

Field Check

A Cotton Management Update from UC Cooperative Extension

Verticillium Wilt Considerations and California Cotton Production Foliar and Vascular Stain Ratings on Acala Varieties During 2004

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A vascular wilt disease caused by multiple strains of the soilborne fungus *Verticillium dahliae* has a long history of causing significant production losses in some California cotton fields. In past decades, it has been estimated that significant populations of strains of this organism can be isolated in soils across wide areas of the San Joaquin Valley, including as much as ½ of the acreage in which cotton remains part of the crop rotation. The result is that there is considerable potential for populations of the *Verticillium* organism to still be present in the soil at levels that can support a reappearance of the disease if susceptible cotton varieties are grown, particularly in years with conditions favorable to the organism.

One measure of the relative success of plant breeding programs in Acala cottons which have for many years incorporated screening for tolerance to *Verticillium* is the overall reduction in incidence of foliar symptoms and yield losses associated with this fungal disease over the past 15 to 20 years. However, one only has to look at the dramatic changes in dominant planted cotton varieties just in the past five years to realize that the need for disease screening continues as new genetic material is introduced into San Joaquin Valley production conditions.

It is worthwhile for consultants, growers and industry to take time and review symptoms associated with *Verticillium* wilt disease. It might also be useful to consider again potential cultural controls and the need to keep an eye out for possible varietal differences in disease susceptibility in choosing the mix of cotton varieties you plant and crop rotations used.

Disease Development / Symptoms You Might See

Extensive research was done on various aspects of this disease in cotton by USDA and University of California researchers during the period of the 1930's through early 1980's. Work in the 1950's through 1980's by researchers including Drs. Richard Garber and James DeVay has provided an excellent basis for understanding how to limit *Verticillium* impacts on cotton under California production conditions, and some of those findings can be reviewed to highlight some continuing management concerns.

Several "resting" forms of the *Verticillium* organism (including mycelial threads, microsclerotia) can survive for long periods in the soil, even when susceptible cotton varieties have not been grown for many years. Under favorable conditions (such as suitable temperature and moisture, proximity of the *Verticillium* fungus to the host cotton plant), the organism typically can enter the plant as small, hair-like filaments (hyphae) capable of penetrating the young tap root or small lateral roots. Within the plant, the hyphae can continue to penetrate the central stele of the root into water-conducting vascular tissue. There it can also produce spores which can spread the fungal organisms through vascular tissue into stems and leaves.

The organism largely proliferates within the water-conducting tissues, often resulting in vascular discoloration and development of some of the more typical recognized symptoms of this fungal disease:

- Early signs (usually seen only for a limited time period) can include an unusually dark-green leaf color – which often doesn't persist long.

- More easily-recognizable signs of *Verticillium* include blotchy, light-yellow areas between leaf veins, which as the disease progresses and becomes more severe, get larger in size and turn brown (necrotic) at the edges of the affected area.
- Leaf wilting and leaf abscission (drop) can occur with more severe disease development, but the disease often does not progress to this level of damage except in more susceptible varieties.
- A brownish discoloration can also develop in stem or upper tap root vascular tissue, often at same time as first development of leaf symptoms. This dark discoloration in vascular tissue is often described as a brownish, spotty flecking, or discoloration, rather than the more continuous discoloration typically seen with damage from *Fusarium oxysporum*. On careful inspection, leaf veins and petioles in some cases will also show the vascular staining.

Relationship between Type and Timing of *Verticillium* Symptoms and Effects on Yield

Past research efforts have looked at differences in symptom development across what could be characterized as “more susceptible” versus “tolerant” varieties, and the relationships between timing and extent of symptoms and impacts on yields and fiber quality. Generalizing from this detailed research is somewhat difficult within the limited space of this article, but a few take-home messages can be summarized as follows:

- The best indicator of potential impact of the disease on yield is the timing of and extent of damaged leaves (ie. yellowed, necrotic, or abscised leaves).
- Earlier and more extensive leaf damage has more potential to reduce photosynthetically-active leaf area and hurt future leaf and fruiting site development. In severe cases, leaves abscise and main stem and fruiting branch development can nearly stop.
- The brownish discoloration in vascular tissue of stems and leaf veins occurring with *Verticillium* wilt is useful as an indicator of presence of the organism in soil and plants, and helps show distribution of the organism across affected fields. Note, however, that the percent of plants with vascular staining or the intensity or extent of vascular staining has been seen in past research to vary with variety and often has not been well-correlated (not a good indicator) of eventual severity of damage to leaf area or yield.

