Verticillium Wilt of Olive

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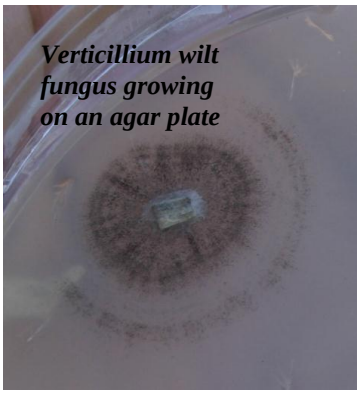
Verticillium wilt symptoms on a large tree

Verticillium wilt is a soil-borne fungus disease caused by the organism (*Verticillium dahliae).* It is one of the most serious diseases of olive trees worldwide because it can kill trees and is difficult or impossible to control. The presence of high levels of certain strains of Verticillium in soil effectively renders the land unusable for olive growing. Over 30 years ago we had entire table olive orchards in California that were destroyed from this disease. We have recently observed, in a few new orchards in California, that some trees have been positively identified as having Verticillium, so this disease must be taken seriously.

SYMPTOMS

Symptoms appear as wilting, leaf rolling, chlorosis, defoliation, and dead brown leaves remaining attached to the branches. On large trees, one or more branches suddenly wilt early in the growing season. Disease generally becomes worse as the season progresses. Yield from infected trees is poor and after several years eventually die. On very young trees, the whole tree begins to look pale and stops growing. The leaves wilt and the tree dies. Darkening of xylem tissue does not occur in olive wood as it does in other species. The most common symptom on all Verticillium infected trees is chlorosis (yellowing of the leaves) followed by defoliation. In some cases, very susceptible cultivars defoliate without leaf chlorosis. Sudden wilt, leaf rolling, and chlorosis is sometimes observed at the same time.

DISEASE DIAGNOSIS



Verticillium wilt fungus growing on an agar plate

Beyond symptoms, positive identification of the presence of Verticillium is typically done by placing thin pieces of infected vascular tissue onto specific types of agar culture medium. After about 4 days of incubation the fungus grows out and can be identified microscopically. Small black thick walled resting structures, called microsclerotia are formed and can be seen with a hand lens. A new technique for identifying the pathogen uses polymerase chain reaction (PCR)-quality DNA extracts. There are several vegetative compatibility groups that are specifically related to host plants. In olive there are two strains, defoliating and non-defoliating, that are quite different in their virulence.

DISEASE PROGRESSION

Verticillium wilt is favored by cool moist soils at temperatures ranging from (70-81^{o} F). Root exudates in contact with microsclerotia stimulate germination, hyphal growth, and penetration into the root cortex and xylem cells (water conducting tissues). Inside the plant's vascular system fungal conidia are produced. The conidia are passed through the vessels where they often become trapped. Germination allows mycelium to pass through the ends of the vessels where the fungus once again produces conidia that move further up the xylem. This presence in the water conducting tissue causes the tree to produce gums and tyloses in the vessels thus helping "wall off" or compartmentalize the infection. This also leads to further plugging of the xylem cells leading to wilt and color loss in the upper part of the plant. The time from infection to first symptoms can be 3-30 weeks. Inside dying plant parts, the fungus produces microsclerotia, which are resting structures that can live for many years in the soil in dormancy after the plant decomposes. *Verticillium dahliae* microsclerotia (resistant spores) have been documented to survive for at least 30 years in the soil.

Verticillium wilt symptoms on a branch

Some trees have been observed to recover naturally from an initial Verticillium infection. The degree of recovery depends on the strain of the fungus (defoliating or non-defoliating, the resistance of the cultivar, and inoculum density in the soil. Trees infected with the defoliating strain or infections in general in cultivars that are very susceptible to Verticillium rarely recover. In contrast, varieties that are more resistant or that have been infected by the non-defoliating strain of the disease often will recover (see table 1). The amount of inoculum in the soil has a significant effect on initial infection and reinfection rates.

