

Some Diseases of Vegetable and Agronomic Crops Caused by *Fusarium* in Florida

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Introduction

The Genus *Fusarium* contains many species of fungi that are commonly found in soil. Some are capable of causing wilts, crown rots, root rots, or fruit rots. Others are opportunists because they colonize plant tissues after some type of stress debilitates the plant. Interestingly, many species of *Fusarium* that abound in the soil are not capable of causing disease.

Fusarium wilts are caused by the species *Fusarium oxysporum*. Infection of plants by other species or other organisms can cause wilt, but diseases called *Fusarium* wilts are caused only by *F. oxysporum*. Within *F. oxysporum*, specificity exists because some forms (form species) within the species are capable of infecting certain plant species. For example, *F. oxysporum* f. sp. *lycopersici* causes *Fusarium* wilt in tomato and *F. oxysporum* f. sp. *niveum* causes *Fusarium* wilt in watermelon. Further complicating this situation is the existence of pathogenic races within form species. One pathogenic race may cause disease in certain varieties of a crop species but not in other varieties. Other varieties may be infected by other pathogenic races. Form species and races of *Fusarium oxysporum* are indistinguishable in appearance. For the remainder of this publication, the generic term

Fusarium wilt will be used to identify the complex group of wilt diseases caused by *F. oxysporum* and its form species and races.

Other species of *Fusarium* cause plant diseases. *Fusarium solani* causes root rots, stem rots, crown rots and fruit rots. *Fusarium subglutinans* infects sugarcane, corn, sorghum, and some broad leaf plants. Identification of the species of *Fusarium* associated with a problem is of little benefit for the grower unless specific control practices (e.g., resistant varieties) are available for control of specific species, form species, or pathogenic races.

Some *Fusarium* spp., including *F. oxysporum* and *F. solani*, produce thick-walled spores called chlamydospores. *F. subglutinans* does not produce chlamydospores. Chlamydospores are capable of surviving in soils, soil debris, or other substrates for more than 10 or 20 years. Chlamydospores that survive in the soil germinate and form tube-like structures (hyphae) that penetrate roots or other plant parts. These spores can be carried in or on seed, transplants, wooden field stakes, clonal propagation stock, such as potato seed piece tubers, and soil attached to equipment.

Fusarium spp. can also survive by colonizing roots or stems of so-called non-host plants.

For example, roots of barley and nutsedge can serve as colonization sites for the *Fusarium* wilt pathogen of cotton. Brazilian pepper, cudweed, and carpet weed will continually support populations of the fungus that causes crown rot in tomato. The fungus that causes *Fusarium* wilt in tomato has been found to infect eggplant, mallow, *Amaranthus* sp., crabgrass, and ricegrass. The watermelon wilt pathogen has been associated with roots of citron, bitter apple, rice, peanut, and tomato. Thus, the production of thick-walled spores and the ability of *Fusarium* spp. to colonize alternate plant hosts provide mechanisms for long-term survival in soil.

Wind-blown dispersal of spores of *Fusarium* spp. may occur. For example, air-borne spores (conidia) of the crown rot pathogen of tomato can recontaminate nearby fumigated sites in the field or the greenhouse. However, for most diseases caused by *Fusarium* spp., soilborne chlamydospores are generally regarded as the primary source of inocula.

Stress factors such as drought, flooding, chemical damage, mechanical damage, low soil pH, deposition of soil on stems while cultivating, or incorrect usage of fertilizer may predispose plants to infection by *Fusarium* spp. Other pests such as fungi, bacteria, nematodes, or insects may occur simultaneously in roots or stems or predispose plants to infection by the *Fusarium* sp. For example, nematode damage accentuates *Fusarium* wilt in cotton but not in any notable way in tomato, watermelon, or sweet potato. Also, lower stems of soybeans and beans are commonly infected with *Fusarium* sp. and other fungi after hot soil is deposited on stems during cultivation.

Root and stem diseases caused by *Fusarium* sp. debilitate plants by rotting (plant cell destruction) root and stem tissue or by plugging the water conducting vessels (xylem) in roots or stems. *Fusarium* wilts can be diagnosed tentatively by slicing the stem in half lengthwise.

