire these viruses and migrate into greenhouses where transmission occurs. Etch infected plants develop an upward cupping of terminal leaflets while petioles turn downward. Plants exhibit mottling, vein-clearing and stunting. Cucumber mosaic-infected plants exhibit stunting, shoestring-like leaves, cessation of fruit set, and malformed older fruits.

Control. Plants with distorted foliage and leaf cupping, should be rogued from the greenhouse to reduce risk of mechanical disease spread. Adjacent vegetation around greenhouses should be removed to eliminate virus weed hosts and feeding sites for aphids. Growers should pursue aphid control measures to reduce populations of these vectors in the greenhouse.

2. Bacterial Wilt. This disease is caused by the soilborne bacterium, *Pseudomonas solanacearum.* This bacterium enters the production site through the movement of contaminated soil or via the transplants. This pathogen is common in land previously cropped to solanaceous vegetables and certain other crops, but has also been found in previously uncropped soil.

Initial symptoms often occur as the first or second fruit cluster gains size although younger plants can also be affected. A progressive mid-day wilt develops until the plant does not recover. Leaves seldom exhibit any yellowing during the wilt phase. When the lower stem is slit lengthwise, the vascular elements and pith areas appear dark brown and slimy. Root systems of affected plants are markedly reduced in size and exhibit vascular discoloration, external browning, and decay. A reliable diagnostic test for the greenhouse is bacterial streaming, where a 2- to 3-inch stem section is cut from the lower stem and suspended in a glass or clear bottle of water for about 30 seconds. When the glass is held up to the sun or a light source, milky white streams of bacteria can be seen as they emerge from the cut stem surface.

Control. NFT crops can be totally lost to bacterial wilt since the bacterium moves readily through water, infecting plants easily through natural wounds in roots formed during lateral root emergence. No chemical controls are available for this disease. NFT systems will require thorough cleaning with a disinfectant. After crop production is finished, sealing and heating the greenhouse by summer radiation will reduce bacterium survival.

3. Botrytis Blight - *Botrytis cinerea* infects all plant parts above ground during favorable weather. Disease can be expected when nighttime temperatures fall below 60F with relative humidity at 90% or higher. The *Botrytis* fungus infects many plants in Florida and the abundant spores are easily carried into greenhouses. Stem lesions commonly develop that girdle individual plants (Fig. 4). Leaflet tips and edges often wither and the grayish-tan growth of the reproductive stage of the fungus develops (Fig. 5). Wind currents, vibrations during pollination, or condensation splash can all effectively spread the spores of this fungus throughout the greenhouse. Green or ripe fruit can be infected (usually at the stem end) where a velvety-gray fungal growth becomes obvious. When weather conditions change rapidly, *Botrytis* infections may abort producing a white, ring“ghost spot” on the green fruits.

Control. Growers must control temperature and humidity to disfavor the fungus (>70F and <90%RH). Houses can be vented to reduce humidity.

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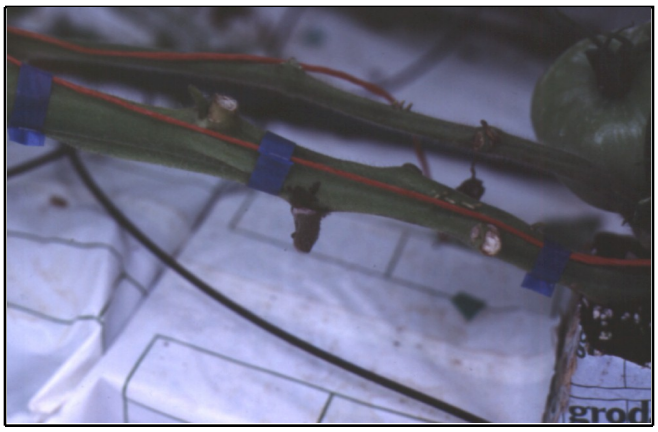

Figure 4. Botrytis (gray mold) on tomato leaf scars; due to improper leaf removal.

