COST AND BENEFIT ANALYSIS OF VERTICILLIUM WILT OF COTTON IN THE SOUTHERN HIGH PLAINS OF TEXAS

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Abstract

Verticillium wilt, which is caused by the soil-borne fungus *Verticillium dahlia* Kleb, causes substantial economic losses in cotton. This disease is recognized as one of the most important biotic yield limiting factors for cotton in the Southern High Plains of Texas and other parts of the US. Management of Verticillium wilt is difficult for many producers and requires multiple tactics. Currently, the greatest benefit that producers can attain is by integrating partially resistant cultivars with other tools like irrigation management and crop rotation. Large scale research data from experiments performed at a research farm at Halfway, TX between 2007 and 2012 were evaluated to determine the effect of cultivars, crop rotation, and irrigation rate on wilt incidence, yield, and quality parameters of upland cotton. This study is aimed to clarify the profitability of different strategies to control this disease. The cost and benefit estimates of various inputs and their combinations is analyzed to determine the economic benefit. A base irrigation rate that was designed to meet between 60 and 80% of the evapotranspiration needs of the crop resulted in better economic returns than increasing irrigation 50% above or below that level. The Highest irrigation rate also increased the incidence of Verticillium wilt. Crop rotation was successful in reducing the incidence of wilt and also resulted in higher economic returns for all three irrigation rates. The strategy of crop rotation and moderate irrigation had the best returns overall in a cotton field infested with Verticillium wilt.

Introduction

Verticillium wilt, which is caused by the soil borne fungus *Verticillium dahliae,* is one of the most economically important diseases of cotton. Since 2004, this disease has arguably been the most important biotic yield limiting factor on cotton in the Southern High Plans of Texas. Verticillium wilt is exacerbated when growing conditions in the latter half of the season (during flowering and boll filling stages) are relatively cool and wet. It has more than 400 plant hosts (Pegg, G. F. and B. L. Brady. 2002). The fungus survives for long periods of time as microsclerotia in the soil. Microsclerotia density can be predictive of Verticillium wilt incidence and used as an indicator of when a producer should switch to partially resistant cultivars (Paplomatas et al., 1992). The fungus initially colonizes the external part of roots, and then moves internally. At some point it begins to spread upwards in the vascular system. The fungi and plant defense response blocks movement of water in the vascular system. This results in yellow/necrotic symptoms on leaves, vascular discoloration, stunting, and premature defoliation. Ultimately, this results in substantial loss in yield. At the end of the growing season, particularly as freezing weather occurs, microsclerotia form in the above and below ground plant parts, and are released into the soil slowly over time as the plant decays (Ashworth et. al., 1972).

Producers are adopting a number of different practices to better manage this disease. Current recommendation are for an integrated approach with multiple tactics and includes use of partially resistant cultivars, use of higher seeding rates, not over irrigating, and crop rotation with non-hosts like sorghum (El-Zik K. M. 1985). All of these practices come with both positive and negative attributes and it is difficult to know which combination of factors, other than using partially resistant cultivars to implement. Producers who continue to experience substantial yield losses to Verticillium wilt after using recommended cultivars then will explore other options. The most difficult options for producers to evaluate for improved profitability involve irrigation rate and crop rotation.

Irrigation can strongly impact Verticillium wilt. But managing that resource during the time when pumping is typically at full capacity is risky. Reduction in irrigation rate must be based on research with strong predictive capabilities. It is possible and even likely that soil temperature is related to severity of Verticillium wilt (Garber and Presley, 1971), but this relationship has not been adequately defined. Soil temperature and/or moisture may be predictive for irrigation rates that lead to excessive Verticillium wilt.

Crop rotation is another option that is difficult for producers to evaluate for its benefit in managing Verticillium wilt. Sorghum is a common rotation crop used with cotton in Texas. It does not require the high amounts of water that corn does, has very few plant pathogens in common with cotton, and its residue provides for good cover to reduce soil erosion. However, it does not bring in as much income as cotton, and returns less irrigation value ($/ha-cm irrigation applied) than cotton.

