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VERTICILLIUM WILT DISEASE

Verticillium wilt is a serious disease that affects over 300 host plants in numerous plant families (Tables 1 and 2). The host range includes trees, shrubs, ground covers and vines, vegetables, field crops, fruits, herbaceous ornamentals, and many weeds.

Figure 1. Norway maple showing Verticillium wilt damage.

The disease is caused by the common soil-borne fungi *Verticillium albo-atrum* and *Verticillium dahliae*. Researchers now believe that *V. albo-atrum* is found mainly in Canada and Europe while V. dahliae is the species prevalent in the Midwest. Most soils in Illinois and other crop-growing areas throughout the world contain numerous strains or pathotypes of Verticillium that show definite host plant preferences.

Once the Verticillium fungus is introduced into a field or garden, it can survive for several years in the soil. Propagules of *Verticillium* are brought into new areas by flowing water (for example, irrigation furrows); by strong winds; on seed, tools, or farm machinery; and in the soil and roots of transplants or nursery stock.

Symptoms of Verticillium wilt are easily confused with two other widespread diseases, Fusarium wilt or yellows and bacterial wilt. However, Verticillium wilt is found mostly in temperate zones and is prevalent in the northern states having relatively low soil temperatures (optimum 70°F or 21°C). The disease is most severe in Illinois during cool to warm weather, but not as prevalent in hot weather.

It is not unusual for every plant in a badly infested field to be infected, especially where susceptible crops have been grown for many years. If weather conditions are unfavorable for Verticillium development, only a slight reduction in yield or quality may occur.

The fungus produces toxins that cause tyloses or gums to form in the vascular (water-conducting) tissues, resulting in a greatly decreased flow of water from the roots to the foliage. This lack of water results in wilting, the characteristic symptom of the disease, and often death of the host.

Symptoms

Vascular discoloration or streaking, consisting of dark-colored, elongated, necrotic tissue, occurs in both woody and herbaceous stems. This streaking may be accompanied by external symptoms, such as wilting,

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the yellowing and death of leaves, and the death of branches or entire plants. Chronic symptoms may follow, including stunted, chlorotic, and deformed foliage; leaf scorch; slow growth; abnormally heavy seed crops; and the dieback of shoots and branches.

WOODY HOSTS. The external symptoms of Verticillium wilt vary and are often difficult to recognize. Usually the foliage on one or more twigs of a branch suddenly wilts. An overall yellowing of the foliage sometimes precedes wilting. When the first wilting stage is not detected, wilt symptoms may appear on an entire branch or in the whole crown (Figure 1). Most trees and shrubs show leaf symptoms in early July. However, in the Midwest some trees may show symptoms as early as March and as late as November. Some tree species, such as ash, may defoliate while still green before noticeable yellowing or wilting has occurred.

Decline in twig growth and the dieback of individual twigs and branches are other external symptoms of Verticillium wilt. In certain trees, such as maple and tuliptree, elongated dead areas of bark may occur on diseased branches or trunks where the inner bark is killed. Water-soaked areas may develop under the dead bark.

Figure 2. Typical discoloration on diseased sapwood from infected maples (IL Nat Hist Survey).

Trees or shrubs that develop a limited amount of branch wilt during a growing season may show additional wilt and dieback the following year. Still others may recover and not wilt in succeeding years or may wilt again after several years. Little information is available about year-to-year behavior of the pathogen in woody hosts. Recurrence is unpredictable.

Figure 3. Verticillium wilt of eggplant. Note the wilted and curled leaves (arrow).

The characteristic internal symptom of Verticillium wilt on woody hosts is the discoloration of the sapwood that occurs in the twigs, branches, and trunk during advanced stages of foliage wilt. When infected wood is cut at a slant, the discoloration in most woody species is brown (Figure 2). In infected maple, magnolia, and sumac plants, the streaks are light to dark green. In all ash species, internal discoloration is rare and seldom observed in diseased plants.

HERBACEOUS HOSTS

Nearly all nonwoody plants are similarly affected. The lower and older leaves often turn yellow and later wilt and wither. The symptoms gradually progress to the upper parts of the plant (Figure 3). Diseased plants are often stunted and, if infected early, generally die prematurely. Midday wilting, followed by evening recovery, is common for a time.

