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Data Sheets on Quarantine Pests

Verticillium spp. on hops

IDENTITY

Taxonomic position: Fungi: Ascomycetes (probable anamorph)
Common names: Verticillium wilt (English) Verticilliose (French)
Verticillium Welke, Wirbelpilz-Welke (German)
Verticillosis (Spanish)
EPPO A2 list: No. 85 (on hops)

- ***Verticillium albo-atrum***

Name: *Verticillium albo-atrum* Reinke & Berthold
Synonyms: *Verticillium albo-atrum* var. *caespitosum* Wollenweber
Verticillium albo-atrum var. *caespitosum* f. *pallens* Wollenweber
Verticillium albo-atrum var. *tuberosum* Rudolph
Bayer computer code: VERTAH
EU Annex designation: II/A2 (on hops)

- ***Verticillium dahliae***

Name: *Verticillium dahliae* Klebahn
Synonyms: *Verticillium dahliae* var. *longisporum* C. Stark
Verticillium dahliae var. *medium* Wollenweber
Verticillium albo-atrum auct. pro parte
Bayer computer code: VERTDH
EU Annex designation: II/A2 (on hops)
Notes on taxonomy and nomenclature: The two species of *Verticillium* (*V. albo-atrum* and *V. dahliae*) covered by this data sheet are involved in verticillium wilt of many hosts. For phytosanitary purposes, EPPO and the EU Plant Health Directive consider only the strains which attack hops to be significant. These strains are relatively specific to hops, being more aggressive on them, but not to the extent of being designated as *formae speciales* or given distinct names.

HOSTS

The principal host of *V. albo-atrum* for phytosanitary purposes in Europe is hops (*Humulus lupulus*). Other strains attack lucerne (*Medicago sativa*), and these have been of quarantine concern elsewhere in the world (and used to be within the the EU, until 1992). *V. albo-atrum* attacks many other plant species such as cucumbers (*Cucumis sativus*), potatoes (*Solanum tuberosum*) and tomatoes (*Lycopersicon esculentum*), but these are not significant hosts for quarantine purposes. *V. dahliae* attacks hops but not (or rarely) lucerne, and also an exceptionally wide range of annual crops, e.g. cotton (*Gossypium* spp.), melons (*Cucumis melo*), rape (*Brassica napus*), strawberries (*Fragaria ananassa*), watermelons (*Citrullus lanatus*), Solanaceae and various ornamentals. It also attacks perennial crops, e.g. olives (*Olea europaea*), pistachios (*Pistacia vera*), avocados (*Persea americana*), *Prunus* spp. and various forest trees, and also weeds and even cereals. Surprisingly perhaps, citrus and pome fruits are resistant (Tjamos, 1989).

Quarantine significance only arises for the two *Verticillium* spp. in a rather special set of circumstances, where: (1) relatively host-specific aggressive strains are reported; (2) the hosts concerned are important for the region in question; (3) the strains have a restricted geographical distribution. On this basis, it is only on hops that the two *Verticillium* species may have quarantine significance for EPPO. The strains concerned cause latent infections of other hosts but too many are potentially involved for it be useful to consider them individually as carriers of the hop strains. There are other relatively host-specific *Verticillium* strains of restricted geographical distribution, e.g. on cotton, but these have not been assessed as quarantine pests.

GEOGRAPHICAL DISTRIBUTION

V. albo-atrum is widespread but predominates over *V. dahliae* in temperate regions, while *V. dahliae* is widespread but dominant in tropical and subtropical areas. The countries specifically listed in distribution maps (CMI, 1986a, 1986b) do not include all those in which these fungi are likely to be present. Furthermore, since many countries, especially in continental Europe, used to include *V. dahliae* in *V. albo-atrum*, some records of the latter may refer to the former. It is in any case not useful to record the distribution of the species, which is very wide, but rather that of the host-specific forms on hops, in so far as their presence or existence is recognized by the countries concerned.