Figure 1. Light to dark brown vascular discoloration is seen in stems and branches

While each of these management tactics has been shown to reduce Verticillium wilt incidence and increase yield, there has been little done to provide a robust cost/benefit analysis. The major objective of this research is to determine the cost/benefit of cultivar selection, irrigation level, and crop rotation for cotton grown in a Verticillium wilt field. The studies have demonstrated that irrigation rate and crop rotation can potentially have much greater impacts on yield in Verticillium wilt fields than the partial resistance that currently is available in commercial cultivars. These results from this project will clarify the profitability of single and multiple strategies to control this disease.

Materials and Methods

Procedures

Experiments were conducted at the Helms Research Farm in Halfway, TX where the soil is heavily infested with *Verticillium dahliae*. Verticillium wilt symptoms were observed for the first time in the 2007 growing season at this site, which had been managed as a research site since 2001. The circle is divided into six pie-shaped wages. A three year, large plot experiment was conducted from 2007-2009 under the circle, where ½ of the circle consisted of a cropping system with 1 year sorghum followed by 2 years cotton, and the other half of the circle was in continuous cotton. The three rotated wages had been in a similar rotation, with either corn or sorghum as the grain crop since 2001. Four of the irrigation spans of the pivot were adjusted to deliver a base irrigation rate (1.0B), or 50% more or less than the base rate (1.5 or 0.5B). The entire rest area received a similar amount of water before planting and during the crop establishment phase. Irrigation rates were initiated once crop water demand increased and the details of this phenomenon are described in Wheeler et al. (2012). Each span represented a replication of the three irrigation rates, each covering approximately 20 rows. A split-plot design was utilized with cultivar as the split plot and irrigation rate as the main plot. The two cultivars that were randomized within irrigation rate were either partially resistant to Verticillium wilt (Pamaster 2104B2RF in 2007 and Deltapine (DP) 104B2RF in 2008 and 2009) or susceptible to Verticillium wilt (Stoneville (ST) 4554B2F). Incidence of wilt was measured in each plot during August of 2008 and 2009, and microsclerotia density in soil was measured in the winter, following each growing season. Details of these procedures can be found in Wheeler et al. (2012). Plots were harvested with a four row cotton stripper and weights measured in a boll buggy equipped with load cells. A sample of harvested cotton (which contains seed, lint, and trash) was ginned to determine turnout, and lint quality was accessed by HVI testing at the Texas Tech Fiber and Biopolymer Research Institute.

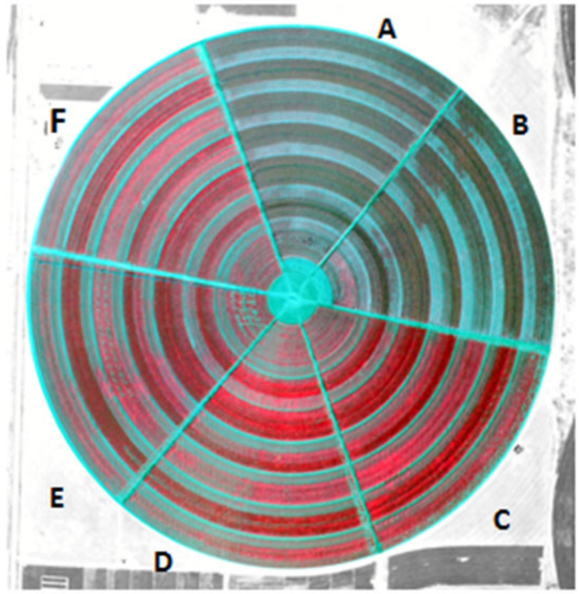

Figure 2. Near-infrared image of Helms farm at Halfway, Texas. Wedges B, C, and D are in a long-term cotton/cotton/sorghum rotation. Wedges E, F, and A were in a long-term continuous cotton rotation until 2010. Currently only wedge E is in continuous cotton. Different irrigation rates are shown by the brightness in the image, with the brightest red associated with the highest irrigation rate for cotton in wedges C, D, E, and F, and the greenish blue color associated with the sorghum wedges and the lowest irrigation rate in the cotton wedges.