For example, outward symptoms on tomato may not develop until the plants are bearing heavily or are under drought stress. Yellow blotches then can develop on older leaves and the veins within the yellowed areas show a brown discoloration. Light, chocolate brown dead areas later

develop in these blotches. Yellowing and wilting of the lower leaves occur first. Later, the upper leaves become pale green and the margins of the leaves tend to curl upward.

Symptoms of Verticillium wilt on herbaceous hosts, such as tomato, can easily be confused with Fusarium wilt, bacterial wilt, or bacterial canker (Figure 4). Laboratory culturing and identification of the causal organism are necessary to distinguish these diseases. Verticillium wilt of strawberries can also be mistaken for drought, red stele disease, black root rot, or winter injury. Again, a culture is necessary for positive identification.

Root-knot nematodes and lesion nematodes in combination with Verticillium wilt on eggplant, pepper, potato, and tomato have been reported to have a synergistic effect. When the Verticillium fungus is not widespread in an herbaceous bed, only an occasional plant or scattered plants may wilt and die, but when the disease is serious, large numbers of plants can wilt, wither, and die quickly.

Figure 4. Symptoms of tomato wilts: (a) bacterial canker; (b) Verticillium wilt; (c)Fusarium wilt (IL Exper Station).

A cross-section of the stem of an infected herbaceous plant at or near the soil line shows a brown discoloration in the vascular tissue. The discoloration is most noticeable in the nodes where the branches begin.

Disease Cycle

Both *Verticillium albo-atrum* and *V. dahliae* (Figure 5) produce one-celled, colorless conidia that are short-lived. *Verticillium dahliae* also produces minute, black, resting structures--called microsclerotia--(Figure 5e), while *V. albo-atrum* produces microsclerotial-like dark, thick-walled mycelium but not microsclerotia. Optimum growth of *V. albo-atrum* occurs at 68° to 77°F (20° to 25°C), while *V. dahliae* prefers slightly higher temperatures (77° to 81°F or 25° to 28°C) and is somewhat more common in warmer regions. Different strains within each species differ considerably in virulence and other characteristics. Although some *Verticillium* strains show host specialization, most of them attack a wide range of host plants. Agricultural soils may contain up to 100 or more microsclerotia per gram. Six to 50 microsclerotia per gram are sufficient to generate 100 percent infection in such susceptible crops as eggplant, pepper, potato, and tomato.

The two Verticillium wilt fungi (Figure 5) invade the root systems of host plants through wounds or by direct penetration. Once within a root, the fungi invade the water-conducting tissue (xylem) of the host and then spread upward through the plant. The disease is spread by fungal spores (conidia) being transported upward in the sapstream where they may become lodged, germinate, and affect new plant parts. Wilt symptoms typically are not observed until the fungus has colonized the roots, stems, or trunks of trees and shrubs. Wounds on the trunk, branches, and twigs of trees may also serve as sites for infection by insect transmission of the fungus.

After the host dies or the growing season ends, both *Verticillium* fungi survive as mycelia overwintering

in dead plant parts that have fallen to the ground; the fungi may also live saprophytically in the soil whether or not a host is available. Survival can occur in roots of nonhost species in which systemic infection does not occur. *Verticillium* is known to naturally colonize soils where susceptible hosts have never been grown.

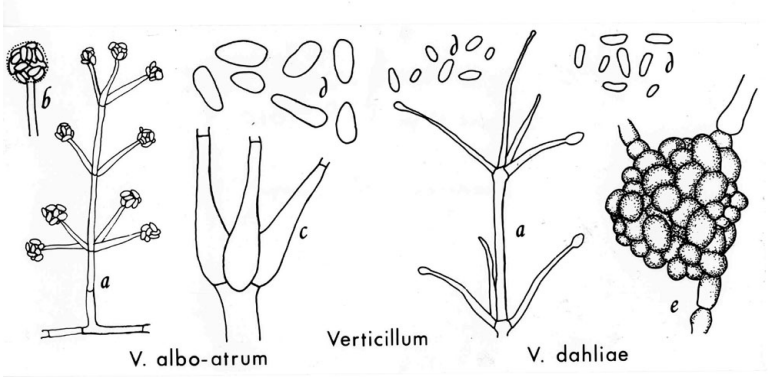

Figure 5. Verticillium wilt fungi under microscope: (a) verticillate conidiophores; (b) conidial head; (c) close-up of conidiophore branching; (d) conidia; (e) mature microsclerotium (drawing by L. Gray).

