

# EPPO Datasheet: '*Candidatus Phytoplasma solani*'

Last updated: 2021-06-17

## IDENTITY

**Preferred name:** '*Candidatus Phytoplasma solani*'

**Authority:** Quaglino, Zhao, Casati, Bulgari, Bianco, Wei & Davis

**Taxonomic position:** Bacteria: Tenericutes: Mollicutes:

Acholeplasmatales: Acholeplasmataceae

**Other scientific names:** *Grapevine bois noir phytoplasma*, *Maize redness phytoplasma*, *Phytoplasma solani* Quaglino, Zhao, Casati, Bulgari, Bianco, Wei & Davis, *Potato stolbur phytoplasma*, *Stolbur phytoplasma*

**Common names:** STOL, black wood of grapevine, maize redness, metabolbur, parastolbur, stolbur of potato, stolbur of tobacco, stolbur of tomato

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**EPPO Categorization:** A2 list

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**EU Categorization:** RNQP (Annex IV)

**EPPO Code:** PHYPSO



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## Notes on taxonomy and nomenclature

Phytoplasmas are wall-less plant pathogenic bacteria (class Mollicutes) that survive and multiply in the plant phloem and insect haemolymph (IRPCM, 2004). The name '*Candidatus (Ca.)*' represents the 'unculturable' status of the phytoplasma (Murray & Stackebrandt, 1995). The taxonomy of phytoplasmas is complex and based on 16S ribosomal gene sequence as well as on biological, phytopathological, and genetic properties (IRPCM, 2004). Based on highly conserved 16S ribosomal gene sequence, phytoplasmas are categorized into 33 groups (Bertaccini & Lee, 2018).

'*Ca. Phytoplasma solani*' was first described as a distinct species in the genus '*Ca. Phytoplasma*' by Quaglino *et al.* (2013). To be classified as '*Ca. Phytoplasma solani*', a strain should (i) share >99% sequence similarity over a minimum length of 1.2kb within the 16S rRNA gene of the reference strain STOL11 (GenBank accession number AF248959), (ii) contain the identical STOL11-unique 16S rDNA signature sequence and (iii) contain two distinguishing sequence blocks noted for the reference strain STOL11 with a tolerance of a single nucleotide difference in no more than one of the sequences. Strains that do not fulfill either criterion (ii) or (iii) are considered '*Ca. Phytoplasma solani*'-related strains, even if they fulfil criterion (i).

Based on 16S rDNA sequence analyses, '*Ca. Phytoplasma solani*' strains are classified into taxonomic subgroups 16SrXII-A, -F, -G, -J, and -K (Quaglino *et al.*, 2017). Molecular typing, based on sequence analyses of several other genes (e.g., *tuf*, *secY*, *stamp*, *vmp1*), highlighted the presence of numerous genetically distinct strains of '*Ca. Phytoplasma solani*' (e.g. Aryan *et al.*, 2014; Murolo & Romanazzi, 2015; Quaglino *et al.*, 2016; Balakishiyeva *et al.*, 2018).

## HOSTS

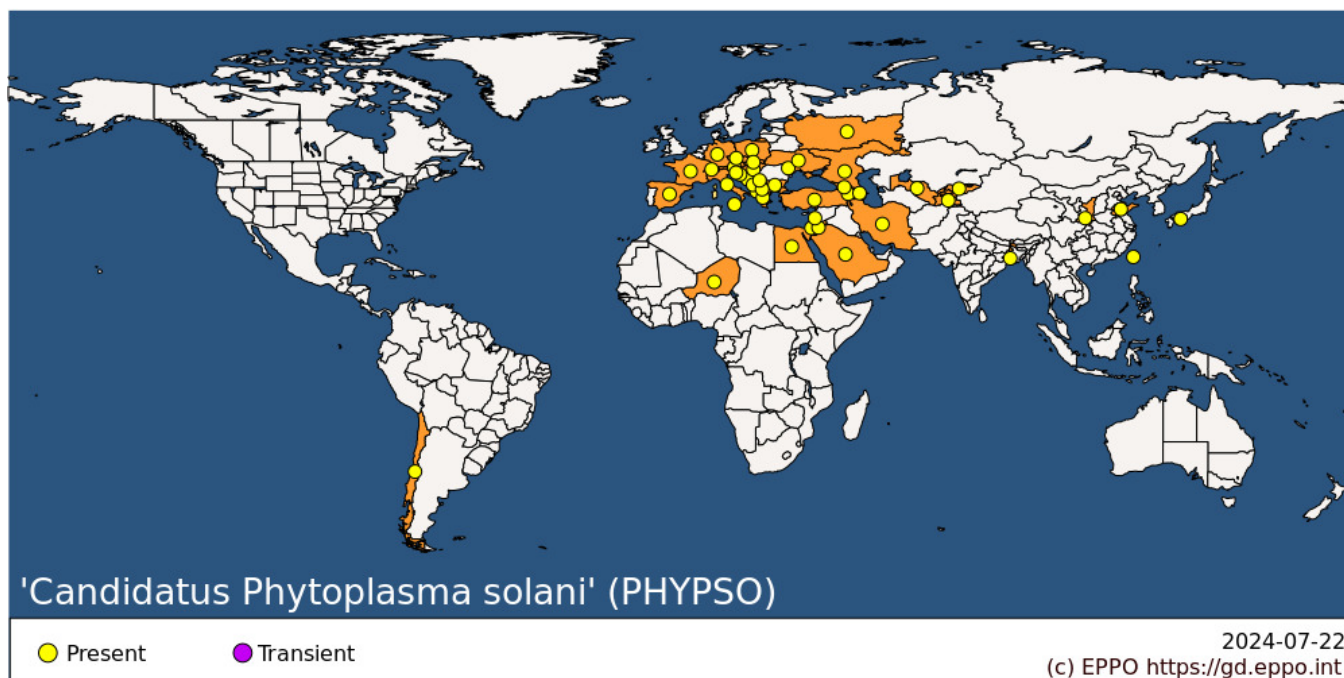
'*Ca. Phytoplasma solani*' has a wide plant host range, including many wild/weed species, ornamentals and crops. Cultivated hosts affected include, grapevine (*Vitis vinifera*), tomato (*Solanum lycopersicum*), potato (*Solanum tuberosum*), maize (*Zea mays*), pepper (*Capsicum annuum*), lavender (*Lavandula angustifolia*), aubergine (*Solanum melongena*), celery (*Apium graveolens*), carrot (*Daucus carota*), strawberry (*Fragaria ananassa*), tobacco (*Nicotiana tabacum*), sugar beet (*Beta vulgaris*). Fruit tree species, such as plum (*Prunus domestica*), peach (*Prunus persica*), cherry (*Prunus avium*), almond (*Prunus dulcis*) and apple (*Malus domestica*), have also been described as '*Ca. Phytoplasma solani*' hosts. The main natural reservoirs for '*Ca. Phytoplasma solani*' are wild plants such as