- ***Verticillium albo-atrum* on hops**

  Strains specific to, and particularly aggressive to, hops have mainly been documented in the UK. In most other countries where *V. albo-atrum* has been recorded on hops, no particular detail is available on specificity or aggressiveness. The disease probably occurs in other hop-growing countries, but presumably only in a mild form.

  EPPO region: Belgium, France (unconfirmed), Germany (mild to moderately severe wilt), Luxembourg, Poland, Russia, Slovakia, UK (mild to severe wilt).

  North America: USA (rare cases of mild wilt in Oregon only).

  Oceania: New Zealand (rare cases of mild wilt in South Island only).

  EU: Present.

  Distribution map: See CMI (1986a, No. 365), which concerns the fungus on all hosts; not only hops.

- ***Verticillium dahliae* on hops**

  Hop wilt is generally attributed to *V. albo-atrum*, but *V. dahliae* is sometimes isolated instead. Specific country reports are few, as shown below, but *V. dahliae* wilt of hops may in fact occur wherever host and pathogen are found together. Until recently, there was no suggestion that special strains might be involved. Though differentially pathogenic strains have been reported in Germany (Zinkernagel, 1982), the German Plant Protection Service does not now consider that strains of *V. dahliae* specific to hops occur in that country. A strain aggressive to hops has been documented in the UK (Chambers *et al.*, 1985).

  EPPO region: Belgium (unconfirmed), Germany, UK.

  Asia: Azerbaijan.

  North America: USA (California, Oregon).

  EU: Present.

  Distribution map: See CMI (1986b, No. 366), which concerns the fungus on all hosts; not only hops.

BIOLOGY

Life cycle, population dynamics and climatic thresholds

V. albo-atrum survives as a resting mycelium in the soil and on diseased plant remnants, on the soil surface or incorporated into it. Mycelium or conidia are able to infect plants through healthy or wounded roots. Following root invasion, the mycelium passes into the vascular tracts throughout the plant and subsequently induces a wilting condition. On hops, the rate and severity of disease development are inversely related to soil temperature. On average, there is a 7.7% wilt increase for each 1°C fall in soil temperature. Exceptionally high and exceptionally low rainfall both reduce occurrence of the disease in hops, while additional rainfall increases it (Talboys & Wilson, 1970).

Latent infection of dicotyledonous weeds can occur, making detection and eradication of the disease extremely

difficult. Saprophytic survival of the fungus in the soil is a declining phase, especially in the absence of dicotyledonous plants; the fungus may disappear under grass sward after 3-5 years (Sewell & Wilson, 1974).

In view of the biological features outlined above, verticillium wilt is essentially a soil-borne or debris-borne disease (and this is certainly so for hops). In areas where *V. albo-atrum* is widespread, very little consideration has been given to other possible means of transmission. However, the recent spread of verticillium wilt of lucerne in North America has led to interest in other pathways (e.g. on insects; Harper & Huang, 1984), which may not be very important in normal epidemiology but might introduce the disease into new areas, despite phytosanitary measures taken against the normal means of transmission. Although it was earlier thought that *Verticillium* transmission by seed was restricted to very few cases (e.g. in sunflower; Sackston & Martens, 1959), a few exceptions have been reported in recent years, including in particular *V. albo-atrum* on lucerne (Huang *et al*., 1985) and seed was probably the main means of spread to new areas in North America.

In general, the biology of *V. dahliae* is similar to that of *V. albo-atrum*. The fungus survives for longer periods on soil particles or plant remnants, because it forms microsclerotia as resting structures and these withstand adverse environmental conditions up to 14 years (Wilhelm, 1955). As shown by its geographical distribution, *V. dahliae* is favoured by higher temperatures than *V. albo-atrum*.