- The extent and timing of development of foliar symptoms and leaf damage or loss has been seen to be strongly impacted by factors such as prevailing air and soil temperatures, soil moisture, plant nutrition, and soil type and inoculum levels as affected by the prior crops.
- In prior research analyses and field observations, the percentage of plants with foliar symptoms of the disease nearly always is significantly less than the percentage of plants with stem vascular staining. These differences have typically become even more pronounced during periods of very high air temperatures.

Impacts of Varietal “Tolerance”, Weather and Cultural Practices

The initial entry of the *Verticillium* organism into the plant can occur as early as during seedling development or much later in plant development. The amount of damage done to the plant is not always tightly related to the timing of the initial “attack”. Instead, the extent of the damage to growth and yield is more impacted by the degree of “tolerance” (defense mechanisms) of the cotton variety as well as weather / cultural conditions that favor development of the organism. Specific plant characteristics that confer “tolerance” are complicated and not always well-understood, and that discussion is beyond the scope of this article.

Weather and cultural conditions that generally favor more severe occurrences of *Verticillium* wilt include prolonged periods of cool, wet weather, cool weather with frequent irrigations, and cultural practices (such as excessive fertilization or irrigation) that encourage rank growth and delayed maturity. A common question in some years that seem to match these environmental conditions but do not produce high levels of recognized *Verticillium* symptoms is “why not more disease if “conditions” are right?” The answer is not entirely clear, but it may in part be that soil levels of the more virulent *Verticillium* inoculum in many cotton fields may be relatively low after many years of growing rotation crops and *Verticillium*-resistant cotton varieties.

Continuous cropping with less-tolerant (more susceptible) cotton varieties and less aggressive crop rotations out of cotton has been shown to sustain or even increase levels of microsclerotia (a “resting” form of the fungus that can survive in the soil for long periods). Higher surface soil levels of microsclerotia have been shown to increase the chance of severe infections with more-susceptible varieties. Numerous crop rotation

studies have typically shown reduced levels of these forms of inoculum under rotations to fallow or to certain crops (including alfalfa, clover, corn, small grains, sorghum, rice, some pasture grasses). The reductions in *Verticillium* wilt incidence and damage levels seen in cotton crops that follow these rotations has been shown to last for at least one and sometimes several growing seasons.

Even one-year rotations have provided significant benefits at sites with *Verticillium* problems. If you are interested in “checking out” the potential advantages of newly-introduced varieties in your operations, it may be prudent to consider a few precautions in your management decisions:

1. consider the availability of information (company, private or public research) on *Verticillium* tolerance of newly-introduced varieties (including where these evaluations were conducted: ie. were evaluations done in an area with known potential for *Verticillium* problems?)
2. make use of your own experience and field records regarding areas with past *Verticillium* problems
3. plan to work with some “test areas” or limited plantings of varieties in which you have an interest
4. use these mixed variety plantings to expand your knowledge of potential for *Verticillium* problems in your field

5. consider planting a “mix” of variety choices representing *Verticillium* tolerance ranging from “unknown” or susceptible to ones known to be most tolerant so you can assess your risk and keep risk of losses from *Verticillium* to a more reasonable level until you have more experience with new varieties.

All things considered, there undoubtedly are advantages likely to come to cotton growers from the broad range of varieties available or in development for California, and growers have good reason to look forward to trying newly-available varieties. Based on past experience, it is reasonable to assume that cotton breeders active in California will remain well-aware of the importance of *Verticillium* tolerance as a criteria to use in selections. Even with this in mind, however, growers and consultants should still know how to recognize *Verticillium* wilt, keep an eye out for any expansion of problem areas, and exercise some caution in how rapidly you integrate new varieties into your plans when available information or experience is limited.

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<http://cottoninfo.ucdavis.edu>

Sincere thanks are again offered to Dr. Richard Garber, who reviewed this information when originally prepared (June, 2000) and for his efforts in explaining prior research activities and summaries mentioned in this article.