SPREAD OF THE PATHOGEN

This fungus does not have a known sexual stage. The hyphae produce conidia asexually and under conditions of fungal stress masses of microsclerotia are produced. Verticillium gets into soil from infected soil or plant material. Movement of soil by wind, water, or dirty equipment carries the fungus into uninfested soil. Spread can occur by bringing in non-symptomatic infected vegetatively propagated olive trees or other host plants grown as an intercrop. Host plants include many ornamental tree and herbaceous flower species; several vegetable crops: cabbage, celery, cucumber, eggplant, lettuce, melons, pepper, potato, pumpkin, radish, squash, tomato, and watermelon; several fruit crops: cane berries, Prunus species, Ribes species, grapes, and strawberry. There are several common weed hosts including groundsel, lambsquarters, nightshade, pigweed, shepardspurse, and velvetleaf. Host plants can build up inoculum levels within the leaves, stems, and roots, which then contribute to the resting population in soils. Unfortunately, even non host plants such as grains and legumes may serve as a reservoir of the pathogen in some environments.

Verticillium wilt symptoms on strawberry

DISEASE PREVENTION and MANAGEMENT

The surest way to prevent this disease is to make sure that Verticillium microsclerotia are not present in the soil of any prospective orchard. This is usually done by staying away from land that had been planted to crops that are highly susceptible to Verticillium wilt, such as cotton, cucurbits, eggplant, peppers, potato, or tomato. The soil can also be tested. For susceptible cultivars, the two most important factors to consider are (1) the strain of the fungus (defoliating or non-defoliating) and (2) the amount of inoculum expressed as number of microsclerotia per gram of soil. Almost any level of infestation (inoculum density) in the soil can cause significant disease problems in olives especially if the defoliating strain is involved or if very susceptible cultivars are grown. Recent research in Spain has shown that when the number of defoliating strain microsclerotia per gram of soil exceeds 3.33 the disease incidence can be 50% or greater after 2.5 years, and can kill 40-100% of the susceptible olive cultivar trees. It has also been observed that higher initial inoculum densities lead to more disease. Any level above 1.0 microsclerotia per gram of soil is considered too risky for olives. Some Verticillium appeared in all of the Spanish test plots even at microsclerotia levels of 0.4/g of soil, but with inoculum levels below 1.0 microsclerotia per gram less than 15% of the trees showed disease symptoms after three years. In soils containing only the non-defoliating strain of Verticillium disease severity is much lower.

Steps should be taken to prevent the introduction of Verticillium onto the ranch. Make sure no soil is brought onto the ranch from trucks or farm equipment. Do not intercrop olives with susceptible plant hosts. No weeds, especially broad leaves that harbor Verticillium should be allowed to grow in the orchard.

Inoculum levels can be reduced before planting by soil solarization, flooding the fields during summer, growing several seasons of grass or crucifer cover crops, fumigation, or a combination of these treatments. Soil solarization (elevated temperature) can reduce microsclerotia inoculum levels to almost undetectable levels within the top foot of soil. Several solarization experiments in Europe in existing Verticillium infected orchards stopped the progression of the disease for about three years. Soil flooding and crop rotation have also been shown to reduce inoculum levels. Incorporating a ryegrass or sudangrass cover crop or cruciferous residues such as broccoli has been shown to have an eradicative effect on Verticillium. It may be that other organic soil amendments would have similar effects due to the development of antagonistic microorganisms or from inactivation from toxic volatile products released by the amendments. Soil fumigation with methyl bromide and chloropicrin, has been shown to reduce inoculum levels by 85-95%. Whether any of these practices are sufficient to make much of a difference is unknown, however. Dry farmed orchards in Europe where drip irrigation was added to improve production have suffered greater losses from Verticillium because the fungus proliferates in the wetted drip zone.

