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FUSARIUM WILT DISEASES OF HERBACEOUS ORNAMENTALS

Fusarium wilts, or yellows, are caused by a number of highly specialized forms and races of the common soil-borne fungus *Fusarium oxysporum*. Fusarium wilt diseases attack many popular garden and greenhouse flowers (Table 1) and are most serious and widespread in Illinois on aster (China-aster), carnation, chrysanthemum, gladiolus, lily, and narcissus.

Other specialized forms of *Fusarium oxysporum* attack numerous vegetables; a few fruits, field crops, and trees plus a wide range of other plants (Table 2). Many soils in Illinois and other crop-growing areas throughout the temperate and tropical regions of the world contain one or more forms of *Fusarium oxysporum*.

Once the fungus is introduced into a garden, nursery, greenhouse, or field, it can live indefinitely in a variety of soil types, independent of any host plant. This ability to survive eliminates, as an effective control measure, any normal rotation program or general sanitation.

Figure 1. Fusarium wilt on cyclamen. Symptoms frequently don't appear until flowers are mature. (Photo courtesy of A.H. McCain).

Symptoms of Fusarium wilt are easily confused with root or crown rots; stem cankers; insect, grub, or borer injury; drought; compacted or poor soil; and two other widespread wilt diseases, Verticillium wilt and bacterial wilt, a common disease in the South. Overall symptoms are the same–a wilting, withering, and dying of the foliage. Only by close observation and experience can you determine the true cause.

In general, *Fusariium oxysporum* attacks plants and is most severe at air and soil temperatures of 24°C to 32° or 35°C (75° to 90° or 95°F) while the Verticillium wilt fungi (*V. Albo-atrum* and *V. dahliae*) infect plants at somewhat lower temperatures (optimum 21°C or 70°F). Fusarium wilt is most severe in the southern half of Illinois during warm-to-hot weather. Transplants that are grown in infested soil usually do not show typical wilt symptoms until they have been transplanted for some time and soil temperatures rise to 24°C (75°F) or higher.

SYMPTOMS

Typical symptoms of Fusarium wilt include a drooping and yellowing of the leaves, often starting on one side, and stunting of the plant (Figure 1). Disease symptoms often commence at the base of the stem and

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progress upwards, causing the leaves and flower heads to wilt, wither, and die. Lower parts of the stem are dark and discolored, always on the inside and sometimes on the outside (Figures 2 and 3). When infected stems are split, brown to black streaks are evident in the vascular system. Flowering plants that start from bulbs, corms, or tuberous roots (crocus, dahlia, freesia, gladiolus, iris, ixia, lily, narcissus, and tulip) show a dark discoloration within underground parts (Figures 4 and 5) that commonly extends into the leaf bases. Seedlings of all flowering plants may suddenly wilt, collapse, and die.

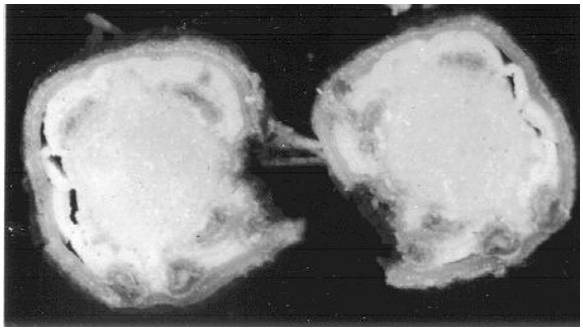

Figure 2. Cross sections of carnation stems infected with Fusarium wilt. Vascular discoloration is dark brown (IL Natural History Survey photo).

Masses of white or pinkish *Fusarium* spores (conidia) are formed in fungus fruiting bodies, called sporodochia, on the surface of infected or dead stems, usually near the soil line, or on infected bulbs and corms.

Figure 3. A black, elongated lesion often develops on one side of an aster stem infected with Fusarium wilt. Branches on the same side of the stem usually die suddenly (IL Natural History Survey photo).

Disease and symptom development are extremely dependent upon air and soil temperatures. Symptoms are usually absent or mild at temperatures below 21° to 24°C (70° to 75°F) and are most severe at constant temperatures of 29° to 32°C (80° to 90°F). Plants that are grown at low temperatures may be infected, yet show no symptoms until the temperatures rise. Specific additional symptoms that occur on selected flowering plants are given in Table 3.