The microsclerotia are capable of long-term survival (up to 15 years) without contact with a host plant. They may be introduced into uncolonized areas by wind or water where they serve as new inoculum. *Verticillium* may also be spread by contaminated seed, vegetative cuttings, transplants, tubers, scions, buds, nursery plants, rootballs, or the bare roots of infected trees. In addition, mycelia and microsclerotia may be transported by normal tillage operations, hand tools, or farm machinery. Once contact is made with a new host, the fungi again infects the root system, progresses upward, and the cycle is repeated.

Control

The Verticillium wilt fungi are difficult to control. Their ability to survive in the soil for long periods **with** or **without** a host plant and the colonization of the water-conducting tissues within a plant limit any scheme to eradicate the pathogens.

The first effort to manage *Verticillium* starts with proper diagnosis. Only laboratory culturing of infected plant material can positively identify *Verticillium* as the causal agent. Similar symptoms are produced by other pathogens. When *Verticillium* has been identified, several measures can be taken to reduce the effects of the disease in nurseries, fields, and landscape plantings.

While various fungicides have been tested for application directly to plants, none have been found practical for continued use. An exception is the use of benomyl (Benlate 50 WP) fungicide as a root dip for transplanted seedlings. Benomyl, however, is a temporary measure and will not protect the plant after new roots emerge and colonize the untreated soil.

Chemical control of Verticillium wilt has been shown to be economically practical in strawberry beds, in small vegetable or flower beds, and in soil in greenhouse benches. A common procedure is to treat the soil with a soil fumigant. These chemicals also will control weeds, insects, and nematodes in the soil.

Fumigation is usually done **not** by the grower but by commercial applicators who are licensed to handle restricted chemicals. Prevention of the disease and the use of resistant varieties or cultivars are perhaps the best methods for controlling Verticillium wilt.

Following are some suggested recommendations:

1. Steam the soil used for potted plants or for bench crops in the greenhouse and nursery at 180°F (82°C) for 30 minutes or 160°F (71°C) for one hour.

2. Do not grow susceptible plants on land where crops previously have been killed by Verticillium wilt. For vegetables, flowers, and field crops, rotations of five years or more may help to reduce the amount of infection. Only nonhost crops should be used in the crop rotation cycle (Table 3).

2. Control weeds that can act as inoculum reservoirs in and around planting sites. Common weed hosts include ground cherries, lamb's-quarter, pigweed, horse nettles, and velvet leaf.

4. Fertilize to promote vigorous growth and maintain a balance of nitrogen, phosphorus, and potassium. Fertilizing can help reduce symptoms in nursery, field, and landscape plantings. Apply a fertilizer containing ammonium sulfate following the suggestions in a soil test report. Affected trees and shrubs should be fertilized and watered as soon as possible after initial wilt symptoms are exhibited. For quick response, the fertilizer should either be injected into the soil in liquid form or be applied to the soil surface and watered in. Ammonium sulfate can be applied at the rate of 29 pounds per 1,000 square feet. Water well immediately after application.

5. Water trees and shrubs that show symptoms every 10 to 14 days during dry periods of the growing season, applying 1 to 2 inches (600 to 1,200 gallons per 1,000 square feet) each time.

6. Destroy dead plants in nurseries or flower beds, removing as much of the root system as possible.

7. Branches or entire trees with recent wilt symptoms should not be removed immediately. They may recover in response to watering and fertilizing (see 4and 5 above). Dead branches on trees should be removed. Cut well below the area of internal discoloration. This wood should not be chipped and used as a mulch as it may spread the fungus to other plantings. Pruning tools should be disinfected by swabbing them with 70 percent rubbing alcohol after working on an infected plant.