The presence of two dark bands of water-conducting tissues indicates that the xylem vessels are plugged from infection. If the stem is sliced perpendicular to the length of the stem, the darkened tissue will often appear as a circle. If the infection is one-sided in the plant, a portion of the circular tissue will be darkened. The blockage of the water and nutrient-conducting tissue of the plant results in stunting, discoloration of leaves (usually yellow, initially), and wilting. Yield losses are greater and plants are more likely to die if infection occurs while plants are young. Because other pests and diseases can cause similar symptoms, you are advised to attain formal diagnoses until you become familiar with symptoms and field diagnostic procedures for the crops you produce.

FUSARIUM WILTS

***Fusarium* Wilt of Tomato**

Fusarium, wilt of tomato (Fig. 1) would be more common and devastating throughout Florida if resistant varieties were not used. Resistance to *Fusarium* wilt in tomato is complete; that is, all plants within a variety are resistant to the designated races unless a seed or transplant mishap has occurred. Currently, races 1, 2, and 3 exist in Florida. If *Fusarium* wilt is present, slicing the stem lengthwise into equal halves will reveal two dark, orange-red, or brown streaks of darkened water-conducting vessels (Fig. 2). Symptoms include lower leaf yellowing and then browning, stunting, vascular discoloration, and plant death. Leaf yellowing is often seen on one side of the plant and frequently in leaflets on one side of the leaf. The darkened vascular tissue often extends up to the middle part of the stem and sometimes to the top of the stem and into the vascular tissue of the fruit.

The optimum temperature for development of *Fusarium* wilt and growth of the fungus is

82°F. Growth of the fungus is reduced at temperatures below 68°F or above 93°F. However, Fusarium wilt has occurred in Florida at temperatures above 95°F.

The primary control for Fusarium wilt of tomato is the combined use of crop rotation, resistant varieties for the pathogenic races in your area, disease free transplants, and preplant fumigation with a broad spectrum fumigant (e.g., methyl bromide + chloropicrin, vapam, etc.). Reinfestation of fumigated soil with non-fumigated soil and pond water should be avoided. Transplant production areas should be sanitary and should not be adjacent to field production areas or equipment cleaning areas.

Sanitizing used field stakes will reduce, not necessarily eliminate, inoculum associated with the stakes that can infest fumigated soil. When tomatoes are planted in a new field, it is best to use new stakes because sterilization procedures such as steam or chemicals may not eliminate all of the inoculum. When planting tomatoes in a field that contained tomatoes in the past, use of sterilized stakes is preferred. However, with use of unsterilized stakes, the crop may be near the end of harvest before the wilt fungus causes any noticeable problem.

Additional controls for Fusarium wilt of tomato include adjusting pH, fertility and moisture of the soil. The soil pH should be 6.5 or above coupled with minimum usage of ammonium- containing fertilizer. Avoid the use of excessive amounts of nitrogen, phosphorus, and magnesium. Soil moisture should be adequate for crop production but not excessive. Use of drip or seepage irrigation coupled with adequate drainage for heavy rains will provide a proper soil moisture situation. These adjustments to the soil will be most effective for control of Fusarium wilt if the entire root system is confined within the treated soil such as that within a plastic mulch system.

This fungus can be seedborne. However this

source of inoculum is not common. The importance of seedborne inoculum, relates to the potential for introducing new races from other areas of the world.

Fusarium Crown Rot of Tomatoes

Fusarium crown rot of tomatoes (Fig. 3) has become widespread in southern Florida on the sandy, acidic soils and it has been found occasionally on the high pH soils in Dade County. Symptoms of Fusarium crown rot are distinctly different from those of Fusarium wilt of tomato. The brilliant yellowing of the foliage typical of Fusarium wilt does not occur with crown rot. With crown rot, the leaflets often have a marginal necrosis (death). Infected plants often wilt during the day and recover during the night (Fig. 4). With crown rot, definite root and crown rots occur (Fig. 5). Additionally, unlike Fusarium wilt, the vascular discoloration is limited to the lower 12" of the stem (Fig. 6). An infected plant rarely dies but infected plants will be stunted. Even with severe vine symptoms, some yield is attainable. This fungus is called *F. oxysporum* f.sp. *radicis-lycopersici*. It grows best from 50°F to 68°F which is lower than the optimum for the fungus that causes Fusarium wilt. The optimum temperature for disease development is 70°F.