DISEASE CYCLE

The Fusarium wilt fungi (Figure 7) invade the root systems or other underground parts of their host plants through wounds that are caused naturally by the growth of young rootlets through the soil and by wounds in older roots that are made during transplanting and cultivating; by root-feeding organisms, such as insects or nematodes (burrowing, lesion, root knot, sheath, sting, stubby-root, and stunt); and by man-made injuries during transplanting, cultivation, harvest, sorting, and grading. Once within the plant, the fungus grows and multiplies in the vascular system (water- and food-conducting tissues) of the roots. It then moves upward in the plant by spores (macroconidia and microconidia) that are transported in the sap stream where they become lodged, germinate, and affect new plant parts; or the fungus extends its colonization as it grows in the vascular tissue of the host. The normal flow of liquids and nutrients from the roots to the foliage is greatly reduced or stopped because the conducting tissue becomes partially plugged or killed by fungal mycelium and spores, or by the overgrowth of neighboring cells. Toxic substances are believed to be secreted by interaction of the fungus and the host plant. These materials apparently cause the wilting and eventual death of the plant. Wilt symptoms typically are not observed until the fungus has colonized the underground parts of the plant.

Resting structures (chlamydospores) are formed within infected plant parts. After the host plant dies or the growing season ends, the *Fusarium* fungi survive as mycelia and chlamydospores, overwintering in

dead plant parts; or, the fungi may live in the soil indefinitely in the absence of the host plant, especially if the soil is warm, as in a greenhouse. Chlamydospores are stimulated to germinate by exudates from the roots of a host plant which they then infect.

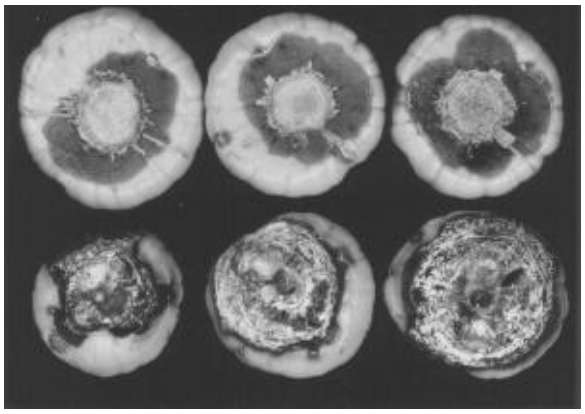

Figure 4. Fusarium corm rot of gladiolus (IL Natural History Survey photo).

The *Fusarium* fungi spread from plantings of contaminated seed cuttings, transplants, tubers, roots, corms (Figure 4), and bulbs (Figure 5). In addition, mycelia, conidia, and chlamydospores may be transported in infested soil by normal tillage operations, in soil clinging to hand tools, equipment, or shoes, by wind, and by surface drainage water. Once contact is made with a new plant host, the fungus again invades the underground parts, progresses upward, and the cycle is repeated. Soil moisture and soil reaction (pH) have little effect on Fusarium wilts, as the fungi establish themselves and thrive in a wide range of soil types.

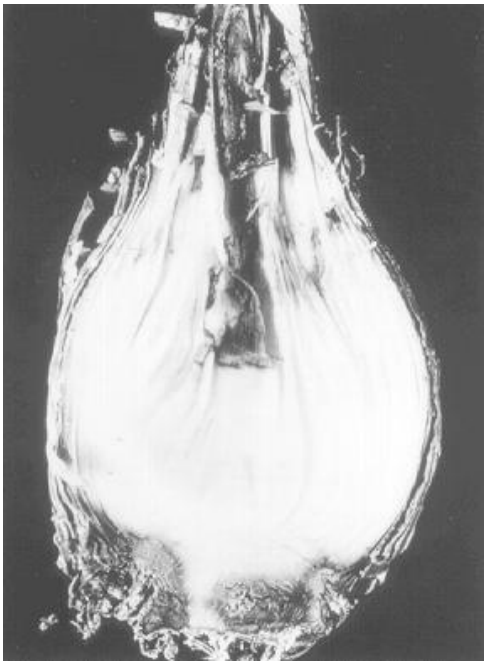

Figure 5. Fusarium basal rot of narcissus. Longitudinal section of an infected bulb, showing how the rot progresses up the scales from the basal plate.

CONTROL

The Fusarium wilt fungi are difficult to control. Schemes to eradicate the pathogen are limited by the ability of the fungi to survive in soil for long periods, with or without a host plant, and the colonization of the vascular tissues within a plant.