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 University of California Cooperative Extension – February 2005

Table 1. **UNIVERSITY OF CALIFORNIA COOPERATIVE EXTENSION - APPROVED ACALA VARIETY TRIALS (Farm Advisors & Specialist Trials) – 2004. Late-Season Foliar Damage Ratings (late September/October rating dates as shown)** (foliar damage ratings alone do not necessarily indicate presence or severity of Verticillium wilt – ratings indicate both presence of yellow/necrotic areas plus leaf bronzing and senescence) – **NOTE: SEE TABLE 4 FOR KEY TO RATINGS**). For comparison purposes, the CA Upland varieties Delta and Pine Land "DP-444 BR" and Bayer Fibermax "FM-960 B2R" were also included in the Shafter and West Side REC sites (UCCE Cooperators: R.B. Hutmacher, R.N. Vargas, B.A. Roberts, S.D. Wright, D.S. Munk, B.H. Marsh, R.M. Davis, M.P. Keeley, R. Delgado in grower fields and the West Side and Shafter Research & Extension Centers). **Note:** Rating date for foliar damage in some cases differs from stem stain ratings – this reflects need to complete foliar ratings prior to defoliation, while stem staining ratings were done as much as 7 days after first harvest aid application.

Seed Company	Variety	MEAN FOLIAR DAMAGE RATINGS * – Approved Acala trial entries – 2004						
		Specific Test Plot Locations—row spacings as shown						
		40" rows Shafter REC rated 9/13	40" rows West Side REC rated 9/09	38" Rows Kings County rated 9/07	30" Rows Tulare County rated 9/14	40" Rows Fresno County rated 9/07	30" Rows Madera County rated 9/28	30" Rows Merced County rated 9/23
CPCSD	Maxxa	0.00	0.50	0.00	0.00	0.00	1.13	1.13
Phytogen	Phy-72	0.63	1.00	0.00	1.00	0.25	2.00	2.50
CPCSD	Riata RR	0.00	0.25	0.00	0.50	0.00	1.50	1.50
CPCSD	Sierra RR	0.25	0.50	0.25	1.00	0.50	1.63	1.75
Phytogen	Phy-78	1.25	1.75	0.50	1.75	0.75	2.75	2.75
Delta Pine	DP-6207	1.00	0.25	0.50	0.25	0.00	2.25	1.63
CPCSD	Ultima	0.25	0.25	0.00	0.00	0.25	1.13	0.88
Delta Pine	DP-6100 RR	0.50	0.50	0.00	0.75	0.00	1.63	1.50
CPCSD	Summit	0.50	0.75	0.00	0.00	0.00	1.38	1.50
United Ag Prod.	OA-265 BR	1.25	1.50	0.25	0.00	0.25	2.00	1.00
CPCSD	Ultima EF	0.25	0.25	0.00	0.50	0.25	1.25	0.88
Mean		0.59 (includes all entries at site)	0.69 (includes all entries at site)	0.14	0.52	0.20	1.70	1.55
Delta and Pine Land	DP-444 BR	1.00	1.00					
Bayer Fibermax	FM 960 B2R	0.75	0.50					
LSD 0.05			0.69	NS	0.64		0.65	0.81
LSD 0.10		0.74				0.43		
C.V. (%)		105.7	69.9	240.5	84.3	173.4	26.8	36.5
Probability (P)		0.055	0.001	0.166	0.000	0.083	0.000	0.000

* see Table 4 for rating levels in index

LSD = least significant difference between yields required to be significantly different at the 5% level of significance; C.V. = coefficient of variation; P = probability **NOTE: STATISTICS SHOWN BELOW EACH COLUMN (trial site) APPLY TO ALL VARIETIES GROWN AT THAT LOCATION**

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Table 2. **UNIVERSITY OF CALIFORNIA COOPERATIVE EXTENSION - APPROVED ACALA VARIETY TRIALS (Farm Advisors & Specialist Trials) – 2004. Stem Vascular Staining – Percent of Randomly-Sampled Plants with Vascular Staining symptoms consistent with staining seen with Verticillium wilt in lower stem (within 5 cm of soil level) during late September / early October rating date.** Sample size was 25 plants cut per variety in each of 4 field blocks. Plants from one to two varieties showing vascular staining from each field were submitted for pathology analysis from each field in order to confirm presence of Verticillium organism in sampled plants. At five of the seven sampling sites, Verticillium presence in plant tissue was confirmed (test not positive at Shafter REC site or Kings Co. site). This may indicate lack of presence of Verticillium organism at site or difficulty in detection late season – in all cases, ratings only indicate staining consistent with Verticillium, not confirmation that all noted damage was due to Verticillium. For comparison purposes, the CA Upland varieties Delta and Pine Land "DP-444 BR" and Bayer Fibermax "FM-960 B2R" were also included in the Shafter and West Side REC sites (*UCCE Cooperators: R..Hutmacher, R..Vargas, B.Roberts, S.Wright, D Munk, R.M. Davis, B.Marsh, M.Keeley, R.Delgado in grower fields and the West Side and Shafter Research & Extension Centers*).