bindweed (*Convolvulus arvensis*) and stinging nettle (*Urtica dioica*) (Quaglino *et al.*, 2013; EFSA, 2014; CABI, 2020).

**Host list:** *Achillea millefolium*, *Actinidia deliciosa*, *Allium ampeloprasum*, *Amaranthus retroflexus*, *Ammi majus*, *Anethum graveolens*, *Apium graveolens*, *Artemisia scoparia*, *Artemisia vulgaris*, *Bellis perennis*, *Beta vulgaris*, *Brassica oleracea* var. *gemmifera*, *Bromus inermis*, *Bupleurum tenuissimum*, *Calendula officinalis*, *Calystegia sepium*, *Capsella bursa-pastoris*, *Capsicum annuum*, *Carica papaya*, *Carum carvi*, *Centaureum erythraea*, *Cephalaria transsylvanica*, *Chenopodium album*, *Chrysanthemum indicum*, *Cichorium intybus*, *Cirsium arvense*, *Cistus ladanifer*, *Convolvulus arvensis*, *Convolvulus tricolor*, *Coronilla varia*, *Crepis foetida*, *Crepis* sp., *Cucumis sativus*, *Cuscuta* sp., *Cynodon dactylon*, *Datura stramonium*, *Daucus carota*, *Dianthus barbatus*, *Digitalis purpurea*, *Echinacea angustifolia*, *Echinacea purpurea*, *Echium vulgare*, *Epilobium* sp., *Erigeron annuus*, *Erigeron bonariensis*, *Erigeron canadensis*, *Eucalyptus camaldulensis*, *Euonymus japonicus*, *Euphorbia falcata*, *Fallopia convolvulus*, *Ficus carica*, *Fragaria x ananassa*, *Galium* sp., *Geranium dissectum*, *Gomphocarpus physocarpus*, *Helianthus annuus*, *Helminthotheca aculeata*, *Helminthotheca echioides*, *Hibiscus cannabinus*, *Hydrangea macrophylla*, *Hypericum barbatum*, *Hypericum perforatum*, *Hyssopus officinalis*, *Jasminum officinale*, *Laburnum anagyroides*, *Lactuca saligna*, *Lactuca sativa*, *Lactuca serriola*, *Lapsana communis*, *Lavandula angustifolia*, *Lavandula x intermedia*, *Levisticum officinale*, *Lilium longiflorum*, *Linaria vulgaris*, *Liquidambar styraciflua*, *Lupinus polyphyllus*, *Macroptilium lathyroides*, *Malus domestica*, *Malva sylvestris*, *Matricaria chamomilla*, *Medicago lupulina*, *Medicago sativa*, *Melilotus albus*, *Melissa officinalis*, *Mentha arvensis*, *Mercurialis annua*, *Monarda fistulosa*, *Myrtus communis*, *Narcissus tazetta*, *Nicotiana tabacum*, *Oenothera biennis*, *Olea europaea*, *Origanum vulgare*, *Oxalis* sp., *Paeonia tenuifolia*, *Paeonia x suffruticosa*, *Parietaria judaica*, *Parietaria officinalis*, *Pastinaca sativa*, *Persicaria maculosa*, *Petroselinum*, *Phaseolus vulgaris*, *Picris hieracioides*, *Pistacia vera*, *Pisum sativum*, *Plantago lanceolata*, *Plantago major*, *Polygonum aviculare*, *Portulaca oleracea*, *Potentilla reptans*, *Prunella vulgaris*, *Prunus armeniaca*, *Prunus avium*, *Prunus domestica*, *Prunus dulcis*, *Prunus mahaleb*, *Prunus mume*, *Prunus persica*, *Punica granatum*, *Pyrus communis*, *Raphanus sativus*, *Rhododendron* sp., *Rubia peregrina*, *Rubus fruticosus*, *Rumex acetosa*, *Salix alba*, *Salix babylonica*, *Salvia miltiorrhiza*, *Salvia rosmarinus*, *Salvia sclarea*, *Sambucus nigra*, *Saponaria officinalis*, *Senecio vulgaris*, *Setaria viridis*, *Silene latifolia* subsp. *alba*, *Silene noctiflora*, *Silene vulgaris*, *Solanum glaucophyllum*, *Solanum lycopersicum*, *Solanum melongena*, *Solanum nigrum*, *Solanum tuberosum*, *Sonchus oleraceus*, *Sonchus* sp., *Sophora alopecuroides*, *Sorghum halepense*, *Spartium junceum*, *Spinacia oleracea*, *Styphnolobium japonicum*, *Tagetes erecta*, *Taraxacum officinale*, *Thymus vulgaris*, *Trifolium medium*, *Trifolium pratense*, *Trifolium repens*, *Trigonella foenum-graecum*, *Triticum aestivum*, *Tussilago farfara*, *Ulmus glabra*, *Urtica dioica*, *Urtica urens*, *Vaccinium corymbosum*, *Valeriana officinalis*, *Veronica persica*, *Viola odorata*, *Vitex agnus-castus*, *Vitis vinifera*, *Zea mays*