Control of crown rot is similar to that of Fusarium wilt (e.g., crop rotation, sanitation, increase soil pH, minimize use of ammoniacal nitrogen, and soil fumigation). Resistant varieties for control of crown rot are currently available only for greenhouse production. Crown rot is likely to occur with a higher frequency where direct seeding is used, instead of healthy transplants, and where the soil contains high levels of chloride salts. The utmost sanitation production scheme for transplants in greenhouses should be used so that individuals or equipment used within or around the transplant site do not become contaminated with disease-causing organisms from the field. Considerable information on sanitation within transplant sys-

tems is available in Plant Protection Pointer No. 25. Finally, transplants should be transported, pulled, and set without tissue damage as damaged tissues are likely to be sites for infection.

Fusarium Wilt of Watermelon

Fusarium wilt of watermelon is common in Florida where resistant varieties are not used but it occurs to some extent even when resistant varieties are used. Resistance to Fusarium wilt in watermelon varieties is not complete; that is, some plants within the “resistant variety” may be susceptible. However, a susceptible variety contains a higher percentage of susceptible plants than a resistant variety. Three races (0, 1 & 2) exist and resistance to all three is necessary. Currently, resistance to race 2 has not yet been incorporated into a commercial variety.

Fusarium wilt of watermelon usually occurs without plant yellowing; usually the entire plant wilts quickly (Fig. 7), becomes brown and dies. Occasionally, wilting of vines on one side of the plant occurs, particularly on older plants. Slicing the tap root lengthwise into two equal halves will reveal two streaks of vascular tissue that are dark yellow-brown, orange brown or reddish brown (Fig. 8). In Florida, Fusarium wilt is likely to occur prior to fruit set. The optimum temperature for infection is near 80°F with little infection occurring above 86°F. This wilt pathogen has been found to be associated with seed but the importance here would be the potential of introducing a new race into the field from other areas of the world.

The best control for Fusarium wilt of watermelons is the use of resistant varieties coupled with crop rotation. Where land is limiting for an adequate rotation scheme on your farm, two alternatives exist. First, you may lease land that has not had watermelons for many years. Secondly, the use of certain varieties (e.g., Crimson Sweet) on the same land year after year, although not advised, may result in less

Fusarium wilt than if other varieties are planted. Rotation includes the absence of watermelon for five years or more. Also, some varieties of yellow summer, zucchini, and scallop squash are susceptible to this fungus and should be excluded from the rotation.

Additional controls include the use of certified, disease-free transplants and delayed thinning of direct seeded stands. Delayed thinning permits a better chance of culling susceptible plants rather than resistant plants within the population. The use of higher soil pH's and less ammoniacal nitrogen has not consistently reduced the amount of wilt in watermelons as it has in tomatoes.

Fusarium Wilt of Cantaloupe

Fusarium wilt of cantaloupe has not been formally identified in Florida. However, it is likely that it has occurred in the panhandle region of Florida. Symptoms are similar to other Fusarium wilts. This wilt pathogen has been found on seed. This disease is favored by cool temperatures between 65 to 77°F.

Fusarium Wilt of Cucumber

Fusarium wilt of cucumber occurs occasionally in Florida, usually where cucumbers are grown on the same land year after year. Symptoms are similar to that of Fusarium wilt of watermelon and cantaloupe. Controls include crop rotation, and liming of soil coupled with use of fertilizer with a minimum amount of ammonium salts.

Fusarium Wilt of Cotton

Fusarium wilt of cotton occurs infrequently in Florida. Prior to the use of varieties with resistance, this disease was more prevalent in Florida. Infection of cotton by the Fusarium wilt pathogen is highly dependent upon damage

from nematodes but does not necessarily occur when plants are infected with nematodes. Symptoms include stunting, lower leaf yellowing and browning, wilting (often seen first at flowering), gradual reduction of plant vigor, and possibly plant death. Vascular discoloration may be dark brown to black. Controls include crop rotation, suppression of nematodes and use of varieties resistant to prevalent races.

Fusarium Wilt of Tobacco

Fusarium wilt of tobacco is present occasionally in Florida. Symptoms include leaf yellowing and wilting (Fig. 9). Leaf yellowing and wilting may occur on one side of the plant but not the other, a symptom not uncommon with Fusarium wilts. Injury from cultivation or nematodes will predispose plants to infection. Calcium deficiency will accentuate Fusarium wilt of tobacco. Fusarium wilt of tobacco will occur across a wide range of soil pH's, but it is likely to be more severe at 7.0. This wilt fungus can grow from 45 to 95°F but grows best between 77 to 86°F. This disease is best controlled by crop rotation, resistant varieties and reduction of nematode damage. Sweet potato should not be used as a rotational crop as they are also susceptible to this fungus.