Seed Company	Variety	STEM VASCULAR STAINING – Approved Acala trial entries - 2004 (percent of sampled plants with staining consistent with Verticillium wilt)						
		Specific Test Plot Locations—row spacings as shown						
		40" rows Shafter REC rated 9/24-25	40" rows West Side REC rated 9/27-29	38" Rows Kings County rated 10/2-4	30" Rows Tulare County rated 9/30	40" Rows Fresno County rated 9/26	30" Rows Madera County rated 9/28	30" Rows Merced County rated 9/23
CPCSD	Maxxa	4.0	8.0	0.0	5.0	4.0	6.0	7.0
Phytogen	Phy-72	15.0	13.0	5.0	11.0	8.0	24.0	26.0
CPCSD	Riata RR	3.0	5.0	0.0	3.0	2.0	9.0	10.0
CPCSD	Sierra RR	3.0	6.0	6.0	11.0	2.0	10.0	12.0
Phytogen	Phy-78	22.0	18.0	8.0	20.0	14.0	28.0	40.0
Delta Pine	DP-6207	13.0	4.0	0.0	8.0	5.0	12.0	15.0
CPCSD	Ultima	6.0	4.0	5.0	5.0	4.0	5.0	7.0
Delta Pine	DP-6100 RR	14.0	7.0	3.0	7.0	0.0	6.0	13.0
CPCSD	Summit	4.0	11.0	0.0	2.0	0.0	6.0	11.0
United Ag Prod.	OA-265 BR	12.0	15.0	5.0	11.0	10.0	16.0	22.0
CPCSD	Ultima EF	4.0	4.0	3.0	5.0	4.0	5.0	8.0
Mean		9.9 (includes all entries at site)	9.7 (includes all entries at site)	3.2	8.0	4.8	11.5	15.5
Delta and Pine Land	DP-444 BR *	14.0	16.0					
Bayer Fibermax	FM 960 B2R *	15.0	15.0					
LSD 0.05		NS	7.9		NS	8.3	9.8	9.8
LSD 0.10				5.0				
C.V. (%)		100.1	56.6	130.5	97.3	118.8	58.7	43.5
Probability (P)		0.149	0.002	0.086	0.123	0.041	0.000	0.000

LSD = least significant difference between yields required to be significantly different at the 5% level of significance; C.V. = coefficient of variation; P = probability NOTE: STATISTICS SHOWN BELOW EACH COLUMN (trial site) APPLY TO ALL VARIETIES GROWN AT THAT LOCATION

Table 3. **UNIVERSITY OF CALIFORNIA COOPERATIVE EXTENSION - APPROVED ACALA VARIETY TRIALS (Farm Advisors & Specialist Trials) – 2004. Severity of Stem Vascular Staining in Randomly-Sampled Plants counted as positive for Vascular Staining symptoms consistent with staining seen with Verticillium wilt in lower stem (within 5 cm of soil level) during late September / early October rating date as shown by location). NOTE: SEE TABLE 4 FOR KEY TO RATINGS**

Sample size was 25 plants cut per variety in each of 4 field blocks.

NOTE: Severity ratings only apply to sampled plants counted as positive for Verticillium as shown in percent affected in Table 2 (for example: if 20% (or 5) of the 25 plants per block showed staining, the average severity rating shown below only represents ratings for those 5 plants, no ratings would be done on plants not showing staining. For comparison purposes, the CA Upland varieties Delta and Pine Land "DP-444 BR" and Bayer Fibermax "FM-960 B2R" were also included in the Shafter and West Side REC sites (UCCE Cooperators: R. Hutmacher, R. Vargas, B. Roberts, S. Wright, D. Munk, R.M. Davis, B. Marsh, M. Keeley, R. Delgado in grower cooperator fields and the West Side and Shafter Research & Extension Centers).