## GEOGRAPHICAL DISTRIBUTION

A yellows-type disease, named 'stolbur', was found several decades ago affecting various plants in the Solanaceae family (mainly potato and tomato) in Southern and Eastern Europe (CABI, 2020). Unusual symptoms of reddening were first observed on maize in 1957 in Serbia, and disease was called maize redness (Duduk & Bertaccini, 2006). The first observation of lavender decline is from France in the late 1960s (Sémétey *et al.*, 2018). A yellows-type disease of grapevine, named bois noir was first reported in 1961 in vineyards in North-Eastern France, and a few years later, similar symptoms were observed in vineyards in the Mosel and Rhine valleys in Germany. The disease was named 'Vergilbungskrankheit' and further studies showed that this was the same disease as bois noir (Belli *et al.*, 2010). Soon after bois noir was observed in France and Germany, it was reported in many countries in the Euro-Mediterranean area (a few reports were also made in other continents), where it is responsible for serious crop losses (Gajardo *et al.*, 2009; Belli *et al.*, 2010). Quaglino *et al.* (2013) demonstrated that phytoplasmas associated with stolbur, maize redness, lavender decline, and yellows-type diseases of grapevine and other wild and cultivated plants, are members of the same species i.e. '*Ca. Phytoplasma solani*'.



**EPPO Region:** Albania, Armenia, Austria, Azerbaijan, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, France (mainland), Georgia, Germany, Greece (mainland), Hungary, Israel, Italy (mainland, Sicilia), Jordan, Kyrgyzstan, Moldova, Montenegro, North Macedonia, Poland, Russia (Central Russia, Southern Russia), Serbia, Slovakia, Slovenia, Spain (mainland), Switzerland, Türkiye, Ukraine, Uzbekistan

**Africa:** Egypt, Niger

**Asia:** China (Shaanxi, Shandong), India (West Bengal), Iran, Israel, Japan (Shikoku), Jordan, Kyrgyzstan, Lebanon, Saudi Arabia, Taiwan, Tajikistan, Uzbekistan

**South America:** Chile

## BIOLOGY

'*Ca. Phytoplasma solani*' is not seed transmissible but can be transmitted by grafting and vegetative propagation of infected hosts, such as potato, tomato, grapevine, strawberry and lavender (EFSA, 2014). In diseased plants, phytoplasmas are restricted to the phloem sieve tubes, and are naturally transmitted between plants mainly by phloem-sap-feeding leafhoppers, planthoppers or psyllids (see below) as well as by parasitic plant species (see Pathways for movement) (Weintraub & Beanland, 2006).

In the Euro-Mediterranean region, '*Ca. Phytoplasma solani*' is usually transmitted from plant to plant by the polyphagous insect vector *Hyalesthes obsoletus* (Cixiidae) which is native to Europe and is ubiquitous in European countries. The acquisition stage is achieved by overwintering nymphs feeding on infected roots. All infected crops except lavender are generally epidemiological dead-end hosts for '*Ca. Phytoplasma solani*', as its main vector *H. obsoletus* does not develop on these crops (Weintraub & Beanland, 2006; Johannesen *et al.*, 2008; Sémétey *et al.*, 2018), but only incidentally transmits the phytoplasma from other host plants to these crops during its feeding probing at the adult stage. The same situation applies to many wild/weed hosts, but some weeds, such as bindweed and stinging nettle, act as plant reservoirs, hosting both '*Ca. Phytoplasma solani*' and its vector (Langer & Maixner, 2004; Bressan *et al.*, 2007). There is no transovarial transfer of '*Ca. Phytoplasma solani*' from infected female planthopper vectors to their progeny. Therefore, the average six-week activity period of adult *H. obsoletus* feeding on annual plants could explain their infection. In addition, such plants are probably hosts (or incidental hosts) of one or more alternative vectors which could also transmit the phytoplasma between these plants, and these vectors are probably present in the agro-system as adults for a longer period during the same vegetative season (Weintraub & Beanland, 2006; EFSA, 2014; Mori *et al.*, 2014b; CABI, 2020).