During 2010-2012 growing seasons, a similar experiment was conducted. This time there were changes in following varieties; DP 0912B2RF and Stoneville 4288B2F (susceptible to Verticillium wilt) and Fibermax (FM) 9180B2F and NexGen (NG) 3348B2RF (partially resistant to Verticillium wilt) were used. The irrigation rates were the same (Base, Base-50% and Base+50%), however, from 2007-2009, the base rate was targeting 80% of estimated ET (when pumping capacity was sufficient). While in 2010-2012, the base rate was targeting 60% of estimated ET. The 1 year sorghum/2year cotton wedges remained the same, as did one wedge in continuous cotton. However, two wedges that had been in continuous cotton since 2001 (and had significant amounts of Verticillium wilt) were placed in a 1 year cotton/1year sorghum rotation.

Economic Analysis

The incidence of wilt, density of microsclerotia, and yield of cotton lint from five of these six years were used in the economic analysis. 2011 was omitted from the analysis because it was a historic year in terms of drought combined with excessive temperature and wind; well beyond the usual pattern of weather for this region. The returns above total specified expenses were calculated by subtracting total expenses from total income. Cotton prices for each year from 2007-2012 were recorded. When calculating the total income, cotton lint and cotton seed were used. The list of total direct expenses and total fixed expenses are available in Helms research farm summary report of each year (found at http://lubbock.tamu.edu). Prices of each year were adjusted to the price of 2013 using the CPI inflation calculator which is available online in the official website of United States Bureau of Labor Statistics (found at http://www.bls.gov/data/inflation_calculator.htm). Cotton prices from 2007-2012 were, in 2007 $0.54/lbs, 2008 $0.60/lbs, 2009 $0.54/lbs, 2010 $0.62/lbs, 2011 $0.90/lbs and 2012 $0.80/lbs.

The result below reflects only the economic analysis of cotton, whereas in future we will include the sorghum prices and expenses as well.

Results and Discussion

The yield of cotton from 2007 to 2012 is provided in figure 2, which shows the total cotton lint yield (lbs/ac) when treated with different irrigation levels with respect to different crop rotation strategies.

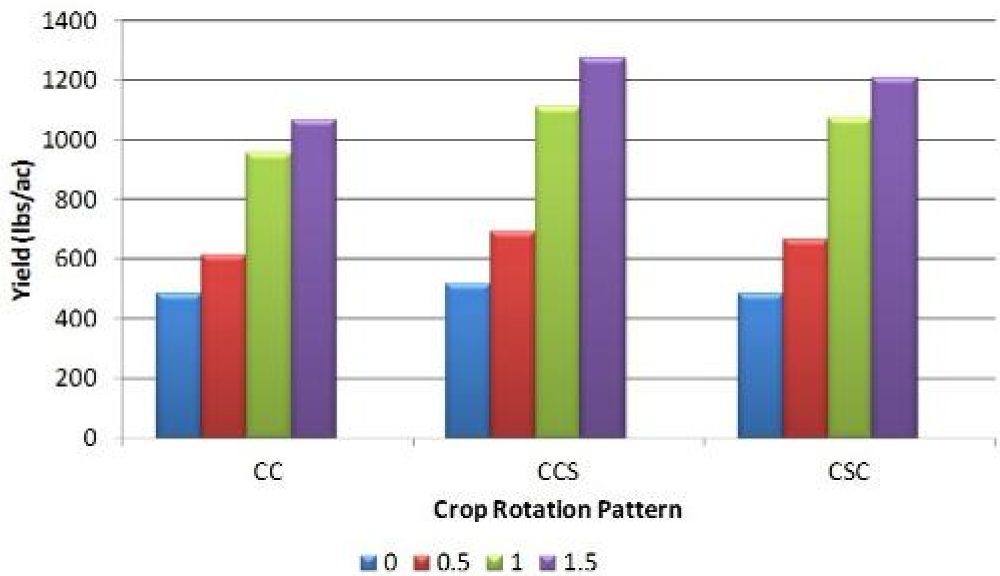

Figure 3. Cotton lint yield (lbs/ac) with interaction of different crop rotation strategies and irrigation level. CC = continuous cotton, CCS and CSC represent the two wedges that were in a two-year cotton/1 year sorghum rotation. Irrigation rates after crop establishment were a base rate (1), Base-50% (0.5), and Base+ 50% (1.5), and no irrigation (0)

Yield increased as irrigation rate increased (Fig. 3). At the Base and Base+50% irrigation rates, yield was higher for the cotton rotated with sorghum than for the continuous cotton (Fig. 3).

