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VERTICILLIUM WILT OF VEGETABLES AND HERBACEOUS ORNAMENTALS

Verticillium wilt is a disease of over 300 species throughout the United States. This includes a wide variety of vegetables and herbaceous ornamentals. Tomatoes, eggplants, peppers, potatoes, dahlia, impatiens, and snapdragon are among the hosts of this disease. Plants weakened by root damage from drought, waterlogged soils, and other environmental stresses are thought to be more prone to infection.

Since Verticillium wilt is a common disease, breeding programs have contributed many varieties or cultivars of plants with genetic resistance—this has significantly reduced the prevalence of this disease on many plants, especially on vegetables. However, the recent interest in planting "heirloom" varieties, which do not carry resistance genes, has resulted in increased incidence of Verticillium wilt on these hosts.

Verticillium wilt is caused by two closely related soilborne fungi, *Verticillium dahliae* and *V. albo-atrum*. Isolates of these fungi vary in host range, pathogenicity, and virulence. *Verticillium* species are found worldwide in cultivated soils.

SYMPTOMS AND DISEASE DEVELOPMENT:

Symptoms of Verticillium wilt vary by host and environmental conditions. In many cases, symptoms do not develop until the plant is bearing flowers or fruit or after periods of stressful hot, dry weather. Older leaves are usually the first to develop symptoms, which include yellowing, wilting, and eventually dying and dropping from the plant. Infected leaves can also develop pale yellow blotches on the lower leaves (Figure 1) and necrotic, V-shaped lesions at the tips of the leaves.

Figure 1. Yellow blotches on lower leaves of eggplant infected with Verticillium wilt.

As the disease progresses, younger leaves begin to wilt and die until healthy leaves are only visible at the top of the plant. Symptoms often appear one-sided, developing on half of a leaf (Figure 2), on half of a leaflet of a compound leaf (Figure 3), or on half of a plant.

Figure 2. Verticillium-infected eggplant with leaves exhibiting symptoms on half of each leaf.

Figure 3. Tomato leaflet with symptoms on half of a leaflet.

Highly susceptible plants wilt and die shortly after initial symptoms appear (Figures 4 and 5). In contrast, although some plants can be infected with Verticillium wilt, they are not killed but are stunted and weak and produce undersized flowers or fruit, depending on the host.

Figure 4. Pepper with irreversible symptoms of Verticillium wilt.

Figure 5. Field of eggplant with symptoms of Verticillium wilt.

A diagnostic characteristic of Verticillium wilt is distinctive discoloration or streaking in the vascular system. When the stem is cut in cross-section, the ring of vascular tissue is brown and the pith remains white. This discoloration is also visible with longitudinal cuts (Figure 6). Discoloration can also occur in roots and tubers (Figure 7) but usually does not occur in the leaf petioles. Since the discoloration of the vascular system is almost identical to that associated with Fusarium wilt, positive diagnosis of Verticillium wilt requires culturing tissues in the laboratory.

Figure 6. Characteristic discoloration in xylem of Verticillium-infected eggplant.

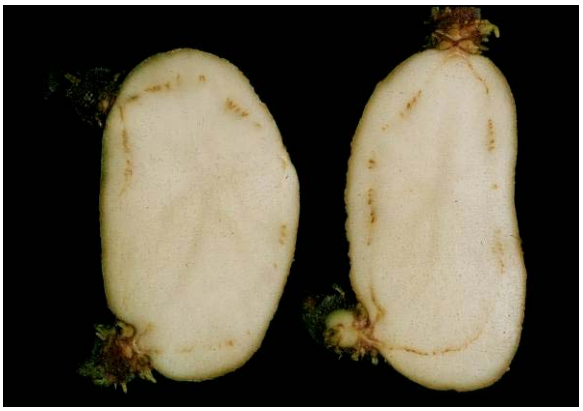

Figure 7. Discoloration in the vascular tissues of potato tubers of a plant infected with Verticillium wilt.

