Fusarium Wilt
Pathogen: *Fusarium oxysporum* f. sp. *lycopersici*

ABOUT

Fusarium wilt is a disease caused by the soilborne fungal pathogen, *Fusarium oxysporum* f. sp. *lycopersici*. This pathogen is specific to tomato, unlike Verticillium dahliae which has a wide host range. There are other tomato disease caused by Fusarium species such as Fusarium crown and root rot, and Fusiarum foot rot. However, these are different pathogens requiring different management strategies and should be addressed specifically.

The fungus enters the plant through rootlets and colonizes the water-conducting xylem vessels, thereby Fusarium wilt can greatly reduce yields in fields with a high incidence of *Fusarium.*
The fungus overwinters and survives for many years in the soil as spores and on the outer surface of other plants, such as weeds and other crops, without causing them harm. Long distance spread is by seed, transplants, and soil on farm machinery. The disease is favored by warm weather.

The fungus only infects tomato but exists as three races. Race 1 is widespread; Race 2 is common in the Sacramento Valley and in the northern San Joaquin Valley; and Race 3 is in the Sacramento Valley and spreading into the San Joaquin Valley.

Macroconidia have been implicated in aerial dissemination of Fol (McGovern). Such aerial spread suggests the possibility of a polycylical phase for FW and FCRR, which is unusual for soilborne diseases.

Mycelia of the pathogens can survive in association with plant debris as saprophytes and alternate hosts, and, most importantly, as thick-walled chlamydospores which enable long-term survival (McGovern).

In addition to S. lycopersicum, Fol can infect and cause symptoms in S. melogena, S. pimpinellifolium and other Sola- num spp. (Katan, 1971; Subramanian, 1970). Amaranthus, Cheno- podium, Digitaria, Malva and Oryzopsis spp. were found to be symptomless carriers of Fol (Katan, 1971; Fassihiani, 2000).

Contamination/infection of tomato seeds by Fol has been documented (Elliott and Crawford, 1922; Elwakil et al., 1998). Contaminated seed was a suspected source of the movement of Fol race 3 in Brazil (Reis and Boiteux, 2007). To- mato transplants infected by Forl (F. oxysporum radici-lycopersici) have been implicated in the long distance spread of the fungus (Hartman and Fletcher, 1991; McGovern and Datnoff, 1992). McGovern et al. (1993) determined that outbreaks of FCRR were linked to the infection of tomato transplants grown in reused Styrofoam and plastic transplant trays contaminated by Forl.

2.1.6. Structures/supports Both Fol and Forl can infest and survive on and inside of wooden

stakes used to support field-grown tomato (Jones and Woltz, 1968; McGovern and Datnoff, 1992). Forl could be recovered from stakes for at least 5 years (McGovern, unpublished data). In addition, Forl isolated from plastic stakes used to secure drip tubes in rock wool cubes was implicated in greenhouse outbreaks of FCRR (Toro et al., 2012). Shlevin et al. (2003) indicated that contaminated green- house structures (walls, poles) were a likely source of Forl inoculum.

SYMPTOMS

- Yellow flagging
    - Sometimes only one branch or one side of the plant is affected,
- Dark, vascular discoloration, especially in stems near the base of the plant
- Premature vine senescence
- Symptoms often first appear during fruit sizing

MANAGEMENT

Reduction of pathogen inoculum viability (population densities) and/or functionality (ability to successfully infect the host) are the keys. (McGOvern)

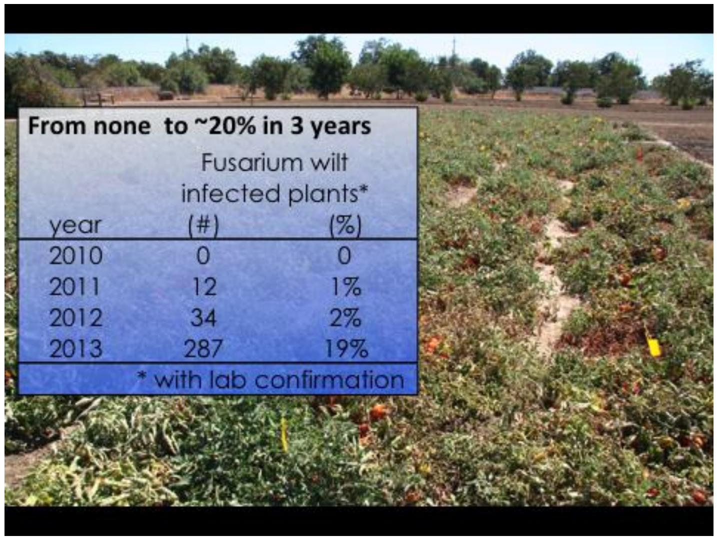
- Limit the spread of infested soil by cleaning farm equipment.
- Avoid root knot nematode infestations because nematode feeding can overcome the plant resistance to Fusarium wilt.
- Rotation out of tomatoes for several years reduces inoculum level, although Fusarium is long-lived.
- Mechanical spread: moving infested stem pieces, moving infested soil

Although polygenic resistance to Fol has been recog- nized in a number of tomato cvs. such as Homestead and Marglobe (Crill et al., 1973; Gao et al., 1995), it does not appear to be a primary focus of commercial tomato breeding programs.

SUMMARY

- Once introduced, Fusarium wilt can establish quickly
- Fusarium can spread quickly

- The pathogen is long-lived in the soil



From Gene Miyao

Table 1
Tomato cvs. reported to be highly resistant to *Fusarium oxysporum* f. sp. *lycopersici* (*Fol*) and *F. oxysporum* f. sp. *radicis-lycopersici* (*Forl*).