Figure 5. Botrytis (gray mold) on tomato leaves.

Supplying plants with adequate calcium will reduce plant susceptibility to this fungus. Workers should avoid pruning operations during overcast periods when new wounds may easily be colonized by *Botrytis*. Tissue should be pruned back close to the stem to avoid stubs that are easily colonized by the *Botrytis* fungus. Growers need to sanitize infected plant tissue and utilize recommended fungicides.

4. Cladosporium Leaf Mold. Leaf mold disease occurs during conditions favorable for *Botrytis*. Lush foliage and close plant spacing also favor this disease by trapping high humidity pockets between plants, favoring infection. Early symptoms develop as a grayish-to-yellow green spot on the upper leaf surface. Within days an olive green-to-brown fungal growth develops on the leaf underside. Spores of this pathogen, *Fulvia fulva* (*Cladosporium fulvum*), are disseminated easily by air currents or on worker's clothing.

Control. Low humidity conditions, below 85% and fungicides are used to contain this disease. A number of greenhouse tomato varieties offer resistance to some strains of this fungus.

5. Damping-off. A young plant disease complex caused by a variety of soil fungi that include *Pythium* and *Rhizoctonia* spp. Damp-off can occur in transplant production or after setting plants into the production house. Typically, infected plants develop a soil-line stem lesion that causes the plant to topple over. The stem lesion may be shrunken and dry or water-soaked and softrotted.

Control. Seed should be sown in presterilized planting media within clean trays or flats. Transplants should be grown physically apart from any crop production so there is no chance for pathogen movement to the new crop. Excessive watering (favors *Pythium* spp.) or overdoses of fertilizer that may lead to plant root or shoot damage must be avoided. Senescent or damaged tissue is more susceptible to certain foliar pathogens like *Botrytis cinerea*.

6. Early Blight. This foliar disease is likely the second most common foliage disease on field-grown tomatoes in Florida. The causal fungus, *Alternaria solani*, can infect tomato and potato commonly in the field. All above-ground portions of the plant are susceptible with early symptoms first appearing on lower, inner canopy. Young lesions are brownish-black expanding beyond 1/4 inch in diameter and developing a zonate appearance with slight chlorosis. Similar lesions can develop on stems and can enlarge to a point of girdling main stems. Fruit spots are rare in greenhouse production but can develop on the shoulders or calyx-end of the fruit. Lesions develop a velvety-black appearance from the sporulation of the causal fungus. Spores of the fungus are windor water splashed into the greenhouse and among plants within the production house. Spores of this fungus germinate in 1.5 hours on a wet leaf in temperatures between 47 to 90F. Infection of the plant may take as much as 12 hours at 50F, 8 hours at 58F, or 3 hours at warmer temperatures. Lesion development to the point of fungus reproduction requires 5 to 7 days.

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Control. Growers should remove severely affected canopy to decrease the inoculum of the causal fungus. Conditions of condensation in the greenhouse that will provide leaf wetness for infection should be minimized. High fertility levels may lessen plant susceptibility to this fungus. Fungicide controls are available for this disease in the greenhouse.

7. Erwinia Rot. The soft rot bacterium, *Erwinia carotovora* pv. *carotovora*, can cause a localized stem decay and soft rot of fruit in the greenhouse. This disease is minor and often confined to areas in the greenhouse where there is excessive water splashing, condensation, etc. The bacteria enter pruning wounds and will cause a light tan-to-greasy black canker of stems or petioles. Affected stems will be hollow for some distance from the point of infection. Usually there is a foul odor associated with the decayed tissue. Bacteria can splash to fruit and enter stem scars or cracks causing a similar decay. Affected fruit resemble water-filled balloons.