Verticillium species are soilborne and persist for indefinite periods of time in the soil as resting structures called microsclerotia. Germination and growth of these structures is stimulated by exudates from a host plant or from decaying organic matter. The fungus enters the roots and the water transport system (xylem) of the plant. It then grows, sporulates, and moves systemically throughout the plant. Spores (conidia) are ovoid and are borne on specialized hyphae (phialides) in a whorl around a conidiophore. Verticillium is named for this verticillate or whorled arrangement of the phialides on the conidiophore (Figure 8). The presence of the fungus in the xylem restricts movement of water and nutrients by its physical presence as well as through production of enzymes and toxins. As the fungus grows in the xylem, the plant responds in both physical and biochemical ways to contain or compartmentalize the fungus. This results in plugging and gumming of water-conducting vessels, which further restricts water in the host.

Figure 8. Verticillate spore-bearing structures on conidiophores.

As more vessels are plugged and collapse, the water supply to the leaves is blocked. In the early stages of infection, plants wilt after a hot, sunny day and recover at night. As the disease progresses, the wilt becomes irreversible.

Verticillium wilt also occurs on a wide range of woody and herbaceous hosts. The fact sheet "Verticillium Wilt of Ornamental Trees and Shrubs" has more information on the effects of the disease on woody hosts.

MANAGEMENT STRATEGIES:

Managing Verticillium wilt is most successful using a multifaceted strategy. There are no satisfactory controls for this disease once plants are infected.

- Fungicides are not effective for control.
- For plants that exhibit mild symptoms, it can help to maintain vigor by following sound cultural practices. These include watering during periods of drought and fertilizing (based on a soil test). Mulching is also beneficial since it helps maintain soil moisture and moderate soil temperatures. Although infected plants cannot be cured, these practices can sometimes delay the progression of the disease until the crop can be harvested.
- *Verticillium* fungi can survive for many years as microsclerotia in the soil. Therefore, it is necessary to avoid planting susceptible species in areas known to be infested. In these cases, resistant or immune species should be planted (Tables 1 and 2). Lists of specific varieties or cultivars of common vegetables with genetic resistance are in Table 3.
- Long rotations of four to five years with non-related crops can be helpful but are not usually feasible in home gardens.
- Since microsclerotia can be present in soil or debris, it is important to avoid moving soil or debris from areas of known infection.
- Weed control is helpful since the fungus can infect a variety of common weeds such as ragweed, cocklebur, and velvetleaf.
- As a precaution against spread, all tools should be disinfested between cuts with a 10% solution of household bleach, 70% alcohol, or one of the commercial products such as Physan 20.

Table 1. Resistance of Selected Herbaceous Ornamentals to Verticillium Wilt.