Fusarium Wilt of Sweet Potato

Fusarium wilt of sweet potato occurs occasionally in Florida if resistant varieties are not used. Leaf yellowing and browning of the oldest leaves during vine elongation is a common symptom. Stunting and eventually plant death may occur. Vascular discoloration may be similar to that of other wilts with two discolored bands being evident when the lower stem above or below the soil surface is cut lengthwise. However, if the wilt is one-sided, the vascular discoloration may be only on one side of the stem. Vascular discoloration will vary in color from brown to purple. Infection can occur anytime during the growth of the crop but infec-

tion is most likely during or shortly after transplanting. Damage to roots from pulling transplants or any other factor favors infection. This fungus grows at all temperatures that are favorable for crop production but may be inhibited to some degree at soil temperatures above 86 to 95°F. Control includes crop rotation, resistant varieties, selection of healthy transplants, minimizing stress and avoidance of planting when soil is cool.

Fusarium Wilt of Crucifers (Cole Crops)

Fusarium wilt of crucifers has occurred sporadically in Florida in cabbage, collards and radish but generally this disease has not impacted crop production significantly. Other cruciferous species are also susceptible. Because little is known about the degree of susceptibility of different cruciferous varieties, except for cabbage, the occurrence of this disease in other cruciferous crops may occur in the future. Symptoms include seedling death (Fig. 10), stunting, stem curling, leaf drying on the edges, yellowing of lower leaves, dropping of leaves, bud formation on leafless stems, vascular discoloration, and often plant death. Black rot, a bacterial disease, can be confused with Fusarium wilt because it causes black veins in stems, roots and leaves. Fusarium wilt is most likely to be a problem in plantings that are initiated in the late summer to early fall or mid to late spring. The fungus grows best at 80 to 90°F and is strongly inhibited below 61°F and above 95°F.

Control of Fusarium wilt in crucifers includes use of crop rotation and disease-free transplants. For cabbage, many resistant varieties are available. When cabbage or other crucifers are grown without crop rotation, use of resistant varieties is essential.

Fusarium Wilt of Soybeans

Fusarium wilt of soybeans has been found on occasion in Florida but the extent of its inci-

dence and importance is unknown. Symptoms include lower leaf yellowing, leaf drop, stunting, wilting in mid season, and possibly plant death. Infection is enhanced by cool temperature from 57°F to 74°F. Thus, this disease might be a problem if soybeans are planted too early (prior to mid May) or if soils remain cool and wet into the normal planting season. Wounding from cultivation, nematodes and herbicides enhance the development of this disease. Resistance exists, but the extent of use of this resistance by plant breeders is not known.

Fusarium Wilts of Beans and Chickpeas

Fusarium wilts of beans and chickpeas have probably occurred in Florida based upon symptoms (Figs. 11 & 12) but official documentation is not available.

Fusarium Root and Lower Stem Rots

Fusarium spp. are commonly associated with roots and lower stems of unthrifty plants. As indicated earlier, the presence of *Fusarium* spp. in roots or lower stems does not indicate that the *Fusarium* spp. are the cause of the problem. However, primary or secondary invasion of plant tissue by *Fusarium* sp. can cause root debilitation which is usually followed by stunting, loss of green color in leaves, wilting, and other decline symptoms. Some crops that are commonly infected with *Fusarium* spp. in Florida include celery (red root, Fig. 13), parsley (Fig. 14), carrot, corn (particularly field corn), sorghum, millet, peanut (Fig. 15), soybean, snow peas (possibly a wilt type of *Fusarium*), beans, southern peas, forage legumes, onions, and some herbs. Probably, most plants sustain some damage from *Fusarium* spp.. Infection by *Fusarium* sp. often begins during the seedling stage of the plant for direct-seeded crops (Fig. 16). Fusarium-induced diseases of potatoes (Fig. 17) would be more of a problem in Florida if certified seed pieces were not used.

