IMPACT OF PLANT POPULATION, IRRIGATION, AND CROP ROTATION ON VERTICILLIUM WILT IN COTTON

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Abstract

Verticillium wilt, caused by *Verticillium dahliae* Kleb., is an increasingly important disease of cotton on the southern High Plains of Texas. Management of Verticillium wilt has been limited to the use of tolerant cultivars; however, additional strategies need to be implemented to mitigate losses associated with *V. dahliae*. A field trial was conducted in 2008 to determine the influence of plant population on Verticillium wilt development. Seeding rates of 2, 4, and 7 seed/ft were evaluated in combination with the cultivars Americot 1532B2RF, AFD 5065B2F, and Fibermax 9063B2RF (susceptible, intermediate, and tolerant, respectively). Lower plant populations resulted in greater disease development. When averaged across cultivars, disease incidence was 14.5, 6.4, and 3.7% for the 2, 4, and 7 seed/ft seeding rate, respectively. Lint yields generally increased with higher seeding rates for all three cultivars. Net returns were similar among seeding rates for Americot 1532B2RF, and greatest for the 4 seed/ft seeding rate ($722 per acre); however, the 7 seed/ft seeding rate provided the highest returns for Fibermax 9063B2RF. Verticillium wilt was also monitored across several different cultivars, in field trials investigating increasing irrigation levels and crop rotation. For the cultivar × irrigation trial, irrigation levels (50%, 100%, and 150% replacement of evapotranspiration (ET)) were evaluated in combination with the cultivars Fibermax 9063B2RF, Americot 1664B2RF, Stoneville 4554B2RF, and Deltapine 117B2RF. When averaged across cultivars, irrigation level greatly influenced disease development. Disease incidence was 0.9, 9.2 and 14.5% for the 50%, 100% and 150% ET irrigation levels, respectively. Lint yields were similar for the 50% and 100% ET irrigation levels (775 and 797 lb/A, respectively). Greater incidence of disease for the 150% ET irrigation level resulted in lower yields; however, this trend was confounded by substantial vegetative growth late in the season. The same irrigation treatments were evaluated in combination with the cultivars Deltapine 104B2RF and Stoneville 4554B2RF under three rotation schemes (cotton-sorghum-cotton, sorghum-cotton-cotton, and cotton-cotton-cotton). Irrigation effects were similar to those observed in the cultivar × irrigation trial, where increased irrigation resulted in higher disease incidence. Rotation scheme greatly impacted disease development and lint yields under all irrigation levels. Disease incidence was greatest in the cotton-cotton-cotton rotation scheme. Although similar for rotation schemes containing sorghum, a trend toward higher disease incidence was observed for the sorghum-cotton-cotton rotation scheme. These results indicate that optimal plant population and irrigation, as well as crop rotation can greatly impact Verticillium wilt development. These factors should be used in conjunction with tolerant cultivars for the integrated management of Verticillium wilt of cotton.

Introduction

Verticillium wilt, caused by the soilborne fungus *Verticillium dahliae* Kleb., is an one of the most economically important diseases of cotton (*Gossypium hirsutum* L.) on the southern High Plains of Texas (Blasingame et al., 2008). The fungus infects plants early in the growing season; however, symptoms become apparent during flowering. Systemic infections lead to the clogging of the xylem vessels, which is characterized by vascular discoloration (Fig. 1). Leaves of infected plants have an intervenial chlorosis (Fig. 2), which may result in premature defoliation (Fig. 3). Significant losses can be experienced in fields infested with *V. dahliae* (Ashworth et al., 1972), furthermore, reductions in fiber quality principally micronaire and uniformity can result in substantial discounts, thus reducing loan value (El-Zik, 1985). *Verticillium dahliae* is capable of surviving long periods of time in the soil via the production of overwintering structures, called microsclerotia, which serve as initial inoculum. Cool temperatures and abundant moisture favor the development of Verticillium wilt (Garber and Presley, 1971). The density of microsclerotia in the soil is directly related to the amount of disease that will be observed during the season (Bell, 1973). Additional factors that affect disease development include fungal isolate, and the developmental stage and condition of the host (Hillocks, 1992). Management of Verticillium wilt is currently achieved through the use of resistant-tolerant cultivars. Recent studies have been conducted to identify cultivars possessing improved Verticillium wilt resistance-tolerance suitable for this region. While the use of resistant-tolerant cultivars can be used to minimize losses associated with Verticillium wilt, additional factors should be evaluated and used to develop an integrated disease management system. The objective of this study was to determine the effect of plant population, irrigation, and crop rotation on Verticillium wilt in cotton.