The first step in managing Fusarium wilt is proper diagnosis. Only by laboratory culturing of infected plant material can you positively identify *Fusarium* as the causal agent. Similar symptoms are produced by other pathogens. Once *Fusarium* has been identified as producing the symptoms expressed in the host, several measures can be taken to reduce the effects of the disease.

1. Disinfest greenhouse, seedbed, and potting soil before planting. Use either steam (hold soil at 82°C [180°F] for 30 minutes at the coolest spot or 71°C [190°F] for one hour) or fumigate the soil with methyl bromide, chloropicrin, Vorlex, or Vapam Soil Fumigant. These chemicals also will control other pathogens, weeds, insects, and nematodes in the soil. You should also treat containers, benches, work surfaces, tools, and other equipment. Fumigation is usually done by larger growers and commercial applicators who are licensed to handle restricted-use chemicals. The manufacturer's directions should be followed carefully.

2. Do not grow susceptible plants in Fusarium-infested soil where the same or closely related plants have grown previously. A rotation of 5 to 10 years or more may help to reduce the amount of infection.

3. Purchase only healthy, top-quality, disease-free seed, cuttings, transplants, bulbs, corms, or other plant material. Start with culture-indexed cuttings or clean, mother-block stock plants of carnation,

chrysanthemum, and geranium from a specialist propagator, preferably CVI (culture-virus-indexed) stock. Fusarium-resistant varieties and cultivars are available for growing in wilt-infested soil. Varieties and cultivars are listed in seed or other catalogs for the following garden and greenhouse flowers: Aster (China-aster), carnation, chrysanthemum, gladiolus, lily, marigold, narcissus, sunflower, tulip, and zinnia.

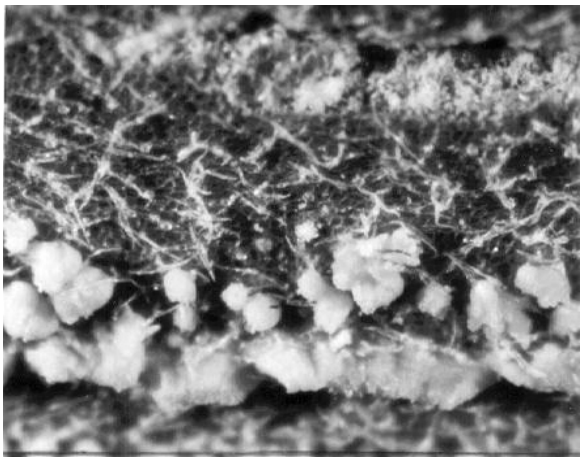

Figure 6. Close-up of whitish pink masses of Fusarium spores (conidia) produced in fungus fruiting bodies (sporodochia) on a chrysanthemum stem (courtesy Dr. P.C. Pecknold, Purdue University)

4. Plant in fertile, well-drained, wilt-free soil. Control soil insects by following the suggestions of University of Illinois Extension entomologists.

5. In home gardens, promptly dig up and burn or haul away with the trash all infected plants including the roots. Do **not** bury this debris or place it in the compost pile.

6. Avoid overwatering, deep plant-ing, overfertilizing with nitrogen or phosphorus, and injuring plants when planting, cultivating, harvesting, grading, or sorting.

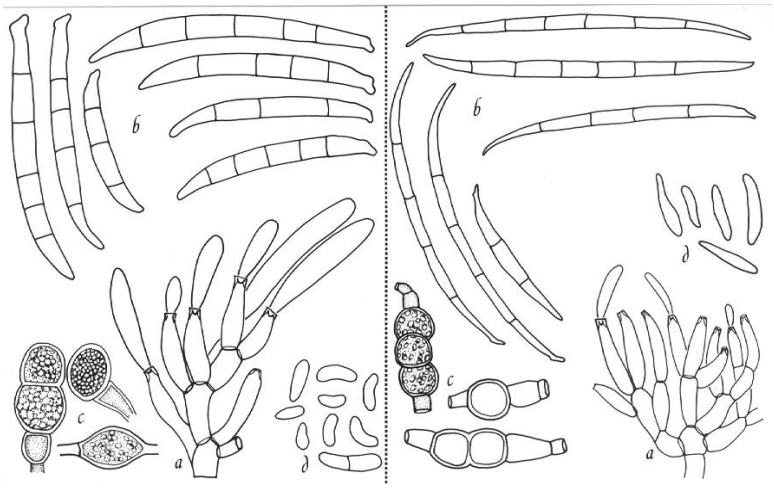

Figure 7. Two specialized forms of Fusarium oxysporum as would be seen under a high-power microscope: (Left) F. oxysporum f. sp. Gladioli; (Right) F. oxysporum f. sp. vasinfectum; (a) conidiophore producing conidia at the tips; (b) macroconidia; (c) terminal and intercalary chlamydospores; (d) microconidia (drawing by Lenore Gray).