Cultural and chemical control practices pre-

sented for Fusarium wilt diseases will reduce Fusarium root rots. Also, recontamination of fumigated soil should be avoided because fumigated soil has less natural biological diversity. Soils with less microbiological diversity may allow for a rapid increase of a plant pathogen (Fig. 14). Fertility adjustments may not be as effective for Fusarium root rots as they are for Fusarium wilts. Additional controls include fungicide seed treatments, destruction of all green manure 30 days or more prior to planting, preparation of soil into a loose tilth for planting, avoidance of deep setting of seeds or transplants, use of healthy, undamaged transplants, and care not to deposit soil on stems when cultivating.

Fusarium Fruit and Flower Rots

Infection of flower or fruit parts by *Fusarium* spp. has not been common in Florida but both occur. Peanut and corn are the crops that are most likely to incur infection of fruit by *Fusarium* spp (Figs. 18 & 19). Infection of peanut pods can be associated with damage from soil insects and nematodes. Fruit (ears) of field corn are commonly infected with *Fusarium* spp., particularly if damage to the husk or silks occurs from hail, insects, etc. Some *Fusarium* spp. that infect grain crops such as corn and wheat produce toxins that can poison livestock.

Occasionally, fruit of vegetables may be infected with *Fusarium* spp. (Fig. 20). Control for such fruit rots include avoidance of damage to fruit from insects or other factors, trellising crops or use of plastic mulch so fruit are not produced in direct contact with the soil. The infection of flowers by *Fusarium* spp. is not a common problem but has been noted in tomato flowers infested with thrips, a small insect.

Summary

It is not possible to adequately generalize about the complex range of symptoms, environmental factors, and controls associated with

Fusarium-induced diseases for the many susceptible crops. The reader is advised to make every effort to seek professional advice on the importance of the *Fusarium* spp found in association with a given situation. However, numerous cultural and chemical controls can be routinely incorporated during the production of a crop so that the impact from *Fusarium*spp. will

be minimized. As noted throughout this publication, successful control of Fusarium-induced diseases begins with healthy seed, healthy seed pieces, healthy transplants, and properly prepared and rotated land. Changes of soil fertility, use of resistant varieties, avoidance of plant stresses (biological and physical), and cultural manipulations can be used successfully in some situations.



Figure 1. Wilting of tomato plants with Fusarium wilt.



Figure 2. Tomato stem with discolored xylem tissue from Fusarium wilt.



Figure 3. Fusarium crown rot of tomato.

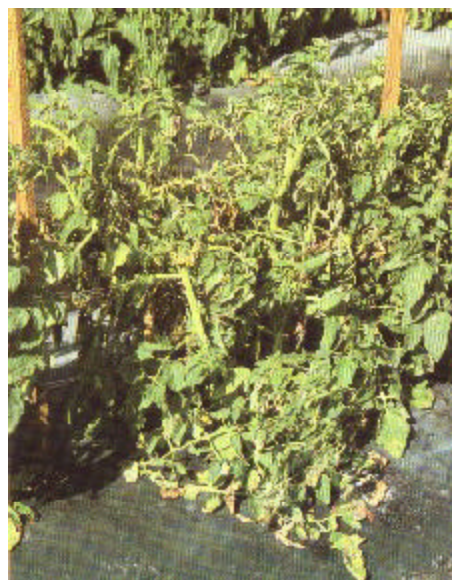


Figure 4. Wilting of tomato plants with crown rot.



Figure 5. Lower stem of tomato with crown rot.



Figure 6. Inner tomato stem with crown rot.



Figure 7. Wilting of watermelon plant with Fusarium wilt.



Figure 8. Inner watermelon tap root with Fusarium wilt.



Figure 9. Fusarium wilt of tobacco.



Figure 10. Fusarium wilt of cabbage seedlings.



Figure 11. Fusarium wilt-like symptoms in beans.



Figure 12. Fusarium wilt-like symptoms in chickpeas.



Figure 13. Fusarium root rot (red root) in celery.



Figure 14. Seedling blight of parsley caused by Fusarium.



Figure 15. Fusarium-infected peanuts.



Figure 16. Onion seedlings infected with Fusarium.



Figure 17. Fusarium-infected potato tubers.



Figure 18. Peanut pods with Fusarium and other fungi.



Figure 19. Fusarium ear rot of field corn.
Photo courtesy of Dr. Johnny Crawford,
University of Georgia.



Figure 20. Pumpkin fruit rot caused by Fusarium.