Within the other known vectors, the planthopper *Reptalus panzeri* has been reported as a natural vector of '*Ca. Phytoplasma solani*' isolates causing maize redness and bois noir in Serbia (Jović *et al.*, 2009; Cvrković *et al.*, 2014). Adult *R. panzeri* lay eggs on infected maize roots. If these roots are infected, nymphs feeding on them will acquire the phytoplasma. The nymphs overwinter on the roots of wheat planted in maize fields in autumn or on

Johnson grass (*Sorghum halepense*), allowing the emergence of infectious vectors the following summer (Jovi? *et al.*, 2009; Cvrkovi? *et al.*, 2014). The planthopper *Pentastiridius leporinus* has been reported to transmit 'Ca. Phytoplasma solani' to sugar beet (Gatineau *et al.*, 2001; EFSA, 2014). *Anaceratagallia ribauti* has been reported as a vector in Austria (Riedle-Bauer *et al.*, 2008). *Reptalus quinquecostatus* has been reported as a putative vector in Serbia and France, but its capability to transmit the phytoplasma to plants has not been established (Chuche *et al.*, 2016; Mitrovi? *et al.*, 2016).

## DETECTION AND IDENTIFICATION

### Symptoms

In Europe and in the Mediterranean basin, 'Ca. Phytoplasma solani' strains are associated with bois noir disease of grapevine, with stolbur disease in wild and cultivated herbaceous and woody plants, and with yellowing, reddening, decline, dwarfism, leaf malformation and degeneration diseases of other plants (Quaglino *et al.*, 2013). The symptoms of 'Ca. Phytoplasma solani' infection are variable, depending on environmental factors. Annual crops develop symptoms a few weeks after inoculation by the insect, whereas symptoms on perennial hosts can appear one or more years after inoculation (EFSA, 2014).

#### On grapevine (bois noir disease)

'Ca. Phytoplasma solani' infection of grapevine, also known as bois noir disease, produces leaf yellows (in white-berried cultivars) or leaf reddening (in red-berried cultivars), downwards leaf rolling, irregular ripening of wood, growth reduction, and shriveling and drying up of berries and bunches. Young plants can die following infection, while older plants tend to recover (Belli *et al.*, 2010). The severity of the symptoms depends on cultivar sensitivity (EFSA, 2014). The symptoms caused by 'Ca. Phytoplasma solani' cannot be distinguished from those caused by grapevine flavescence dorée. Symptoms are illustrated in EPPO (2018b).

#### On potato (potato stolbur)

Symptoms of 'Ca. Phytoplasma solani' on potato plants include upward rolling and purplish or red discoloration of the top leaves, shortened internodes, aerial tubers, early senescence and, finally, plant wilting and death (Holeva *et al.*, 2014; Mitrovi? *et al.*, 2016).

#### On tomato (tomato stolbur)

Typical symptoms on tomato plants infected with 'Ca. Phytoplasma solani' are short internodes near to the plant apex and smaller curled leaves with thicker tissues. The leaves are discoloured and show yellowing or purpling. Adventitious roots sometimes appear on the stem. Plants infected early are bushy because of the development of numerous axillary buds. The flowers of infected plants are abnormally straight, they are sterile and have altered morphological development: (i) sepals, with purple veins, remain completely sealed and the calyx is enlarged (big bud); (ii) petals are green with stamens of the same colour (virescence); (iii) sepals may be leaf-like (phyllody); (iv) dysfunction may occur in flower differentiation. Fewer fruits are produced, and they are smaller, lacking colour, and dense (CABI, 2020).

#### On maize (maize redness)

Symptoms on *Zea mays* caused by 'Ca. Phytoplasma solani' infection appear in late July and continue to intensify until the beginning of September. Typical symptoms are reddening of the leaf midrib, followed by reddening of leaves and stalks and then whole-plant desiccation. Ear development is abnormal and seed set is greatly reduced (Duduk & Bertaccini, 2006; Jovi? *et al.*, 2007).

#### On lavender (lavender decline)

Early symptoms of lavender decline are low vigour and leaf yellowing, then the canopy of infected lavender dries in sectors and plants eventually die (Sémétey *et al.*, 2018).

Symptom description in strawberry is available in EPPO (2017b).

## Morphology

Under transmission electron microscopy, phytoplasmas are pleomorphic, as they can appear in many shapes and sizes (Waters & Hunt, 1980). They can almost completely fill the phloem sieve tubes (Dermastia *et al.*, 2017).

## Detection and inspection methods

Plants, especially the leaves, should be inspected for symptoms. Attention should be paid to the presence of the leafhopper vectors. Where appropriate, samples for laboratory testing should be taken for the final identification of the pest. Crop inspection procedures for strawberry plants for planting (EPPO, 2017b), potatoes (EPPO, 2007), vegetable plants for planting (EPPO, 2016), and grapevine plants for planting (EPPO, 2018b) have been developed.

Various PCR based tests have been developed to detect ‘*Ca. Phytoplasma solani*’. A widely applied procedure is based on nested PCR amplification with phytoplasma-universal primer pairs, followed by sequencing or restriction fragment length polymorphism (RFLP) analyses (Lee *et al.*, 1998; EPPO, 2018a). An online phytoplasma classification tool iPhyClassifier can be used for sequence similarity analysis and generation of virtual RFLP profiles (Wei *et al.*, 2007; Zhao *et al.*, 2009). Multiplex nested PCR developed by Clair *et al.* (2003) allows the detection of ‘*Ca. Phytoplasma solani*’ and allows it to be distinguished from grapevine flavescence dorée phytoplasma. Several real-time PCR tests have also been developed for ‘*Ca. Phytoplasma solani*’ detection (e.g. Angelini *et al.*, 2007; Hren *et al.*, 2007; Pelletier *et al.*, 2009). Loop mediated isothermal amplification (LAMP) can be used for on-site detection as well as for screening in laboratories (Kogovšek *et al.*, 2017).