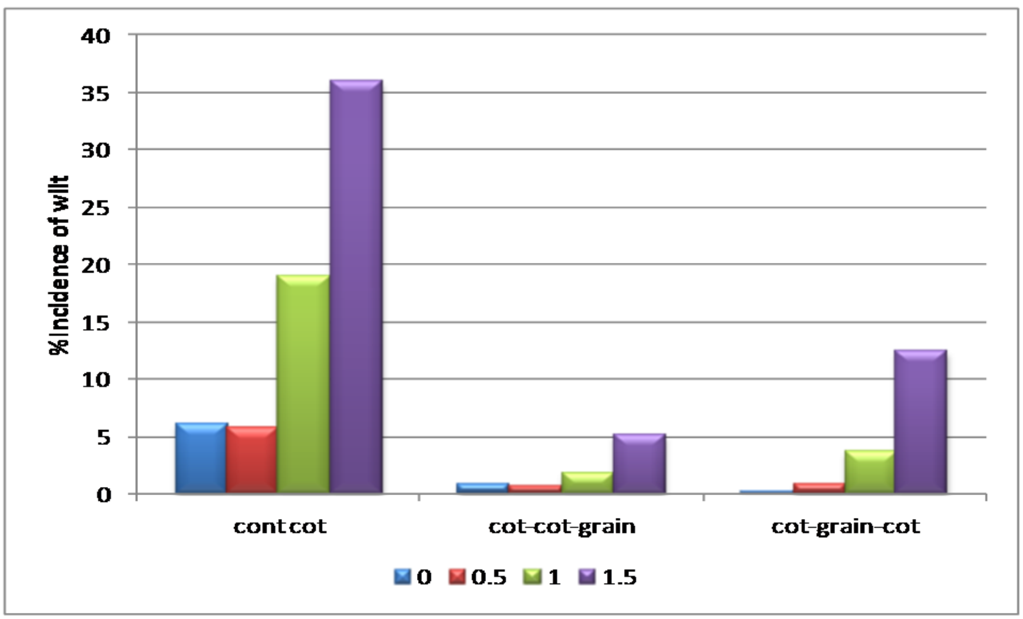

Figure 4. Incidence of wilt with three crop rotation pattern and different irrigation rates (2007-2009). Contcot = continuous cotton since 2001; cot-cot-grain and cot-grain-cot= a 2 year cotton and 1-year grain (typically sorghum) rotation since 2001. Irrigation rates after crop establishment were a base rate (1), Base-50%), (0.5) Base+50% (1.5), and no irrigation (0).

There is a drastic change in percentage of wilt incidence when comparing continuous cotton with a rotated cotton cropping pattern. The continuous cotton has a higher percentage of wilt incidence, whereas the rotated cotton has a much lower incidence of wilt (Fig. 4). Higher irrigation rate was also associated with, higher incidence of wilt (Fig. 4). The Base +50% has an enormous increase in wilt relative to the other irrigation rates for all three cropping systems. This shows that, high water not only provides high yield but also results in more severe Verticillium wilt. This will clearly damage the crop, resulting in lower profit to farmers.