Control. All infected tissue should be removed from the greenhouse to eliminate spread. Pruning should be done prior to tying, suckering, pollinating, or harvesting activities that can spread this bacterial pathogen. Relative humidity and temperature should be managed to prevent condensation that will splash the causal bacteria from plant to plant in the greenhouse. Plants should not be handled when wet. No chemicals are available for use with this disease.

8. Fusarium Wilt. Fusarium wilt is a field disease of 'old land.' This soilborne fungus (*Fusarium oxysporum* f.sp. *lycopersici*) exists in Florida as three races (biotypes) but is infrequently seen in greenhouse production since gross contamination with infested soil is needed to initiate disease. Initial symptoms include slower growth, development of mid-day wilt, and the progressive yellowing of older, lower leaves. Affected plants may exhibit symptoms in one stem only or develop wilt and/or chlorosis in the leaflets on one side of a leaf. When infected plants are sliced lengthwise at soil line, *Fusarium*-infected plants exhibit vascular browning but no pith decay as with bacterial wilt. Infected plants gradually die.

Management. Where this disease has occurred, thorough sanitation must be performed prior to the next crop. Hydroponic systems must be rigidly disinfested with suitable materials. Bag culture growers can either discard infested bags or fumigate with suitable materials. No fungicides exist that offer curative control of this problem. Fumigation can be effective in greenhouses where ground-grown tomatoes are produced if done properly and not subsequently contaminated. Resistance is known to Race 1 and 2 of this pathogen but is not presently available to Race 3.

9. Pythium Root Rot disease is primarily restricted to recirculating hydroponic production systems (Fig. 6). The causal fungus, *Pythium* spp., is a water fungus that can be introduced through infected transplants, soil contamination, or pathogen contaminated water. Since the pathogen is a water fungus, it spreads rapidly and extensively through the circulation system. Typical symptoms start as a reduction in plant vigor, development of a progressive mid-day wilt, and the decay of the root system (Fig. 7). Individual roots develop discolored areas that are soft rotted such that the outer root layer (cortex) slips off between the fingers when pulled. Young plants may reach a stage of terminal wilt within two weeks while older plants may last longer if fruit loads are not high.

Figure 6. Wilted tomato plants from Pythium root rot in a recirculating hydroponic system.

Management. Growers must use only pathogen-free transplants. Nutrient film systems normally experience more disease severity than bag systems. Before setting plants into nutrient film systems, growers must make sure system has been

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Figure 7. Root system of a tomato plant damaged by Pythium root rot.

thoroughly cleaned since the last crop. A number of disinfestants are available for this purpose. The system must be inspected for possible points of entry of unsterile soil or poor quality water that may introduce *Pythium* spp. Observations indicate that nutrient film systems that pulse the solutions over the plant roots rather than have a constant immersion offer higher oxygenation and more tolerance to this disease. No fungicides are legal for this disease in the greenhouse. Growers experiencing problems with this disease are encouraged to investigate a nonproduction system, such as peat bag, perlite, or rockwool.

10. Sclerotinia Stem Rot - Sclerotinose disease (timber rot) is caused by the soilborne fungus *Scierotinia sclerotiorum*. This fungus has a wide host range that includes numerous weeds and crop species, especially cabbage and related plants. The fungus survives as mycelium in living or dead plant tissue and as sclerotia (black, irregularly shaped vegetative propagules up to 1 cm in length) in the soil. These soil sclerotia may survive for many years in Florida and give rise to sexual, airborne spores that enter air intakes into greenhouses. This sexual stage must infect within 2 days or the spore dies. Although this fungus can invade tomato tissue at temperatures ranging between 32 to 82F, the optimal temperature for disease is between 60 to 70F.

Symptoms of Sclerotinose usually occur at soil line, at points of injury, or at crotches between main stems or lateral branches. Early infection appears as a water-soaked area that may develop into a soft rot or dry to a light to dark brown canker. Under moist conditions, a mass of white mycelium will develop, followed by the sclerotia on and in infected pith tissue. Plant parts distal from infection sites will die back. Secondary spread is limited to direct fungus contact between adjacent plants.