## PATHWAYS FOR MOVEMENT

‘*Ca. Phytoplasma solani*’ is naturally dispersed over fairly long distances by its planthopper vectors (see Biology). It can be transmitted by the parasitic plant dodder (*Cuscuta campestris*, *C. epilinum*, *C. trifolii*). In addition, the plant *Orobancha aegyptiaca*, which parasitizes roots of diseased tomato plants, has been shown to contain phytoplasmas, so it could be involved in transmission in the field. ‘*Ca. Phytoplasma solani*’ is not thought to be transmitted in the true seed of any of its hosts, but it can be transmitted by vegetative propagation of infected host plants. The phytoplasma has a complex ecology and epidemiological cycle, and a high capability to adapt to different agro-ecosystems. The risk of introduction of ‘*Ca. Phytoplasma solani*’ to new regions is related to the dispersal of its vectors and to trade in cultivated host plants (e.g., symptomless seedlings) (EFSA, 2014; CABI, 2020).

## PEST SIGNIFICANCE

### Economic impact

Severe ‘*Ca. Phytoplasma solani*’ outbreaks have been reported in potato fields in several countries, including the Czech Republic, Hungary, Romania and Russia, causing significant yield loss (30–80 %) and a reduction in seed potato quality (Paltrinieri & Bertaccini 2007; Girsova *et al.*, 2008; Fialová *et al.*, 2009; Lindner *et al.*, 2011; EFSA, 2014). ‘*Ca. Phytoplasma solani*’ infection increases the sucrose content of tubers by three- to six-fold; severely affecting the suitability of tubers for fried potato processing (Lindner *et al.*, 2011). In severe epidemics, yield losses as high as 60 % in tomato, 90 % in pepper, and 100 % in celery have been reported (Navrátil *et al.*, 2009). Maize redness has been linked to yield reductions of 40–90 % in Serbia (Jović *et al.*, 2007). As the main symptom caused by ‘*Ca. Phytoplasma solani*’ on grapevine is the loss of production due to berry shrivel, the economic impact of the disease, especially on susceptible varieties, is significant. As ‘*Ca. Phytoplasma solani*’ causes symptoms that cannot be distinguished from those caused by grapevine flavescence dorée, high local incidences of ‘*Ca. Phytoplasma solani*’ infection can severely complicate the surveys for grapevine flavescence dorée (EFSA, 2014). ‘*Ca. Phytoplasma solani*’ also has a high economic impact on lavender crops. Unlike the situation with most crop plants, *H. obsoletus* can complete its life cycle on lavender; thus, disease propagation is epidemic and lavender fields can be destroyed within 4–5 years in South-Eastern France (EFSA, 2014).

Economic impact of '*Ca. Phytoplasma solani*' is variable, depending on yearly variations in insect vector abundance, and can also be significant in a range of other hosts. Economic impact may increase in the future from range extension and from increase in density of vector populations as a consequence of climate change (EFSA, 2014).

## Control

The use of healthy planting material and control of surrounding weeds that are main hosts of *H. obsoletus* is considered crucial for '*Ca. Phytoplasma solani*' control. Trials conducted to control nettle growth with glyphosate or other herbicides significantly reduced the density of emerging adult vectors (Mori *et al.*, 2014a). Neonicotinoid insecticides, applied in early spring, gave protection levels comparable to those of herbicide treatments (Mori *et al.*, 2014a). However, the use of herbicides and insecticides can have negative effects on beneficial insects (e.g. honeybees) as well as human health and biodiversity (EFSA, 2014). Preventive measures such as checking the phytosanitary status of propagation materials, and treating diseased mother plants through thermotherapy, are applied to limit long-distance dissemination and in-field spread of the disease (CABI, 2020). Hot water treatment of dormant canes of grapevines may be used to eliminate phytoplasmas (EPPO, 2008; EPPO, 2012). In addition, other strategies to reduce '*Ca. Phytoplasmas solani*' on grapevines are available, such as treatments with resistance inducers (Romanazzi *et al.*, 2013).

'*Ca. Phytoplasma solani*' is included in the certification system for grapevine (EPPO, 2008), petunia (EPPO, 2002) and seed potato tubers (EPPO, 1999). This reduces the spread and impact associated with the plants for planting pathway.

## Phytosanitary risk

'*Ca. Phytoplasma solani*' may cause serious losses in economically important cultivated species, such as grapevine, maize, potato, tomato. In addition, it can survive and complete its life cycle without cultivated host plants, because wild plants are main hosts of '*Ca. Phytoplasma solani*'. '*Ca. Phytoplasma solani*' and its main vector have been found in different agro-ecosystems in many countries in Europe and the eastern Mediterranean area. In terms of disease epidemiology, the wide range of the vector's host plants and '*Ca. Phytoplasma solani*' plant hosts are factors which should be considered. Disease control is difficult in the field, and there is limited information about effective methods to control the insect vector or about the availability of resistant/tolerant crops. Finally, climate change might significantly influence the epidemiology of '*Ca. Phytoplasma solani*' diseases.

## PHYTOSANITARY MEASURES

To prevent the introduction and spread of '*Ca. Phytoplasma solani*', import requirements for different host species apply worldwide. These requirements can vary with regards to crop and prevalence at the place of origin. When deregulated as a quarantine pest, '*Ca. Phytoplasma solani*' was recommended for regulation as a regulated non-quarantine pest (RNQP) for seed potatoes and propagation material of *Lavandula* and *Vitis* during the EU Quality pest project (Picard *et al.*, 2018).