Susceptible	Resistant or Immune
African daisy (*Arctotis* spp.)	Ageratum (*Ageratum* spp.)
Aster (*Aster* spp.)	Alyssum (*Alyssum* spp.)
Belladonna (*Atropa belladonna*)	Anemone (*Anemone* spp.)
Bellflower (*Campanula* spp.)	Baby's breath (*Gypsophila paniculata*)
Black-eyed Susan (*Rudbeckia hirta*)	Balloon flower (*Platycodon grandiflorum*)
Blue sage (*Salvia azurea* var. *grandiflora*)	Browallia (*Browallia* spp.)
Butterfly flower (*Schizanthus pinnatus*)	Calendula, pot marigold (*Calendula officinalis*)
Cape marigold *(Dimorphotheca sinuata*)	Candytuft (*Iberis* spp.)
China aster (*Callistephus chinensis*)	Christmas rose (*Helleborus niger*)
Chinese lantern plant (*Physalis alkekengi*)	Cleome (*Cleome* spp.)
Chrysanthemum (*Chrysanthemum* spp.)	Columbine (*Aquilegia* spp.)
Cockscomb (*Celosia argentea* var. *cristata*)	Coral bells (*Heuchera sanguinea*)
Dahlia (*Dahlia variabilis*)	English daisy (*Bellis perennis*)
Foxglove (*Digitalis purpurea*)	Evening primrose (*Oenothera* spp.)
Garden balsam (*Impatiens balsamina*)	Gaillardia (*Gaillardia* spp.)
Gayfeather (*Liatris* spp.)	Geum (*Geum* spp.)
Geranium (*Pelargonium* x *hortorum*)	Hollyhock (*Althaea rosea*)
Heliotrope (*Heliotropium arborescens*)	Honesty, silver dollar (*Lunaria annua*)
Jacob's ladder (*Polemonium* spp.)	Impatiens (*Impatiens sultani*)
Lobelia (*Lobelia erinus*)	Lantana (*Lantana* spp.)
Oriental poppy (*Papaver orientale*)	Monkey flower (*Mimulus* spp.)
Pelargonium (*Pelargonium* x *domesticum*)	Moss rose (*Portulaca grandiflora*)
Peony (*Paeonia* spp.)	Nasturtium (*Tropaeolum majus*)
Petunia (*Petunia hybrida*)	Nemesia (*Nemesia strumosa*)
Phlox (*Phlox* spp.)	Pansy, viola, violet (*Viola* spp.)
Rocket larkspur (*Delphinium ajacis*)	Penstemon (*Penstemon* spp.)
Sage (*Salvia haematodes*)	Periwinkle (*Vinca minor*)
Shasta daisy (*Leucanthemum* x *superbum*)	Persian buttercup (*Ranunculus asiaticus*)
Snapdragon (*Antirrhinum majus*)	Pinks, sweet William (*Dianthus* spp.)
Stock (*Matthiola incana*)	Potentilla (*Potentilla* spp.)
Strawflower (*Bracteantha bracteata*)	Primrose (*Primula* spp.)
Sweet pea (*Lathyrus odoratus*)	Scabiosa, sweet scabious (*Scabiosa atropurpurea*)
Tickseed (*Coreopsis lanceolata*)	Sunflower (*Helianthus* spp.)
Transvaal daisy (*Gerbera jamesonii*)	Tuberous begonia (*Begonia tuberhybrida*)
	Verbena (*Verbena* x *hybrida*)
	Wallflower (*Cheiranthus cheiri*)
	Wax begonia (*Begonia semperflorens*)
	Wishbone plant (*Torenia fournieri*)
	Zinnia (*Zinnia* spp.)

Table 2. Resistance of Selected Vegetables and Field Crops to Verticillium Wilt.

Susceptible	**Resistant or Immune**
Brussels sprouts (*Brassica oleracea* var. *gemmifera*)	Asparagus (*Asparagus officinalis*)
Cabbage (*Brassica oleracea* var. *capitata*)	Bean (*Phaseolus* spp.)
Cantaloupe, honeydew, muskmelon (*Cucumis melo*)	Carrot (*Daucus carota*)
Cucumber (*Cucumis sativus*)	Celery (*Apium graveolens*)
Eggplant (*Solanum melongena)*	Lettuce (*Lactuca* spp.)
Horseradish (*Armoracia lapathifolia*)	Pea (*Pisum sativum*)
Mint (*Mentha* spp.)	Sweet potato (*Ipomoea batatas*)
New Zealand spinach (*Tetragonia expansa*)	
Pepper (*Capsicum* spp.)	
Potato (*Solanum tuberosum*)	
Pumpkin (*Cucurbita pepo*)	
Radish (*Raphanus sativus*)	
Rhubarb (*Rheum rhaponticum*)	
Rutabaga (*Brassica napobrassica*)	
Salsify (*Tragopogon porrifolius*)	
Spinach (*Spinacia oleracea*)	
Tomato (*Lycopersicon esculentum*)	
Watermelon (*Citrullus vulgaris*)	

Table 3. List of Selected Vegetables with Resistance or Tolerance to Verticillium Wilt.

Host	**Variety***
Tomato	Early Cascade (VF), Celebrity (VFN), Jet Star (VF), Show Me (VF), Burpee's (VF), Beefmaster (VFN), Celebrity (VFN), Sunny (VF), Carolinia Gold (FV), Baja (VFN), Betterboy (VFN)
Potato	Century Russet, Gold Rush, Itasca, Ranger Russet, Reddale, Targhee
Eggplant	No cultivars are resistant or tolerant. However, Classic, Rosa Bianca, and Italian Bicolor will survive enough to yield a harvest.

*Key to Abbreviations: Letters indicate resistance or tolerance. V=Verticillium Wilt, F=Fusarium Wilt, N=Nematode.

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