Materials and Methods

Cultivar ×plant population trial

An experiment was conducted in a field infested with *V. dahliae* in Floyd Co., TX. The trial was planted on 30-Apr-08 using a John Deere cone planter. Combinations of three seeding rates (2, 4, and 7 seed/ft) and the cultivars Americot 1532B2RF (susceptible), AFD 5065B2F (intermediate), and Fibermax 9063B2RF (tolerant) were arranged in a randomized complete block design with four replications. Final plant populations were determined approximately 40 days after planting. Plots were rated for Verticillium wilt on 1-Aug, 11-Aug, and 28-Aug by counting the number of plants exhibiting foliar symptoms, and converted to a % incidence. The area under the disease progress curve (AUDPC) was calculated using disease incidence and time in days after planting (Shaner and Finney, 1997). Plots were harvested on 28-Oct using a two row stripper equipped with digital scales. Samples were collected from each plot and ginned for percent turnout. Sub-samples were submitted to the Texas Tech University Fiber and Biopolymer Institute for HVI analysis. Fiber properties were used to determine loan values, which were used to calculate loan values. Net returns were calculated for each plot by multiplying the yield by loan value and subtracting the seed and technology fees.

Irrigation × cultivar trial

A field trial was conducted at the Texas AgriLife Research and Extension Helms farm located in Halfway, TX to evaluate the performance of the cotton cultivars Fibermax 9063B2RF, Americot 1664B2RF. Stoneville 4554B2RF, and Deltapine 117B2RF under three irrigation levels (50%, 100%, and 150% evapotransporation rate (ET) replacement), and the effect of these factors on Verticillium wilt development. Plots were planted 21-May-08; however, adverse conditions resulted in the trial being replanted on 21-May. Plots (4-rows wide by the length of the field) were arranged in a split-plot design with three replications. Irrigation level served as the whole-plot, and cultivar served as the sub-plot. Mid-season disease assessments were made by counting the number of diseased plants per 100 ft of row. Plots were harvested between 13- and 16-Dec and weighed using a crust Buster Boll Buggy equipped with digital scales. Samples were collected from each plot and ginned for percent turnout.

Rotation × irrigation × cultivar trial

An additional trial was conducted at the Texas AgriLife Research and Extension Helms farm to evaluate the performance of the cotton cultivars Stoneville 4554B2RF, and Deltapine 104B2RF under vary irrigation levels (described above), and three crop rotation schemes (cotton-sorghum-cotton, sorghum-cotton-cotton, and cotton-cotton-cotton). Plots (4-rows wide by the length of the field) were planted on 14-May, and arranged in a split-plot design with three replications. Irrigation level served as the whole-plot, and cultivar served as the sub-plot. Rotation schemes were restricted to separate wedges of the field. Disease was assessed during the middle of Aug as described above. Plots were harvested on 16-17 Dec and weighed using a crust Buster Boll Buggy equipped with digital scales. Samples were collected from each plot and ginned for percent turnout.

Statistical analysis

An analysis of variance was performed using the ANOVA procedure of SAS (SAS Institute, Cary, NC, version 9.1). Means were separated using Fisher's Protected LSD. Differences were deemed significant if $P \leq 0.05$.