Table 1. OLIVE VARIETY SUSCEPTIBILITY TO VERTICILLIUM

Variety	*Resistance Level*
Aglandau	**Resistant**
Arbequina	**Susceptible**
Arbosana	**Susceptible**
Ascolano	**Resistant**
Blanqueta	**Unknown**
Bouteillan	**Very Susceptible**
Cayon	**Unknown**
Changlot Real	**Resistant**
Coratina	**Susceptible**
Cornicabra	**Very Susceptible**
Dolce Agogia	**Resistant**
Empeltre	**Very Resistant**
Frantoio/Oblonga	**Very Resistant**
Gordal Sevillana	**Susceptible**
Hojiblanca	**Very Susceptible**
Koroneiki	**Resistant**
Kalamon	**Resistant**
Leccino	**Susceptible**
Manzanilla	**Susceptible**
Maurino	**Susceptible**
Mission	**Susceptible**
Moraiolo	**Resistant**
Pendolino	**Susceptible**
Picholine	**Susceptible**
P. Marocaine	**Unknown**
Picual	**Very Susceptible**
Picudo	**Very Susceptible**

Blanco-López, M. A. and F. J. López-Escudero. 2005. U de Córdoba, Spain; Teviotdale, B. L. 2005. U of CA; López-Escudero, F. J., C. Del Rio, J. M. Caballero, and M. A. Blanco-López, 2004; Civantos López-Villalta, M. 1999, U of Jaén; Trapero, A. and M. A. Blanco. 1997

Cultivar resistance or the use of resistant rootstocks has been extensively studied as a way to potentially prevent losses from Verticillium wilt (See Table 1). There is no known rootstock that has been successfully used to protect trees. It appears that the fungus can move through the resistant rootstock into the susceptible cultivar, killing the top. Many varieties are quite resistant or immune to the non-defoliating strain, but most varieties are susceptible to the defoliating strain and none are immune to either strain. Only the varieties: Empeltre and Frantoio are very resistant. Observations in California for table varieties indicate that Ascolano is the most resistant,

Sevillano is the most susceptible, and Manzanillo and Mission were intermediate. In Spain, in an experimental plot with 2.5 microsclerotia per gram of soil, 73-84% of the very susceptible and susceptible varieties were killed when the defoliating strain was present while only 8-20% of the trees of resistant varieties were killed. Those same varieties expressed disease levels of between 47 to 84%. When only the non-defoliating strain was present, 10 to 50% of the very susceptible and susceptible cultivars died and expressed disease levels of 20 to 73%. None of the resistant and very resistant cultivars were killed and most showed disease levels of 7 to 13%. It should also be noted that in several cases trees that showed initial Verticillium wilt symptoms (non-defoliating strain) later recovered from the disease.

Trials investigating soil or plant fungicidal sprays have been unsuccessful in controlling or preventing Verticillium wilt. Chemical control by means of tree trunk injection, however, with Dodine, Fosetyl-Al and Benomyl has been demonstrated to be successful in some cases and is currently under investigation in Europe. This may be a very useful tool in specific situations with high value trees.

LABS for VERTICILLIUM IDENTIFICATION

A sample of a branch that has both dead and live tissue can be sent to a plant pathology laboratory for identification. The plant tissue should be kept cool (about 50^{o} F) in transit to the lab. Soil samples can also be evaluated for microsclerotia inoculum levels.

- Selected Private Labs Conducting Plant and Soil Disease Analysis
  http://ucce.ucdavis.edu/files/filelibrary/2161/32230.pdf

REFERENCES

1. Blanco-López, M. A. and F. J. López-Escudero. 2005. Resistencia y Susceptibilidad a la Verticilosis – Chapter 11, in: Variedades de Olivo en España. Eds. Junta de Andalucía, M.A.P.A. y Ediciones Mundi-Prensa. Madrid.

2. Blanco-López, M. A., F. J. López-Escudero and M. Moreno. 2002. Diagnóstico y lucha contra la verticilosis del olivo. Olint, No. 5, Abril. 19-25. http://www,olint.com

3. Civantos López-Villalta, M. 1999. Olive Pest and Disease Management. International Olive Oil Council. Madrid, Spain

4. Ferguson, F., P. M. Vossen, and B. L. Teviotdale. 2008. UC IPM Pest Management Guidelines: Olive Diseases. UC ANR Publication 3452. http://www.ipm.ucdavis.edu/PMG/r583100111.html

5. Fodale, A. S., R. Mulé, M. Tagliavia, and M. L. Perrotta. 2006. Chemical control of olive Verticillium wilt by "dodine" trunk injection. Proceedings of Olivebiotec. Nov. 5-10 - Mazara del Vallo, Marsala, Italy. Dipartimento colure arboree U di Palermo. Vol. II:227-230.