7. Where feasible, drench growing plants, such as those in containers or greenhouse benches, using a fungicide or mixture suggested in Commercial Growers Landscape and Turfgrass Pest Management Handbook. This circular is revised annually. Carefully follow the manufacturer's directions as printed on the package label.

8. For Gladiolus, Iris, Lily, Narcissus, and Tulip, carefully dig bulbs or corms early in dry weather, and dry them immediately in the shade, using warm-to-hot circulating air. Avoid sunburning, bruising, or cutting the bulbs and corms when digging, cleaning, sorting, or grading. Carefully inspect all bulbs and corms immediately after digging, before storage, and again before planting. Discard all those showing decay or rot lesions. Fungicide-treated bulbs and corms (see below) should be planted in clean or fumigated soil, where the disease has not occurred in the past 5 to 10 years or more.

A. **For Gladiolus Corms and Cormels**

Within 24 hours after digging, soak disease-free corms in a basket or loosely woven sack for 15 to 30 minutes in warm water (80° to 85°F or 27° to 29°C) containing one of the fungicides listed in Commercial Growers Landscape and Turfgrass Pest Management Handbook.

Clean the corms when the old and new corms separate easily, then hold at the curing temperatures (85° to 95°F or 29° to 32°C) for several days before storing at 40° to 50°F (3.5° to 10°C). Inspect corms carefully before planting and discard all those showing rot lesions. All healthy appearing corms should be dipped in Benomyl, Mertect 160-F, Topsin M. or Ornalin as outlined in Commercial Growers Landscape and Turfgrass Pest Management Handbook.

Treat fully dormant cormels in January with hot water to greatly reduce the number of rot-producing pathogens. Dormancy varies with the gladiolus variety and the temperature under which the variety was grown and stored. Cure cormels for one week or longer at 95°F (32°C), and then presoak them for 2 days in water at room temperature. Discard the cormels that float; they are diseased. Soak the remainder in 38 percent USP formaldehyde solution (1 part to 200 parts of water) for 2 to 5 hours, remove the cormels from the formaldehyde solution, drain well, place them in wire mesh containers, and immerse in hot water (135°F ± 1/2°F) for 30 minutes. Immediately after treatment, cool the cormels by plunging them into clean, cold water for 10 to 15 minutes, then dry rapidly in thin layers in sterilized trays. Place the cormels in cool storage (40°F or 3.5°C) until ready to plant in wilt-free soil.

B. **For Iris Bulbs**

Within 24 to 48 hours afer digging, soak the clean bulbs for 15 to 30 minutes in warm water containing benomyl (Benlate, 50WP) or thiabendazole (Mertect 160-F, 60WP), as outlined for gladiolus corms. The iris bulbs should be dried rapidly in single layers in open trays after treatment. Store the bulbs in a cool, dry location, preferably where the temperature is 48° to 50°F (9° to 10°C) and the relative humidity is 60 to 80 percent.

C. **For Lily Bulbs**

Soak clean, unblemished bulbs within 24 hours after digging and again just before planting. Dip bulbs for 10 to 15 minutes in a suspension of fungicide as outlined in Commercial Growers Landscape and Turfgrass Pest Management Handbook. These fungicides also can be blended into the soil just before planting or applied as a drench after potting. Carefully follow the manufacturer's directions as printed on the container label. Keep stored bulbs cool after treatment until ready to plant.

Propage using only rot-free scales. Dust with thiram, 50-75WP or thiram plus benomyl, 50WP. Carefully follow label directions. Shake small, weighed amounts of scales in a paper sack containing the proper amount of fungicide. Plant at once in steamed or fumigated soil.

D. **For Narcissus Bulbs**

Soak clean, blemish-free bulbs within 24 hours after digging in a suspension of fungicide as outlined for gladiolus corms in Commercial Growers Landscape and Turfgrass Pest Management Handbook. Store dry, treated bulbs in a cool (55° to 60°F; 13° to 15°C), well-ventilated area until ready for planting.