Results and Discussion

Cultivar ×plant population trial

Inoculum density at this location was moderate (7.5 microsclerotia/cc soil), and disease incidence ranged from 0.4 to 16.8% (data not shown). Germination of seed was above 65%; however, germination decreased as seeding rates increased for Americot 1532B2RF (Table 1). Seeding rate significantly affected disease development (Table 1). Disease incidence (AUDPC) was greatest for the two seed per foot seeding rate for all three cultivars and decreased as seeding rate increased. Lint yields were greatest for Fibermax 9063B2RF, and lowest for Americot 1532B2RF (Table 1), which could be related to the inherent differences in susceptibility of the cultivars to Verticillium wilt (Wheeler, 2008). Seeding rates of 4 or 7 seed per foot resulted in increased yields over the 2 seed per foot rate Americot 1532B2RF; however, the 4 seed per foot rate was intermediate for Fibermax 9062B2RF. There was a strong negative correlation between yield and disease incidence (data not shown), supporting finding from previous studies (El-Zik, 1985). Differences in loan value were observed between seeding rates for Fibermax 9063B2RF and AFD 5065B2F and ranged from $0.511 to $0.544/lb and $0.511 to $0.539/lb, respectively. Gross returns where generally highest for the 4 seed per foot rate. As input costs increase, producers may be inclined to reduce seeding rates in order to maximize profitability; however, results from this study suggest that significant losses can be incurred if seeding rates are reduced to two seed per foot in fields infested with *V. dahliae*.

Irrigation × cultivar trial

There was no cultivar × irrigation level interaction therefore data were pooled for analysis. There were no differences in disease incidence among the four cultivars; however, differences in yield were observed (Table 2). Yields were greatest for Fibermax 9063B2RF and lowest for Deltapine 117B2RF. Irrigation level greatly affected disease development (Table 2). Disease incidence was 0.9, 9.2, and 14.5% for the 50, 100, and 150% ET irrigation level, respectively. These results corroborate findings from El-Zik, 1985 where irrigation timing and amount increased disease severity. In this study, lower irrigation levels (50 and 100% ET replacement) resulted in similar yields (775 and 797, respectively); however, yields were significantly reduced under the 150% ET irrigation level. While *V. dahliae* may have attributed to this reduction, above average rainfall experienced late in the season lead to abundant vegetative growth which may have confounded the overall effect. Additional studies investigating the interaction of irrigation level with these cultivars in Verticillium wilt fields are needed.

Rotation × irrigation × cultivar trial

No significant interactions were observed among factors regarding disease severity, therefore, data were pooled for analysis among rotation schemes. Irrigation had an affected on disease development similar to what was observed in the previous trial, where increased irrigation incited Verticillium wilt development. Overall, disease severity was greatest for the 150% ET irrigation level and lowest for the 50% ET irrigation level (Table 3). Significant cultivar × irrigation level interactions were observed for the cotton-sorghum-cotton and sorghum-cotton-cotton rotation schemes, therefore data were sorted accordingly (Table 3). No differences in yield were observed between irrigation levels in the cotton-cotton-cotton rotation. Yields were similar for Stoneville 4554B2RF under all irrigation levels for both the cotton-sorghum-cotton and sorghum-cotton-cotton rotations. The relationship between disease incidence and yield was not as strong in this trial as seen in previously; however, the density of microsclerotia in this area of the field is much lower than for the previously described study (Wheeler, unpublished). The higher irrigation levels (100 and 150% ET) provided significantly higher yields that the 50% ET irrigation level, indicating that irrigation capacity was a key limiting factor in this study. Overall, disease severity was greatest in the cotton-cotton-cotton rotation, and the incorporation of sorghum reduced the amount of Verticillium wilt by as much as 13%. Although the amount of disease observed in the sorghum-cotton-cotton rotation did not differ from the cotton-sorghum-cotton rotation statistically, there is a trend indicating that disease severity increases in rotations where cotton follows cotton. The converse was observed for yield, where yield was improved with the incorporation of sorghum into the rotation. Yields increased by 255 lb/A and 100 lb/A over the cotton-cotton-cotton for the cotton-sorghum-cotton and sorghum-cotton-cotton rotations, respectively. This study suggests there is a potential benefit to including sorghum in rotations with cotton in fields with a low to moderate level of Verticillium wilt pressure. Higher grain prices make sorghum rotations more economically feasible and attractive to producers. The benefit of extended rotations with sorghum or other non-host crops, especially in severely infested fields with *V. dahliae*, is unknown.