Management. Use of forced air and heat will lower humidity and prevent leaf wetness which is a prerequisite for fungus invasion. Sanitation of infected plant parts or of entire plants will effectively prevent any plant to plant spread in the greenhouse. Infected plant parts must be judiciously destroyed because of the highly persistent sclerotia formed on and in the tissue. Infected plants in bag culture should be removed and bags fumigated prior to reuse. Labeled fungicides can be used as part of the disease control program.

11. Target Spot. This disease is caused by the foliar fungus *Corynespora cassiicola*. The pathogen is wind carried or rain splashed from such diverse hosts as cucumber, bean, *Ligustrum sinense*, and others. Infection usually begins with lower, inner leaves. Small brown spots develop and enlarge to appear indistinguishable from early blight disease. Fruits can develop zonate lesions but this is uncommon. Disease buildup can defoliate the inner, lower canopy quite quickly. The fungus can cause symptoms in 6 to 7 days after infection and is favored by temperatures between 77 to 99F. Target spot cannot be diagnosed from early blight without the use of a compound microscope, as would be found in a diagnostic laboratory.

Management. Early infection can be slowed by the discrete removal of severely infected leaf tissue to reduce the surviving reservoir of fungus. Conditions that lead to condensation splash, which will move this fungus about the greenhouse should be avoided. Recommended, labeled fungicides can be a component of the diseased control program. There are no varieties with resistance to this fungus.

12. Tomato Mosaic Virus. Traditionally, tomato mosaic virus (TMV) has been the most important tomato virus since it is both seedborne and mechanically transmitted by workers. However, most conventional tomato seed processing techniques now effectively eliminate the seedborne source of this virus. Workers using tobacco products may

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unknowingly inoculate the virus into plants during pruning, tying, or pollinating activities. Symptoms include mosaic and mottling of leaves and leaf distortion. Fruit distortion and uneven ripening may also occur. Once TMV becomes established in a greenhouse, simple activities like pollinating, suckering, or tying are enough to allow virus spread plant-to-plant.

Management. Smoking should be prohibited from production sites and all workers should scrub their hands with soap and water or a 3% solution of trisodium orthophosphate followed by an adequate water rinse. Growers should not save their own seed but rather purchase acid extracted, aged tomato seed to avoid seedborne virus.

Where TMV does occur, plants should be rogued as rapidly as possible to prevent additional spread. Hydroponic systems can incur a rapid disease spread due to the virus movement through the nutrient solution and its passive entrance into natural root wounds. These systems will be difficult to clean once this virus occurs since the system is not easily steamed and use of fumigants will not necessarily be effective. Scrub all surfaces with detergent in water and follow this cleanup with a spray of 3% trisodium orthophosphate solution. Peat bag, perlite, or rockwool culture can sustain the virus in root debris in the bags so disposal of these bags with infected roots is important. Fumigation will not necessarily purge the virus from these bags. Varietal resistance to some virus strains is available in some tomato cultivars.

13. Tomato Yellow Leaf Curl Virus (TYLCV) - A disease caused by tomato yellow leaf curl virus (TYLCV) that threatens both commercial tomato plantings and home gardens was identified in 1997 in south Florida. The disease spread north rapidly and TYLCV was first identified in north Florida and south Georgia in the Fall of 1998. TYLCV is transmitted by adult silverleaf whiteflies (*Bemisia tabaci* Biotype B = *Bemisia argentifolii*). TYLCV is not trasmitted through seed or by mechanical transmission. The presence of other cultivated or wild hosts of silverleaf whitefly (i.e., cotton) during summer may lead to additional whitefly migration to tomato. During the season, growers need to monitor whitefly populations very closely and follow recommendations in this Fact Sheet. TYLCV has a broad host range from several plant families including Solanaceae (tomato, tobacco), Malvaceae (cheeseweed), and Fabaceae (common bean, lentil).