The question of host-specific strains

The quarantine significance of *Verticillium* spp. is closely linked to the existence of host-specific strains, and to the ways in which these arise, spread or are selected. These phenomena are interpreted somewhat differently in different countries, and in relation to different hosts. An attempt is made here to assess the alternative possibilities. In the UK, hops are attacked by strains of *V. albo-atrum* which have classically been described as "mild" (or "fluctuating") and "progressive". The latter at least are specific to hops. Hop wilt was severe in south-east UK, where progressive strains were present, until tolerant cultivars were widely planted. In the West Midlands, where only mild strains were present, susceptible cultivars could be grown. In the late 1980s, however, it was recognized (1) that there is a continuum of variation between less and more severe strains, and (2) that this variation exists in all hop-growing areas in the UK. Thus, the classically described pattern, of progressive wilt contained in the south-east and absent from the West Midlands, no longer corresponds to reality. The progressive form of the disease has never, in any case, been recognized as a distinct entity outside the UK, although differences in aggressiveness between strains have been reported in Germany (Zinkernagel, 1982).

Hop wilt attributed to *V. dahliae* is moderately severe in Germany, where Zinkernagel (1982) reported differences in aggressiveness between *V. dahliae* strains, just as between *V. albo-atrum* strains (see above). Chambers *et al*. (1985) described a very virulent isolate of

V. dahliae in the UK. Elsewhere in Europe and outside Europe, hop wilt is always mild, and no special strains are known.

The situation in the UK can usefully be described in more detail (Sewell & Wilson, 1984). Old commercial cultivars such as Fuggle used to be tolerant of *V. albo-atrum*. Under selection pressure, *V. albo-atrum* populations apparently gave rise to more severe ("progressive") strains (named V1); later the supervirulent strains V2 and V3 emerged, overcoming the tolerance of other cultivars. Resistance rating of four reference hop cultivars against a highly virulent strain of *V. albo-atrum* showed that Fuggle possesses low resistance, Bramling Cross moderate, Wye Target high and Wye 27/57/264 very high resistance (Talboys, 1987). Clarkson & Heale (1985) confirmed that there were significant differences in pathogenicity between three fluctuating (M18, M33, M50) and three progressive (PV1, PV2, PV3) isolates of *V. albo-atrum* from hops tested against Fuggle, Wye Challenger and Wye Target. It is thus probable that the British strain differences in *V. albo-atrum* on hops arose in the presence of a specific set of cultivars, relate specifically to them, and are of no particular significance elsewhere.

DETECTION AND IDENTIFICATION

Symptoms

Affected plants usually occur in scattered groups or may be distributed generally through the hop garden. Symptoms are usually most prevalent and severe in wet seasons, or in areas where the soil is excessively wet in summer. Disease intensity fluctuates from season to season; plants affected one year may look healthy the next year and for a number of seasons after that. The first symptoms on leaves usually appear in late July or early August as a yellowing of the lower leaves, which gradually spreads to other leaves higher up the bine; only occasionally is the whole plant affected. The lower leaves dry out, wither and may fall, while wedge-shaped necrotic areas may develop on the upper leaves. Bines often become swollen ("fat bine") and externally may appear brown and corky. Notching or cutting the bine about 0.3-1 m from the base will reveal a characteristic light-brown discoloration of the internal woody tissues.

The symptoms described above are those of the mild or fluctuating type, which is most commonly seen. With more aggressive strains and susceptible cultivars (a combination which will occur more and more rarely in practice), symptoms can be of the more severe "progressive" type. A new outbreak usually starts from one infected plant but, by the time it is noticeable, there are often several together in a patch. On leaves, infection is usually first apparent from the end of May onwards. The bottom leaves on one or more bines turn yellow; this yellowing progresses upwards within a few days and, within a week, half or more of the leaves on affected bines may be yellow or dead. Other bines on the infected plant may also begin to show symptoms. A tiger-striping effect is infrequently found on the upper leaves. After 2-3 weeks, all the leaves are dead and usually fallen, and plants often die before the end of the season. Bines rarely become swollen, but do show the characteristic internal brown discoloration when cut. They eventually turn black. Plants which survive the following winter often throw only a few weak bines the next season, and these soon develop symptoms and die.