EPPO countries where '*Ca. Phytoplasma solani*' does not occur, or where it is not widely distributed, may regulate it. If they do, EPPO recommends that they should require measures for import of seed potatoes (except microplants and minitubers). According to EPPO Standard PM 8/1 (EPPO, 2017a) seed potatoes imported from a country where the pest occurs should come from a pest-free area according to EPPO Standard PM 3/61 (EPPO, 2019b) or a pest-free place of production for '*Ca. Phytoplasma solani*' since the last growing season. In addition, post-entry quarantine programs are established to allow safe movement of potato germplasm for research and breeding purposes. During post-entry quarantine for potato, it is recommended that Phytoplasmas should be tested for by using universal phytoplasma primers (EPPO, 2019a).

As well as preventing introduction, it is essential to start cultivation with non-infected plants. Therefore, the absence of the phytoplasma in germplasm, mother plants and nuclear stock should be assured before the start of breeding, propagation and/or production of plants. During the EU Quality pest project, recommended measures included a zero tolerance for all categories of seed potatoes, *Lavandula* and *Vitis*, based on absence of symptoms and/or testing.

There is no possibility of complete eradication of 'Ca. Phytoplasma solani' from the natural environment.

## REFERENCES

- Angelini E, Bianchi GL, Filippin L, Morassutti C & Borgo M (2007) A new TaqMan method for the identification of phytoplasmas associated with grapevine yellows by real-time PCR assay. *Journal of Microbiological Methods* **68**(3), 613-622.
- Aryan A, Brader G, Mörtel J, Pastar M & Riedle-Bauer M (2014) An abundant 'Candidatus Phytoplasma solani' tuf b strain is associated with grapevine, stinging nettle and *Hyalesthes obsoletus*. *European Journal of Plant Pathology* **140**, 213-227.
- Balakishiyeva G, Bayramova J, Mammadov A, Salar P, Danet JL, Ember I, Verdin E, Foissac X & Huseynova I (2018) 'Candidatus Phytoplasma solani' related strains associated with bois noir grapevine yellows and planthoppers in Azerbaijan. *European Journal of Plant Pathology* **151**, 937-946.
- Belli G, Bianco PA & Conti M (2010) Grapevine yellows in Italy: past, present and future. *Journal of Plant Pathology* **92**(2), 303-326.
- Bertaccini A & Lee IM (2018) Phytoplasmas: An Update. In: Rao GP, Bertaccini A, Fiore N, Liefting LW (Eds) *Phytoplasmas: Plant Pathogenic Bacteria—I: Characterisation and Epidemiology of Phytoplasma—Associated Diseases*. Springer: Singapore, 1-29.
- Bressan A, Turata R, Maixner M, Spiazzi S, Boudon-Padiou E & Girolami V (2007) Vector activity of *Hyalesthes obsoletus* living on nettles and transmitting a stolbur phytoplasma to grapevines: a case study. *Annals of Applied Biology* **150**, 331-339.
- Chuche J, Danet JL, Salar P, Foissac X & Thiéry D (2016) Transmission of 'Candidatus Phytoplasma solani' by *Reptalus quinquecostatus* (Hemiptera: Cixiidae). *Annals of Applied Biology* **169**(2), 214-223.
- Clair D, Larrue J, Aubert G, Gillet J, Cloquemin G & Boudon-Padiou E (2003). A multiplex nested-PCR assay for sensitive and simultaneous detection and direct identification of phytoplasma in the Elm yellows group and Stolbur group and its use in survey of grapevine yellows in France. *Vitis* **42**(3), 151-157.
- Cvrkovi? T, Jovi? J, Mitrovi? M, Krsti? O & Toševski I (2014) Experimental and molecular evidence of *Reptalus panzeri* as a natural vector of bois noir. *Plant Pathology* **63**(1), 42-53.
- Dermastia M, Bertaccini A, Constable F & Mehle N (2017) *Grapevine Yellows Diseases and Their Phytoplasma Agents*. Springer International Publishing. Cham, (SZ). <https://dpo.org/10.1007/978-3-319-50648-7>
- Duduk B & Bertaccini A (2006) Corn with symptoms of reddening: New host of stolbur phytoplasma. *Plant Disease* **90**, 1313-1319.
- EFSA Panel on Plant Health (2014) Scientific Opinion on the pest categorization of *Candidatus Phytoplasma solani*. *EFSA Journal* **12** (12). <https://doi.org/10.2903/j.efsa.2014.3924>
- EPPO (1999) Certification schemes. PM 4/28 (1) Seed potatoes. *EPPO Bulletin* **29**, 253-267.
- EPPO (2002) Production of healthy plants for planting. PM 4/26 (2) Certification scheme for petunia. *EPPO Bulletin* **32**, 211-221.
- EPPO (2007) Phytosanitary procedures. PM 3/71 General crop inspection procedure for potatoes. *EPPO Bulletin* **37**, 592-597.
- EPPO (2012) Phytosanitary treatments. PM 10/18 (1) Hot water treatment of grapevine to control Grapevine flavescente dorée phytoplasma. *EPPO Bulletin* **47**(3), 490-492.