6. Kelley, K., G.S. Sibbett, L. Ashworth. 1983. Solarization - a tool for verticillium wilt control in orchards. UC Leaflet #21346. http://vric.ucdavis.edu/veginfo/topics/disease/Solarization-vertwilt.pdf

7. López-Escudero, F. J. and M. A. Blanco-López. 2007. Relationship between the inoculum density of *Verticillium dahliae* and the progress of Verticillium wilt of olive. Plant Disease. Vol. 91 No. 11:1372-1378.

8. López-Escudero, F. J., C. Mwanza, and M. A. Blanco-López. 2006. Reduction of *Verticillium dahliae* microsclerotia viability by dried plant residues. Crop Protection 26:127-133.

9. López-Escudero, F. J. and M. A. Blanco-López. 2005. Recovery of young olive trees from *Verticillium dahliae*. European Journal of Plant Pathology 113: 367-375.

10. López-Escudero, F. J., C. Martos-Moreno, M. C. Raya-Ortega, and M. A. Blanco-López. 2005. Resistencia del olivo a la Verticilosis causada por *Verticillium dahliae*. Vida Rural – dossier olivar. 48-54.

11. López-Escudero, F. J. and M. A. Blanco-López. 2005. Effects of drip irrigation on population of *Verticillium dahliae* in olive orchards. J. Phytopathology 153:238-239.

12. López-Escudero, F. J. and M. A. Blanco-López. 2005. Isolation and morphologic characterization of microsclerotia of *Verticillium dahliae* isolates from soil. Biotechnology, 4 (4):296-304.

13. López-Escudero, F. J., C. del Rio, J. M. Caballero, and M. A. Blanco-López. 2004. Evaluation of olive cultivars for resistance to *Verticillium dahliae*. European Journal of Plant Pathology 110: 79-85.

14. López-Escudero, F. J. and M. A. Blanco-López. 2001. Effect of single or double soil solarization to control Verticillium wilt in established olive orchards in Spain. Plant Disease. Vol. 85, No. 5:489-496.

15. McCain, A. H., R. D. Raabe, and S. Wilhelm. 1981. Plants resistant and susceptible to Verticillium wilt. University of California Leaflet 2703.

16. Mercado-Blanco, J., D. Rodríguez-Jurado, S. Parilla-Araujo, and R. M. Jiménez-Díaz. 2003. Simultaneous detection of the defoliating and non defoliating Verticillium dahliae pathotypes in infected olive plants by duplex, nested polymerase chain reaction. Plant Disease. Vol. 87, No. 12:1487-1494.

17. Mulé, R., A. S. Fodale, and A. Tucci. 2002. Control of olive Verticillium wilt by trunk injection with different doses of Fosetyl-Al and Benomyl. Acta Hort. 586:761-764.

18. Schnathorst, W.C. 1981. Life cycle and epidemiology of Verticillium. Pages 81-111 in: Fungal Wilt Diseases of Plants. E. Mace, A.A. Bell, C.H. Beckman (eds). Academic Press, San Francisco.

19. Teviotdale, B. L. 2005. Diseases of Olive - in Olive Production Manual 2nd ed. G. S. Sibbett and L. Ferguson, eds. Oakland, University of California Agriculture and Natural Resources Publication 3353. 119-222.

20. Trapero, A, and M. A. Blanco. 1997. Enfermedades. In El Cultivo del Olivo. Madrid: Junta de Andalucía Conserjería de Agricultura y Pesca, Ediciones Mundi-Prensa. 460-507.

21. Tjamos, E. C. 1991. Recovery of olive trees with Verticillium wilt after individual application of soil solarization in established olive orchards. Plant Disease. Vol. 75, No. 6:557-562