Seed Company	Variety	MEAN STEM STAINING SEVERITY RATINGS *- Approved Acala trial entries - 2004						
		Specific Test Plot Locations—row spacings as shown						
		40" rows Shafter REC rated 9/24-25	40" rows West Side REC rated 9/27-29	38" Rows Kings County rated 10/2-4	30" Rows Tulare County rated 9/30	40" Rows Fresno County rated 9/26	30" Rows Madera County rated 9/28	30" Rows Merced County rated 9/23
CPCSD	Maxxa	1.00	1.13	0.00	1.20	1.00	1.17	1.29
Phytogen	Phy-72	1.07	1.23	1.00	1.18	1.13	1.33	1.35
CPCSD	Riata RR	1.00	1.00	0.00	1.00	1.00	1.22	1.30
CPCSD	Sierra RR	1.33	1.17	1.00	1.27	1.50	1.30	1.25
Phytogen	Phy-78	1.27	1.67	1.38	1.35	1.29	1.25	1.53
Delta Pine	DP-6207	1.15	1.00	0.00	1.29	1.20	1.17	1.27
CPCSD	Ultima	1.17	1.00	1.00	1.00	1.00	1.00	1.14
Delta Pine	DP-6100 RR	1.36	1.43	1.00	1.14	0.00	1.17	1.23
CPCSD	Summit	1.25	1.27	0.00	1.00	0.00	1.50	1.36
United Ag Prod.	OA-265 BR	1.33	1.27	1.20	1.27	1.10	1.44	1.32
CPCSD	Ultima EF	1.00	1.00	1.00	1.00	1.00	1.00	1.25
Mean		1.19 (includes all entries at site)	1.21 (includes all entries at site)	0.69	1.15	0.93	1.23	1.30
Delta and Pine Land	DP-444 BR *	1.36	1.19					
Bayer Fibermax	FM 960 B2R *	1.13	1.33					
LSD 0.05		--	--	--	--	--	--	--
LSD 0.10		--	--	--	--	--	--	--
C.V. (%)		--	--	--	--	--	--	--
Probability (P)		--	--	--	--	--	--	--

* see table 4 for description of rating index

LSD = least significant difference between yields required to be significantly different at the 5% level of significance; C.V. = coefficient of variation;
 P = probability NOTE: STATISTICS SHOWN BELOW EACH COLUMN (trial site) APPLY TO ALL VARIETIES GROWN AT THAT LOCATION

Table 4. Key to INDEX RATINGS used in Verticillium evaluations in University of CA Cooperative Extension Approved Acala Variety Trials in 2004. The ratings shown in the table are descriptions for the full range of “Late Season Foliar Damage Ratings” used in Table 1 of this series, plus the descriptions for the “Stem Vascular Staining Ratings” used in Table 3.

Type of Rating	Rating Number	Description of Rating by Number
Late Season Foliar Damage	0	No foliar symptoms associated with wilt diseases evident (wilting leaves, upper canopy leaf loss, yellowing or necrotic areas on leaves)
	1	Foliar symptoms (localized leaf yellowing or red, bronze color of leaves late season) consistent with either mild Verticillium wilt injury or late-season plant nutritional stress (K, other nutrients). Symptoms evident on limited # of plants in the field, <10% of plant stand affected – <i>no leaf yellow or necrotic areas consistent with recognized Verticillium injury</i>
	2	More widespread general leaf discoloration (evident on up to 50 percent of plants), but with limited number of plants (between 5 and 10%) with evidence of leaf yellow and necrotic areas consistent with Verticillium injury – <i>few plants (<5%) showing any wilting or leaf loss</i>
	3	Widespread leaf discoloration (50-75% of plants) with up to 25% of plants showing evidence of leaf yellow and necrotic areas consistent with Verticillium injury AND some indication of leaf wilting or leaf abscission in plants showing yellowing or necrosis
	4	As in # 3 but with more extensive yellowing, necrosis, wilt or leaf loss on up to 50% of original plant stand
	5	Severe foliar damage, including general leaf discoloration on most plants, evidence of yellowing and necrotic areas, wilting leaves, loss of >25% of leaves on >25% of original plant stand - evident defoliated or dead plants within stand
Stem Vascular Staining	0	No vascular staining evident in lower part of stem (within 7.5 cm of soil level)
	1	Light vascular staining evident as spots in vascular tissue cross-section – may cover as much as 1/4 of stem cross-section, but generally light in color
	2	Moderate vascular staining (moderate in intensity of brown or flecked staining) but evident across up to 1/2 of stem cross section area
	3	Vascular staining darker in color than in # 1 or #2 above, and evident across up to 3/4 of stem cross section area
	4	Vascular staining darker in color and staining evident throughout cross-section of damaged stem tissue (plant also shows either major leaf loss or wilting)