- EPPO (2008) Certification schemes. PM 4/8 (2) Pathogen-tested material of grapevine varieties and rootstocks. *EPPO Bulletin* **38**, 422-429.
- EPPO (2016) Phytosanitary procedures. PM 3/77 (1) Vegetable plants for planting under protected conditions – inspection of places of production. *EPPO Bulletin* **46**(1), 40-48.
- EPPO (2017a) Commodity-specific phytosanitary measures. PM 8/1 (2) Potato. *EPPO Bulletin* **47**(3), 487-503.
- EPPO (2017b) Phytosanitary procedures. PM 3/83 (1) *Fragaria* plants for planting – inspection of places of production. *EPPO Bulletin* **47**(3), 349-365.
- EPPO (2018a) Diagnostics. PM 7/133 (1) Generic detection of phytoplasmas. *EPPO Bulletin* **48**(3), 414-424.
- EPPO (2018b) Phytosanitary procedures. PM 3/85 (1) Inspection of places of production – *Vitis* plants for planting. *EPPO Bulletin* **48**(3), 330-349.
- EPPO (2019a) Phytosanitary procedures. PM 3/21 (3) Post entry quarantine for potato. *EPPO Bulletin* **49**(3), 452-479.
- EPPO (2019b) Phytosanitary procedures. PM 3/61 (2) Pest-free areas and pest-free production and distribution systems for quarantine pests of potato. *EPPO Bulletin* **49**(3), 480-481.
- Fialová R, Válová P, Balakishiyeva G, Danet JL, Šafářová D, Foissac X & Navrátil M (2009) Genetic variability of stolbur phytoplasma in annual crop and wild plant species in south Moravia. *Journal of Plant Pathology* **91**(2), 411-416.
- Gajardo A, Fiore N, Prodan S, Paltrinieri S, Botti S, Pino AM, Zamorano A, Montealegre J & Bertaccini A (2009) Phytoplasmas associated with grapevine yellows disease in Chile. *Plant Disease* **93**(8), 789-796.
- Gatineau F, Larrue J, Clair D, Lorton F, Richard-Molard M & Boudon-Padieu E (2001) A new natural planthopper vector of stolbur phytoplasma in the genus *Pentastiridius* (Hemiptera: Cixiidae). *European Journal of Plant Pathology* **107**, 263-271.
- Girsova N, Bottner KD, Mozhaeva KA, Kastalyeva TB, Owens RA & Lee IM (2008) Molecular detection and identification of group 16SrI and 16SrXII phytoplasmas associated with diseased potatoes in Russia. *Plant Disease* **92**(4), 654.
- Holeva MC, Glynos PE, Karafla CD, Koutsoumari EM, Simoglou KB & Eleftheriadis E (2014) First report of *Candidatus* phytoplasma solani associated with potato plants in Greece. *Plant Disease* **98**(12), 1739.
- Hren M, Boben J, Rotter A, Kralj P, Gruden K & Ravnikar M (2007) Real-time PCR detection systems for Flavescence dorée and Bois noir phytoplasmas in grapevine: comparison with conventional PCR detection and application in diagnostics. *Plant Pathology* **56**, 785-796.
- IRPCM (2004) 'Candidatus Phytoplasma', a taxon for the wall-less, non-helical prokaryotes that colonize plant phloem and insects. *International Journal of Systematic and Evolutionary Microbiology* **54**, 1243-1255.
- Johannesen J, Lux B, Michel K, Seitz A & Maixner M (2008) Invasion biology and host specificity of the grapevine yellows disease vector *Hyalesthes obsoletus* in Europe. *Entomologia Experimentalis et Applicata*, **126**(3), 217-227.
- Jović J, Cvrković T, Mitrović M, Krnjajić S, Petrović A, Redinbaugh MG, Pratt RC, Hogenhout SA & Toševski I (2009) Stolbur phytoplasma transmission to maize by *Reptalus panzeri* and the disease cycle of maize redness in Serbia. *Phytopathology* **99**(9), 1053-1061.
- Jović J, Cvrković T, Mitrović M, Krnjajić S, Redinbaugh MG, Pratt RC, Gingery RE, Hogenhout SA & Toševski I (2007) Roles of stolbur phytoplasma and *Reptalus panzeri* (Cixiidae, Auchenorrhyncha) in the epidemiology of Maize redness in Serbia. *European Journal of Plant Pathology* **118**(1), 85-89.