The impact of TYLCV on tomato production can be severe. If plants are infected at an early stage, they won't bear fruit and their growth will be severely stunded. Other symptoms that are typical for this disease are: yellow (chlorotic) leaf edges, upward leaf cupping, leaf mottling, reduced leaf size (Fig. 8) and flower drop. Identification based only on symptomatology is unreliable, because similar symptoms can be caused by other viruses or various growing conditions. Proper identification of TYLCV is available at Plant Disease Clinics in Florida. Send suspected samples through University of Florida County Extension offices.

Figure 8. Note yellowing of edges, cupping, distortion, and reduced size of the leaflets.

Management. a) Use virus-free transplants. Transplants should be treated with labelled insecticides against whiteflies. Transplants should be produced in areas well away from tomato production fields. Virus and whitefly free transplants should be planted. b) Whitefly control. Monitor whitefly populations by scouts throughout the season. Use includings insecticides including soaps against whiteflies based on UF/IFAS recommendations. Highly UV-reflective mulches (metalized) and low rates of crop oil (0.25 -0.50 percent) could be used as whitefly repellents to reduce whitefly feeding and virus transmission. c) Sanitation. Learn to identify early symptoms of TYLCV and rogue infected and infected-looking plants from field and place in plastic bags immediately at the beginning of the season, especially during first 3-4 weeks. Spread of any whiteflies to healthy plants should be prevented.

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Tomato houses should be cleaned up immediately after harvest. Delay planting for fall will help to reduce risk of whiteflies infestations. Plantings of tomatoes should be separated in time and space from plantings of hosts (cabbage, collards, cucurbits, tobacco, soybean, cotton and weeds) which are good sources of whiteflies. TYLCV resistant tomato cultivars should be used if available for your production area.

14. Other Viruses - An other viruses appearing in Florida greenhouses is Tomato Spotted Wilt Virus and other Gemini viruses. These viruses have been particularly serious on tomato crops in fields in Florida, and have been observed in tomato greenhouses. These viruses are evidently insect transmitted (Spotted Wilt by thrips and Gemini by silverleaf whitefly). Similar control tactics as with other viruses (roguing diseased plants and vector control) are important activities for controlling spotted wilt and Gemini viruses.

More Information

For more information on greenhouse crop production, please visit our website at http://nfrec-sv.ifas.ufl.edu.

For the other chapters in the Greenhouse Vegetable Production Handbook, see the documents listed below:

Florida Greenhouse Vegetable Production Handbook, Vol 1

Introduction, HS 766

Financial Considerations, HS767

Pre-Construction Considerations, HS768

Crop Production, HS769

Considerations for Managing Greenhouse Pests, HS770

Harvest and Handling Considerations, HS771

Marketing Considerations, HS772

Summary, HS773

Florida Greenhouse Vegetable Production Handbook, Vol 2

General Considerations, HS774

Site Selection, HS775

Physical Greenhouse Design Considerations, HS776

Production Systems, HS777

Greenhouse Environmental Design Considerations, HS778

Environmental Controls, HS779

Materials Handling, HS780

Other Design Information Resources, HS781

Florida Greenhouse Vegetable Production Handbook, Vol 3

Preface, HS783

General Aspects of Plant Growth, HS784

Production Systems, HS785

Irrigation of Greenhouse Vegetables, HS786

Fertilizer Management for Greenhouse Vegetables, HS787

Production of Greenhouse Tomatoes, HS788

Generalized Sequence of Operations for Tomato Culture, HS789

Greenhouse Cucumber Production, HS790

Alternative Greenhouse Crops, HS791

Operational Considerations for Harvest, HS792

Enterprise Budget and Cash Flow for Greenhouse Tomato Production, HS793

Vegetable Disease Recognition and Control, HS797

Vegetable Insect Identification and Control, HS798