Morphology

Conidia occur singly at the apices of phialides, mainly one-celled but occasionally one-septate, 3.5-10.5(-12.5) x 2-4 µm. They are hyaline, ellipsoidal to irregularly subcylindrical. Phialides are borne on the verticillately branched conidiophores, which are darkened at the base when grown on plant tissues. Resting dark-brown to blackish mycelium is the characteristic overwintering structure of *V. albo-atrum*, which forms neither microsclerotia nor chlamydospores. In contrast, *V. dahliae* is able to form dark-

brown to black microsclerotia arising from single hyphae by repeated budding and consisting of swollen, almost globular cells. This epidemiologically important resting structure varies in shape from elongate to irregularly spherical, 15-50(-100) µm in diameter. See also Hawksworth & Talboys (1970).

Detection and inspection methods

V. albo-atrum can easily be identified after isolation from suspect plant tissue (canes or plants). *V. dahliae* can easily be isolated from infected hosts by isolation from xylem of roots, stems, branches, twigs and even leaves and seeds. Recent efforts to detect both species of fungi are mainly concentrated on the use of DNA hybridization probes (Heale *et al*., 1990; Robb *et al*., 1990). An ELISA test for *V. albo-atrum* is in use in France for testing certified pelargoniums (OEPP/EPPO, 1992).

MEANS OF MOVEMENT AND DISPERSAL

As soil-borne fungi, *Verticillium* spp. are not readily dispersed over long distances. In general, they are most likely to be moved into new areas by human transport of soil, plants accompanied by soil (bulbs and tubers) or planting material. Thus, restrictions on the movement of hop planting material, and of soil, machinery and hop poles, were applied in the UK in the attempt to prevent spread of progressive wilt from south-east England.

PEST SIGNIFICANCE

Economic impact

V. albo-atrum and *V. dahliae* generally cause a mild disease of hops, which can however be severe when more aggressive strains attack susceptible cultivars. In this way, the pathogen almost eliminated hop cultivation in south-east England in the 1940s, but selection of wilt-tolerant cultivars along with the application of various agronomic measures enabled production to be sustained. Emergence of strains able to attack the tolerant cultivars constitutes the main threat for the hop industry in England (Talboys, 1987). Elsewhere, verticillium wilt of hops is only of moderate importance, and has not presented such special problems as in the UK.

Control

Use of disease-free planting material is essential for hops. Control also relies on the use of resistant cultivars, discussed under Biology.

Phytosanitary risk

EPPO has listed hop-infecting strains of *V. albo-atrum* and *V. dahliae* as A2 quarantine pests (OEPP/EPPO, 1982), but no other regional plant protection organization has done so. The main justification for this lay in the concept that distinct "progressive" strains existed, and that these were absent from certain areas (in particular, the West Midlands hop-growing area in England). With the acceptance that there is continuous variation in aggressiveness, in all hop-growing areas in the UK, the quarantine status of these *Verticillium* spp. on hops is likely to be reviewed. Regulatory control may remain appropriate, but may take on the character of a certification scheme for planting material.

PHYTOSANITARY MEASURES

Measures were taken in the UK to prevent spread of the progressive strain of *V. albo-atrum* on hops. They required removal and destruction of diseased plants, grassing over infested areas for a period of years, and exclusion of diseased plantations as sources of propagative material.

Only certified planting material was normally allowed to be moved. Movement of used hop poles and picking machinery was prohibited. Finally, only susceptible cultivars were permitted to be grown in areas where progressive wilt did not occur (so that outbreaks could easily be detected). The recent change in the view of hop wilt in the UK has in particular been reflected in a change in these regulations. Eradication is no longer attempted, nor is there any limitation on the cultivars which may be planted. However, the controls on planting material, and on used poles and machinery, have been maintained.

EPPO recommends (OEPP/EPPO, 1990) that hop planting material should come from a field where verticillium wilt has not occurred in the last 5 years and that consignments and their mother plants should have been found free from the disease in the last growing season. Such measures are as relevant in a national certification scheme as for international phytosanitary certification.

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