E. **For Tulip Bulbs**

Soak clean, healthy-appearing bulbs within 24 to 48 hours after digging in a suspension of fungicide as outlined for gladiolus corms in Commercial Growers Landscape and Turfgrass Pest

Management Handbook. Store treated bulbs in a dry, well-ventilated area below 59°F (15°C) until ready for planting.

Table 1. Herbaceous Ornamentals susceptible to One or More Specialized Forms and Races of Fusarium Wilt

Alternanthera	Dahlia	Pansy, Violet, Viola
Asparagus-fern	Daphne	Passionvine
Aster, China-aster	Delphinium, Larkspur	Petunia
Astilbe	Eupatorium	Pinks, Garden (*Dianthus*)
Bleeding-heart	Foxglove	Poinsettia
Browallia	Freesia	Polemonium (Jacob's ladder
Cape-marigold	Geranium	or Greek-valerian)
Carnation	Gerbera (Transvaal Daisy)	Salpiglossis (Painted-tongue)
Centaurea (Bachelor's-	Gladiolus	Senecio (Groundsel)
button, Basketflower,	Goldenseal	Snapdragon
Cornflower, or Dusty-	Iris	Speedwell
miller)	Ixia	Stock
Chrysanthemum	Lantana	Sunflower
Cineraria	Lily	Sweetpea
Clarkia	Lupine	Sweet William
Coriander	Marigold	Tritonia (*Montbretia*)
Cosmos	Morning-glory	Tulip
Crocus	Narcissus	Zinnia
Cyclamen	Painted-tongue	

Table 2. Vegetables, Fruits, Field Crops, Trees, Shrubs, and Miscellaneous Plants Susceptible to One or More Specialized Forms and Races of Fusarium Wilt

Aechmea	Coffee	Lentil
Alfalfa	Collard	Lettuce
Artichoke, Japanese	Cotton	Lorus (*Nelumbo*)
(*Stachys*)	Cowpea (*Vigna*)	Muskmelon (Cantaloupe)
Asparagus	Cucumber	Mustard
Banana	Cumin (*Cumimum*)	New Zealand flax
Bean, garden	Dill	(*Phormium*)
Beet, garden	Eggplant	Oak
Broad bean (*Vicia*)	Eucalyptus	Okra
Broccoli	Fig	Orchids
Brussels sprout	Flax	Onion
Cabbage	Garlic	Palm, date
Cacti (*Cereus, Opuntia*)	Gourds	Parsley
Casaba	Gram (*Cicer*)	Pea, garden
Cassia toro	Grape	Peanut
Castorbean	Guava	Pepper
Catnip	Hebe	Plantain
Cauliflower	Hemp	Potato
Celery	Kale	Pumpkin
Chinese cabbage	Kohlrabi	Pyracantha
Citron	Leek	Radish

Rape	Sesbania	Sumac, staghorn
Rauvolfia	Shallot	Sweet potato
Russian-olive	Silktree or “mimosa”	Tobacco
Rutabaga	Soybean	Tomato
Safflower	Spinach	Turnip
Seakale	Squash	Vegetable-marrow
Sedum	Strawberry	Vetch
Sesame	Sugarcane	Watercress
		Watermelon

Table 3. Symptoms of Fusarium Wilt, Yellows, Corm or Bulb Rot of Various Selected Flowering Plants

Host	Typical Symptoms
Aster, China-aster (Figure 3)	Seedlings may suddenly wilt, collapse, and die. Older plants gradually turn yellow, followed by wilting, starting with the lower leaves. Plants are often stunted and show one-sided development. Black streaks may form up one side of stems on older plants (Figure 3), followed by death of the entire plant. The stem base is often externally blackened with a dark brown vascular ring just beneath the bark. Roots are rotted. Masses of pink-colored *Fusarium* spores commonly form at the base of the stem.
Carnation Figures 1 and 2)	The foliage, starting with the lower leaves, gradually changes from a dull gray green to a pale straw yellow (Figure 1). Affected plants slowly wilt and wither, often only on one side. The yellowing gradually spreads up the plant. Infected plants may die slowly or fairly quickly depending on the temperature and the variety. Vascular discoloration is dark brown (Figure 2). Pinkish masses of spores are usually evident on the stem surface and base of the branches. A dry, shredded rot develops in the stem and branches. This disease can be a major limiting factor in commercial production.
Chrysanthemum (Figure 6)	The upper leaves turn yellow and wilt, often first on one side of the plant; later, the entire plant wilts and dies. The stem near the soil line becomes dark brown or black and dry. An external black streak sometimes extends from the roots into the upper parts of the stem. Flower development is poor. Masses of pinkish or white *Fusarium* spores form abundantly on dead parts of stems (Figure 6). Vascular discoloration is brown to reddish brown. This disease can be a major limiting factor in commercial production.
Cyclamen	The leaves on young plants gradually turn a vivid yellow. The leaves and flowers on mature (flowering) plants suddenly wilt, wither, and the plant dies. Internal vascular discoloration in the roots and tuber (corm) is brown to brownish black. Older roots are decayed.