- Kogovšek P, Mehle N, Pugelj A, Jakomin T, Schroers HJ, Ravnikar M & Dermastia M (2017) Rapid loop-mediated isothermal amplification assays for grapevine yellows phytoplasmas on crude leaf-vein homogenate has the same performance as qPCR. *European journal of plant pathology* **148**(1), 75-84.
- Langer M & Maixner M (2004) Molecular characterisation of grapevine yellows associated phytoplasmas of the stolbur-group based on RFLP-analysis of non-ribosomal DNA. *Vitis* **43**(4), 191-199.
- Lee IM, Gundersen-Rindal DE, Davis RE & Bartoszyk IM (1998) Revised classification scheme of phytoplasmas based on RFLP analyses of 16S rRNA and ribosomal protein gene sequences. *International Journal of Systematic Bacteriology* **48**(4), 1153-1169.
- Lindner K, Haase NU, Roman M & Seemüller E (2011) Impact of stolbur phytoplasmas on potato tuber texture and sugar content of selected potato cultivars. *Potato Research* **54**(3), 267-282.
- Mitrović M, Jakovljević M, Jović J, Krstić O, Kosovac A, Trivellone V, Jermini M, Toševski I & Cvrković T (2016) 'Candidatus Phytoplasma solani' genotypes associated with potato stolbur in Serbia and the role of *Hyalesthes obsoletus* and *Reptalus panzeri* (Hemiptera, Cixiidae) as natural vectors. *European Journal of Plant Pathology* **144** (3), 619-630.
- Mori N, Pavan F & Maixner M (2014a) Control of *Hyalesthes obsoletus* nymphs based on chemical weeding and insecticides applied on *Urtica dioica*. *Vitis* **53** (2), 103-109.
- Mori N, Quaglino F, Tessari F, Pozzebon A, Bulgari D, Casati P & Bianco PA (2014b) Investigation on 'bois noir' epidemiology in north-eastern Italian vineyards through a multidisciplinary approach. *Annals of Applied Biology* **166** (1), 75-89.
- Murolo S & Romanazzi G (2015) In-vineyard population structure of 'Candidatus Phytoplasma solani' using multilocus sequence typing analysis. *Infection, Genetics and Evolution* **31**, 221-230.
- Murray RGE & Stackebrandt E (1995) Taxonomic note: Implementation of the provisional status *Candidatus* for incompletely described procaryotes. *International Journal of Systematic Bacteriology* **45**, 186-187.
- Navrátil M, Válková P, Fialová R, Lauterer P, Šafářová D & Starý M (2009) The incidence of stolbur disease and associated yield losses in vegetable crops in South Moravia (Czech Republic). *Crop Protection* **28**(10), 898-904.
- Paltrinieri S & Bertaccini A (2007) Detection of phytoplasmas in plantlets grown from different batches of seed-potatoes. *Bulletin of Insectology* **60**(2), 379-380.
- Pelletier C, Salar P, Gillet J, Cloquemin G, Very P, Foissac X & Malembic-Maher S (2009) Triplex real-time PCR assay for sensitive and simultaneous detection of grapevine phytoplasmas of the 16SrV and 16SrXII-A groups with an endogenous analytical control. *Vitis* **48**(2), 87-95.
- Picard D, Afonso T, Benko-Beloglavec A, Karadjova O, Matthews-Berry S, Paunovic SA, Pietsch M, Reed P, van der Gaag DJ & Ward M (2018) Recommended regulated non-quarantine pests (RNQPs), associated thresholds and risk management measures in the European and Mediterranean region. *EPPO Bulletin* **48**, 552-558.
- Quaglino F, Maghradze D, Casati P, Chkhaidze N, Lobjanidze M, Ravasio A, Passera A, Venturini G, Failla O & Bianco PA (2016) Identification and characterization of new 'Candidatus Phytoplasma solani' strains associated with bois noir disease in *Vitis vinifera* L. cultivars showing a range of symptom severity in Georgia, the Caucasus region. *Plant Disease* **100**(5), 904-915.
- Quaglino F, Murolo S, Zhao Y, Casati P, Durante G, Wei W, Bianco PA, Romanazzi G & Davis RE (2017) Identification of new -J and -K 16SrXII subgroups and distinct single nucleotide polymorphism genetic lineages among 'Candidatus Phytoplasma solani' strains associated with bois noir in Central Italy. *Australasian Plant Pathology* **46**(1), 31-34.
- Quaglino F, Zhao Y, Casati P, Bulgari D, Bianco PA, Wei W & Davis RE (2013) 'Candidatus Phytoplasma solani',

a novel taxon associated with stolbur- and bois noir-related diseases of plants. *International Journal of Systematic and Evolutionary Microbiology* **63**, 2879-2894.

Riedle-Bauer M, Sára A & Regner F (2008) Transmission of a stolbur phytoplasma by the Agalliinae leafhopper *Anaceratagallia ribauti* (Hemiptera, Auchenorrhyncha, Cicadellidae). *Journal of Phytopathology* **156**(11/12), 687-690.

Romanazzi G, Murolo S & Feliziani E (2013) Effects of an innovative strategy to contain grapevine Bois noir: field treatment with resistance inducers. *Phytopathology* **103**(8), 785-791.

Sémétey O, Gaudin J, Danet JL, Salar P, Theil S, Fontaine M, Krausz M, Chaisse E, Eveillard S, Verdin E & Foissac X (2018) Lavender decline in France is associated with chronic infection by lavender-specific strains of '*Candidatus* Phytoplasma solani'. *Applied and Environmental Microbiology* **84**(24), e01507-18.

Waters H & Hunt P (1980) The in vivo three-dimensional form of a plant mycoplasma-like organism by the analysis of serial ultrathin sections. *Journal of General Microbiology* **116**, 111-131.

Wei W, Davis RE, Lee IM & Zhao Y (2007) Computer simulated RFLP analysis of 16S rRNA genes: identification of ten new phytoplasma groups. *International Journal of Systematic and Evolutionary Microbiology* **57**, 1855-1867.

Weintraub PG & Beanland L (2006) Insect vectors of phytoplasmas. *Annual Review of Entomology* **51**, 91-111.

Zhao Y, Wei W, Lee IM, Shao J, Suo X & Davis RE (2009) Construction of an interactive online phytoplasma classification tool, iPhyClassifier, and its application in analysis of the peach X-disease phytoplasma group (16SrIII). *International Journal of Systematic and Evolutionary Microbiology* **59**(10), 2582-2593.

### **CABI resources used when preparing this datasheet**

CABI Datasheet on Pest '*Candidatus* Phytoplasma solani' (Stolbur phytoplasma) (<https://www.cabi.org/isc/datasheet/108243>; date of the last modification: 10 December 2020; accessed on May 2021)

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CABI/EPPO (1992/1997) *Quarantine Pests for Europe (1<sup>st</sup> and 2<sup>nd</sup> edition)*. CABI, Wallingford (GB).

EPPO (1978) Data sheets on quarantine organisms No. 100, stolbur mycoplasma. *EPPO Bulletin* **8**(2), 115-120. <https://doi.org/10.1111/j.1365-2338.1978.tb02782.x>



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