Tomato cultivar	Fruit type	Application/ Adaptability[a]	Source[b]
Resistant to Fol races 1, 2, 3			
Tymoty	Cherry	GH	Hazera
Samurai	Plum		Harris–Moran
Katya, Sheena, Olivia	Plum	F	Hazera
Charger, Supremo	Plum	F, E. USA – Central America	Sakata
Afrodita, Meteoro, Mixteco	Plum	Mexico, USA	US Agriseeds
BHN 602, 685	Round	F, Worldwide	BHN Seed
Fiorentino	Round	Protected culture	Enza Zaden
Amelia VR, Halcon, Red Mountain, Solar Fire	Round		Harris–Moran
SunGuard	Round	USA	Seminis
Finishline, Redline, Rocky Top, Seventy III	Round	F, S.E. USA	Syngenta
Fabiola, Julieta, USATX 012, 0128, 0250	Round	Mexico, USA	US Agriseeds
Resistant to Fol races 1, 2 and Forl			
Trebus	Cherry	Protected culture	Enza Zaden
Komeett, Merlice	Cluster	GH	De Ruiter
Avalantino, Brired, Diamantino, Dirk	Cluster		Enza Zaden
Antonella, Ladylee	Cluster		Hazera
Clermon, Clinchy, Classy, Idoia, T47100, etc.	Cluster	GH	Syngenta
Prunus	Plum	GH	De Ruiter
Atavico, Savantas, Susanti	Plum	GH	Enza Zaden
Sabroso (resistant to *Fol* races 1, 3 and *Forl*)	Plum		Hazera
Hybrid 46	Plum	USA	Seminis
Celine, T35206	Plum	GH	Syngenta
Bolzano, Beorange, DRW 7749, Foronti, Torero, etc.	Round	GH	De Ruiter
Floyd, Fizuma, Kanavaro	Round	GH	Enza Zaden
Afamia, Amaneta, Elpida, Ingar. etc.	Round	Worldwide	Enza Zaden
HM 1823, HM 8829, Sophya (green fruit)	Round		Harris–Moran
Verdone (green fruit)	Round		Hazera
Raceway, Rally	Round	F, S.E. USA	Sakata
Crown Jewel	Round	USA	Seminis
Bigdena, Euforia, Evolution, Franco, Growdena, Jimbo, etc.	Round	GH	Syngenta
Tomato Tex 2721	Round	GH	Takii
Resistant to Fol races 1, 2, 3 and Forl			
Barbarian	Plum		Harris–Moran
Juan Pablo	Plum	Mexico, USA	US Agriseed
Hechihero	Round	Subtropical areas	Enza Zaden
Sebring, Soraya, Sunkeeper	Round	F, S.E. USA	Syngenta

[a] GH = greenhouse, F = field.
[b] More information on these and other tomato cvs. may be obtained from the seed sources.

(Table: McGovern)

Disinfestants (disinfectants)

Given their tenacious survival on and in all types of horticultural surfaces including tomato seeds, irrigation water, containers, sup- ports, and structures, elimination of Fol and Forl propagules through disinfestation is an essential component of their man- agement. Disinfestants (sensu Agrios, 2005) commonly used in agriculture such as sodium hypochlorite (NaOCl), hydrogen peroxide (H_2O_2), and ozone (O_3) are strong oxidizers that inactivate pathogens through protein and nucleic acid disruption and/or function impairment; other common disinfestants, alcohols (ethanol, isopropyl alcohol) and quaternary ammonium salts, cause denaturation of proteins and membrane disruption (McDonnell and Russell, 1999). A phenolic compound, hydroquinone, was highly effective in disinfesting peanut seed contaminated with F. oxysporum (Elwakil and El-Metwally, 2000).

Spray application of NaOCl and another oxidizer, peroxyacetic acid, reduced microconidial densities of F. oxysporum f. sp. callis- tephi on Styrofoam to an undetectable level; hydrogen peroxide, ethanol, Lysol®, and a quaternary ammonium salt significantly reduced microconidial numbers but the pathogen could still be detected (Gilbert et al., 2007). Mixing a NaOCl (Clorox®) solution with soil contaminated with F. oxysporum f. sp. vasinfectum reduced the number of chlamydospores to an undetectable level (Bennett et al., 2011).

Spraying a quaternary ammonium salt solution was ineffective in sanitizing reused Styrofoam transplant trays contaminated with Forl (McGovern et al., 1993). Toro et al. (2012) demonstrated that soaking plastic irrigation stakes in NaOCl or a quaternary ammonium salt solution reduced Forl to an undetect- able level. Personnel disinfestation (hands and shoes) should be routinely practiced especially in tomato transplant production; dispensers of alcohol-based antimicrobials for hand cleansing, and foot baths containing hydrogen peroxide or quaternary ammonium salts can be used (Woodske and Sabaratnam, 2012).

Feliciano Cayanan et al. (2009) found that the free chlorine threshold and critical contact time to inactivate conidia of F. oxysporum in water was 14 mg/L for 6 min. NaOCl (Clorox®) was superior to a number of household detergents in reducing F. oxysporum f. sp. vasinfectum conidial numbers in water; chlamydopores of the fungus were found to be more resistant than conidia (Bennett et al., 2011). (Physical disinfestation techniques are presented in Section 3.4.)

Heat

Lethal temperatures for Forl in roots in soil have been reported to be 57.5e60 –C for 30 min (Baker and Roistacher, 1957; Bollen, 1985).

Treating wooden tomato stakes under a tarp with steam (93.3 –C/30 min) reduced Fol to an undetectable level (Jones and Woltz, 1968). Steam disinfestation of Styrofoam transplant trays at 71 –C for 45 min reduced Forl popu- lation densities to an undetectable level (McGovern et al., 1993).

REFERENCES
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