Summary and Conclusions

Results from this work indicate that plant population (seeding rate), irrigation, as well as crop rotation affect the development of Verticillium wilt. Use of these practices in conjunction with cultivars with improved tolerance or resistance to Verticillium wilt can be helpful in minimizing losses associated with this disease on the southern High Plains of Texas.

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Figure 1. Vascular discoloration associated with Verticillium wilt.

Figure 2. Foliar symptoms of Verticillium wilt of cotton.

Figure 3. Healthy cotton plant (left), and stunting and defoliation associated with Verticillium wilt.

Table 1. Effect of seeding rate on Verticillium wilt incidence, lint yield, loan value, and gross returns for three cotton cultivars

Cultivar, seeding rate	Final stand (% of planted)	Wilt incidence (AUDPC)[w]	Lint yield (lb/A)	Loan value ($/lb)	Gross returns ($/A)[x]
FM 9063B2RF					
2 seed/ft	85.0	2765 A[y]	1414 b[z]	0.511 b[z]	691 b[z]
4 seed/ft	87.5	1494 CD	1462 ab	0.539 ab	724 ab
7 seed/ft	81.4	357 E	1677 a	0.544 b	801 a
AFD 5065B2F					
2 seed/ft	75.0	2025 BC	1175 a	0.521 b	584 b
4 seed/ft	72.5	835 DE	1444 a	0.539 a	722 a
7 seed/ft	74.3	636 E	1451 a	0.511 ab	642 ab
AM 1532B2RF					
2 seed/ft	85.0	2615 AB	1156 b	0.475 a	519 ab
4 seed/ft	77.5	956 DE	1270 a	0.517 a	596 a
7 seed/ft	68.6	954 DE	1244 a	0.482 a	494 b

[w] Represents the area under the disease progress curve, which was calculated from disease incidence (% symptomatic plants) ratings taken throughout the season.
[x] Returns were calculated using the formula: Returns = (yield x loan value) – (seed + technology fees)
[y] Means within a column followed by the same uppercase letter are not different according to Fisher's protected LSD ($P \leq 0.05$).
[z] Means within a column followed by the same lowercase letter are not different for that specific cultivar according to Fisher's protected LSD ($P \leq 0.05$).

Table 2. Effect of irrigation level and cultivar on Verticillium wilt incidence and lint yields.

Factor, level	Disease incidence (%)[y]	Lint yield (lb/A)
Irrigation level		
50% ET	0.9 c[z]	775 a[z]
100% ET	9.2 b	797 a
150% ET	14.5 a	489 b
Cultivar		
FM 9063B2RF	7.3 a	828 a
AM 1664B2RF	8.0 a	676 b
ST 4554B2RF	9.6 a	664 bc
DP 117B2RF	7.9 a	581 c

[y] Disease incidence represents the % of plants exhibiting foliar symptoms of Verticillium wilt.
[z] Means within a column followed by the same uppercase letter are not different according to Fisher's protected LSD ($P \leq 0.05$).

Table 3. Effect of irrigation level and rotation scheme on Verticillium wilt incidence and lint yields of cotton.

Rotation, irrigation level	**Disease incidence (%)**[y]	**Lint yield (lb/A)**[z]	
Cotton-Cotton-Cotton			
50% ET	1.8 c	683 a	
100% ET	10.6 b	901 a	
150% ET	32.5 a	747 a	
Mean	*15.0*	*777*	
Sorghum-Cotton-Cotton		ST 4554B2RF	DP 104B2RF
50% ET	0.2 b	828 a	660 b
100% ET	3.8 ab	1029 a	1154 a
150% ET	8.2 a	795 a	1123 a
Mean	*4.1*	*932*	
Cotton-Sorghum-Cotton		ST 4554B2RF	DP 104B2RF
50% ET	0.0 c	949 a	830 b
100% ET	2.1 b	1081 a	1143 a
150% ET	3.5 a	974 a	1213 a
Mean	*1.9*	*1032*	

[y] Disease incidence represents the % of plants exhibiting foliar symptoms of Verticillium wilt.

[z] Means within a column followed by the same uppercase letter are not different according to Fisher's protected LSD ($P \leq 0.05$).