Dahlia	The lower leaves gradually wilt and turn yellow, frequently starting on one branch; later, the entire plant dies. A dark brown discoloration develops in the stem ends of the tuberous roots. Affected tubers decay in storage, especially if kept moist.
Delphinium, Larkspur	Enlarging, chocolate brown, sunken, water-soaked cankers form in the petioles and stems. The centers of older cankers, which may be a foot or more long, shrink, appear bleached, and are covered with masses of salmon pink *Fusarium* spores. The fungus eventually reaches the crown, the vascular system turns brown, and the young basal shoots wilt. Lastly, foliage above the stem canker may wilt. Yellowing of the leaves and wilting and drooping of the flower head may occur.
Freesia	Affected plants are often stunted and yellowish, then gradually wilt, die, and collapse. Roots are pinkish, later turn dark brown, and are covered by a whitish pink coating of *Fusarium*. Infected corm tissue is yellow, then dark brown and shrunken. The entire corm eventually becomes chalky white, hard, dry, and crumbles easily.
Geranium	Seedlings lack vigor. Older leaves turn yellow. A brown rotted area develops at or near the soil line, over which a white mold (*Fusarium*) may form.
Gladiolus (Figure 4)	Progressive yellowing, browning, and premature dying of the leaves from a rot at the soil line and below. A firm brownish to black dry corm rot (Figure 4), usually starting at the base and core, extends upward into the leaf bases. Roots may decay. Corms may rot before digging, in storage, or after planting. Corms and plants may be infected but show no obvious symptoms.
Iris	Bulbs fail to grow, or the young plant is stunted, turns yellow, wilts, and dies from a rather firm basal rot of the bulb that is shrunken and light to reddish brown or dark brown. Such bulbs have few or no roots. The husks are matted or adhere firmly to the bulb. Sometimes a white- or red-tinged mass of *Fusarium* is visible.
Lily	The lower leaves turn yellow or purple and die prematurely from a chocolate brown or bluish gray basal rot of the bulb. Plants are stunted. Infected bulb scales fall away easily. The surface of rotting scales remains smooth until disintegration begins.

Narcissus (Figure 5)	Shoots arising from diseased bulbs may be stunted, distorted, turn yellow, and die prematurely. Roots are few or there are none. The basal plate of the bulb is partially or entirely decayed with a dry and spongy, chocolate brown to purplish brown rot that usually progresses into the scales and eventually rots the entire bulb (Figure 5). A white or pinkish white mold usually develops between the scales and sometimes on the surface at the base. The disease is most common in double nose and mother bulbs during storage and transit.
Pansy, Violet, Viola	Plants suddenly wilt and die from a dark sunken area on the stem near the soil line. The root system is destroyed, leaving only the stubs of the main roots.
Petunia	Infected plants gradually wilt and eventually are severely stunted. In advanced stages, entire plants die.
Stock	The lower leaves turn yellow, wither, and drop, starting at the stem base, often on one side of the plant only. Plants are stunted and may die suddenly. A brown discoloration develops in the vascular system within the roots and stems.
Sweet William	Plants of all ages are attacked. The leaves on young shoots gradually turn partially or completely yellow. Diseased plants finally become conspicuously stunted. A brown discoloration occurs within the vascular system of the roots and lower stems.
Tulip	Diseased bulbs fail to sprout or produce leaves that turn red, wilt, and die prematurely. Such bulbs develop few roots. Diseased bulbs are dull gray to chalky white with a rather firm, shrunken basal rot that may appear zoned. A white to pink, felt-like mold of *Fusarium* may develop on or under the husk, usually at the base of the bulb. This is primarily a storage disease that is aided by mites.