8. Plant only resistant species, varieties, or cultivars where Verticillium wilt is a problem (Table 3).

Table 1. North American Trees and Shrubs Susceptible to Verticillium Wilt

Almond
Apricot
Ash
  Black
  Blue
  European
  Green
  White
Azalea (Rhododendron molle)
Barberry
  European
  Japanese
Boxelder
Catalpa
  Northern
  Southern
  Western
Cherry
  Sour or tart
  Sweet
Chestnut, Spanish
Chinaberry
Coffee tree, Kentucky
Cork tree, Amur
Cotoneaster
Cotton
Currant
Deutzia
Dogwood
Elder
Elm
  American,
  'Augustine Ascending',
  'Henry Field',
  'Littleford',
  'Moline'
  Chinese
  English
  Slippery
Goldenrain tree
Holly osmanthus
Honeysuckle
Horse chestnut
Indian hawthorn
Judas-tree or redbud
Lilac
Linden
  American
  Little-leaf
Locust, black
Magnolia
  Saucer
  Southern Star
Maple
  Amur
  Bigleaf
  Black
  Hedge
  Japanese
  Norway, 'Crimson King',
  'Schwedleri'
  Oregon
  Painted
  Red
  Silver
  Striped
  Sugar
  Sycamore
Oak
  Pin
  Red
Olive
Osage orange
Pagoda tree, Japanese
Peach
Pear
Persimmon
Plum
  Canada
  Garden
Privet, Amur
Quince
Rose, daphne
Rose, multiflora
Russian-olive
Sassafras
Smoke tree
Sour gum or tupelo
Spirea
Sumac
  Fragrant
  Smooth
  Staghorn
Tulip tree
Viburnum
  Burkwood
  Doublefile
  Japanese
  Snowball
Wayfaringtree
Yellowwood

Table 2, Partial List of Nonwoody Plants Susceptible to Verticillium Wilt

Abutilon
Aconite
Alfalfa
Artichoke
Aster, China
Bachelor's button or cornflower
Balsam, garden
Bean, broad
Beet
Begonia
Bergamot, wild
Belladonna
Blackberry
Black-eyed Susan or Rudbeckia
Blazing star
Butterfly flower
Calceolaria
Campanula
Cantaloupe
Cape marigold
Carnation
Castor bean
Chrysanthemum
Cineraria, florist's
Clarkia
Coleus
Crown of thorns
Cucumber
Dahlia
Daisy, Shasta
Dame's rocket
Dandelion
Dewberry
Eggplant
  Scarlet
  Tomato
Feverfew, American
Fleabane or Erigeron
Foxglove
Fuchsia
Gayfeather
Geranium, florist's
Ginseng, American
Grape
Ground cherries
Groundsel
Heather
Hebe
Heliotrope, common
Hibiscu
Hop
Horsenettles
Horseradish
Jerusalem cherry
Lamb's-quarter
Lantern plant, Chinese
Larkspur, rocket
Liatris
Lily-of-the valley, wild
Lupines
Marguerite
Melon
  Honey dew
Persian
Mignonette
Monarda
Monkshood
Muskmelon
Nettle, beaked
Nightshade, silver
Painted tongue
Pea
  Black-eyed
  Sweet
Peony
Pepper
Peppermint
Petunia
Pigweed
Poppy mallow
Potato
Pumpkin
Pyrola, pink
Radish
Raspberry
Rhubarb
Sage
  Blue
  Mealy-cup
Salsify
Slipperwort
Snapdragon
Spearmint
Spinach
Stock
  Common
  Evening scented
Strawberry
Sunflower
Thimbleberry
Tickseed
Tobacco
Tomato
Udo
Velvet leaf
Watermelon
Zinnia

Table 3. Woody Ornamentals That Are Not Known To Be Susceptible To Verticillium Wilt

Arborvitae	Katsura-tree
Aspen	Larch
Bald cypress	Mountain-ash
Beech	Mulberry
Birch	Oak, bur and white
Boxwood, Korean	Pawpaw
Crabapple	Pecan
Fir	Pine
Ginkgo	Planetree, London
Hackberry	Poplar
Hardy rubber tree	Serviceberry
Hawthorn	Spruce
Hazelnut	Sweet gum
Hickory	Sycamore
Holly	Tree-of-heaven
Honeylocust	Walnut
Hornbeam	Willow
Hophornbean	Yew
Juniper (red cedar)	Zelkova

Adapted from E. B. Himelick, Verticillium Wilt of Trees and Shrubs, Illinois Natural History Survey, Leaflet B-1.