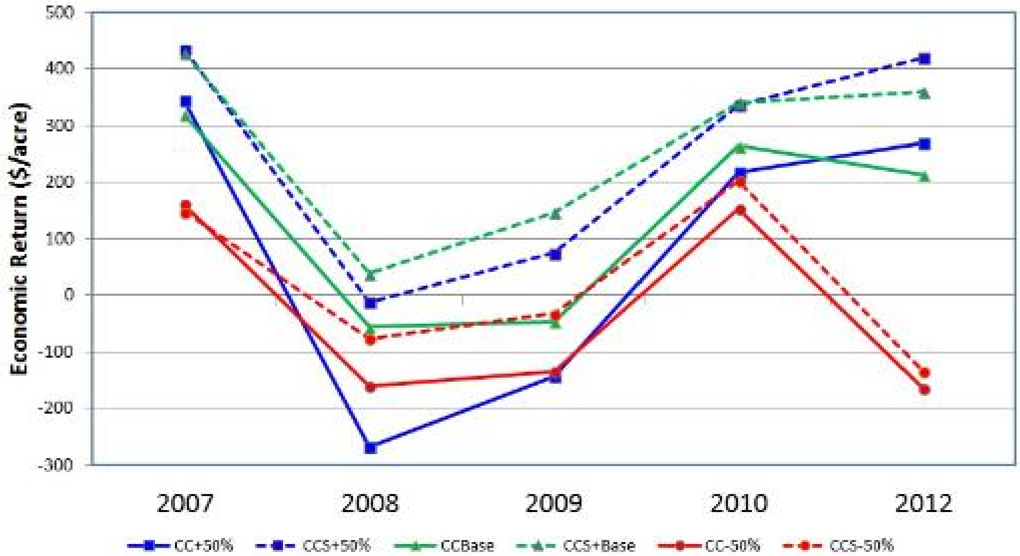

Figure 5. Returns above total specified expenses for 2007 – 2010 and 2012 for continuous cotton (CC) and cotton rotated with sorghum (CCS) at three irrigation rates (Base ▲ , Base +50% ■ and Base-50% ●).

Table 1. Average economics return for different combinations of crop rotation systems and irrigation rate in dollars/acre

Cropping System [1]	Irrigation Rate	Profit Level
CC	+50% Base	83.52
CCS	+50% Base	233.53
CC	Base	120.08
CCS	Base	244.58
CC	-50%Base	-29.24
CCS	-50%Base	21.37

[1]CC=continuous cotton and CCS = a 2-year cotton, 1-year sorghum rotation, Base refers to the irrigation rate, which maintained approximately 80% of what the crop needed during the season for 2007-2009, and 60% of what the crop needed in 2010 and 2012, when pumping capacity permitted.

For the continuous cotton system and Base+50% irrigation rate, two of the five years, the economic returns were < 0 (Fig. 5) and the average return over the five years was $83.52/acre (Table 1), For the rotated cotton system and Base+50% irrigation rate, only one year made negative returns (Fig. 5), and the average rate of return was $233.53 (Table 1). So, there was an increase of $150/acre by rotating cotton with sorghum once every three years, with the highest irrigation rate. For continuous cotton and the base irrigation rate, in 2 of 5 years, the return was < 0, and the average return for the five years was $120.08/acre (Table 1). With the rotated cotton system and base irrigation ate, there was a positive economic return every year (Fig. 5) and the average return was $244.58 (Table 1). So the average value of the rotation crop with the medium irrigation rate was $124.50/acre. With continuous cotton and the Base-50% irrigation rate, the economic return was < 0 in 3 of 5 years (Fig. 5), and the average return was $-29.24 (Table 1). With the rotated cotton and the Base-50% irrigation rate, the economic return was < 0 in 3 of 5 years (Fig. 5), and the average return was $21.37 (Table 1). The value of the crop rotation with the low irrigation rate was $50.61/acre. In this semi-arid region, typically higher irrigation rate means higher yields. However, in this case, the higher economic returns were found with the base irrigation rate, not the Base+50% irrigation rate (Table 1). Given the much higher incidence of Verticillium wilt that was associated with the Base+50% irrigation rate, it is possible that the disease kept the cotton from being able to adequately respond to the higher irrigation rate. Even in the rotated cotton, which overall had a lower incidence of wilt than the continuous cotton, the Base irrigation rate had a slightly better economic return than the Base+50% irrigation rate. Producers may be able to increase their profits by reducing their irrigation when this disease is present in a field. However, too much reduction of water is not beneficial, as was clearly seen with the Base-50% irrigation rate.

Summary

No single management option is very effective in controlling Verticillium wilt. However; practices like irrigation, seeding rate and crop rotation can reduce disease incidence and soil population density of *Verticillium dahliae*. A base irrigation rate that was designed to meet between 60 and 80% of the evapotranspiration needs of the crop resulted in better economic returns than increasing irrigation 50% above or below that level. The Highest irrigation rate also increased the incidence of Verticillium wilt. Crop rotation was successful in reducing the incidence of wilt and also resulted in higher economic returns for all three irrigation rates. The strategy of crop rotation and moderate irrigation had the best returns overall in a cotton field infested with Verticillium wilt.

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