DISEASE CONTROL AND YIELD RESPONSE OF A TARGET SPOT SUSCEPTIBLE AND PARTIALLY RESISTANT CULTIVAR AS INFLUENCED BY FUNGICIDE INPUTS OVER A THREE YEAR PERIOD

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Abstract

A study was conducted at the Gulf Coast Research and Extension Center to assess the control of target spot and yield response of susceptible and partially resistant cotton varieties as influenced by applications of recommended fungicides. A factorial set of treatments was arranged in a split-split plot with year as the whole plot, cotton variety resistance as the split plot, and fungicide program as the split-split plot. While the partially resistant varieties Deltapine 1050 B2RF, Deltapine 1252 B2RF, and Deltapine 1137 B2RF were produced in 2012, 2013, and 2016, respectively, the target spot susceptible variety PhytoGen 499 WRF was sown in all three study years. Fungicide programs consisted of two applications of Headline 2.09SC at 6 and 9 fl oz/A, Quadris 2.08SC at 6 and 9 fl oz/A, or Twinline at 7 and 8.5 fl oz/A along with a non-fungicide treated control. Applications, which were scheduled at the 1st and 3rd week of bloom in 2012 and 2013, were delayed until the 3rd and 5th week of bloom in 2016. In all study years, final % defoliation was greater for PhytoGen 499 WRF than any of the Deltapine varieties. For PhytoGen 499 WRF, the highest final defoliation of 71% was noted in 2012, while a low of 47% defoliation was recorded in 2013. When compared with Deltapine 1050 B2RF at 34% defoliation in 2012, 25% and 21% defoliation was noted for Deltapine 1252 B2RF and Deltapine 1137 B2RF in 2013 and 2016, respectively. Over the three-year study period, lower final % defoliation was observed for the Headline, Quadris, and Twinline-treated cotton than the non-fungicide treated control with the 9 fl oz/A rate of Headline proving more efficacious than both rates of Quadris against target spot. Application rate did not influence disease control with either Headline, Quadris, or Twinline. Significant year × variety and variety × fungicide program interactions for seed yield were noted. While the 3239 and 2869 lb/A seed yield for PhytoGen 499 WRF was similar to Deltapine 1050 B2RF at 3321 lb/A and Deltapine 1137 B2RF at 2975 lb/A in 2012 and 2016, respectively, Deltapine 1252 B2RF produced higher seed yields of 3195 lb/A than PhytoGen 499 WRF at 3001 lb/A in 2013. Seed yield for PhytoGen 499 WRF as well as the three Deltapine varieties differed by study year. For the Deltapine varieties, similar seed yields were noted across all fungicide programs including the non-fungicide treated control. With PhytoGen 499 WRF, significant gains in seed cotton yield were recorded with all fungicide treatments except for the 6 fl oz/A rate of Quadris compared with the non-fungicide treated control. Also, PhytoGen 499 WRF seed cotton yields were greater for both rates of Twinline than the 6 fl oz rate of Quadris.

Introduction

Target spot, which is caused by the fungus *Corynespora cassiicola*, has been linked with 250 to 400 lb/A lint yield losses on selected cotton cultivars (Hagan et al, 2015). Mehl et al. (2017) has also reported a negative correlation between target spot-incited defoliation and yield. Disease distribution in the U.S. includes all cotton producing states except for Arizona and California (Butler et al. 2016; Conner et al. 2013; Donahue 2012; Edmisten 2012; Fulmer et al. 2012; Price et al. 2015a, Damicone, personal communication; Woodruff, personal communication). Target spot outbreaks have also been reported in Brazil (Galbieri et al. 2014) and China (Wei et al. 2014).

Typically, lesions with alternating concentric rings of light and dark brown bands (bulls eye or target spot pattern) first appear on foliage at canopy closure one to three weeks after first bloom in the lower and mid-canopy, and, with favorable wet conditions, often quickly spread upward through the plant canopy (Conner et al. 2013). Leaves with multiple lesions prematurely senesce and defoliation levels may reach 75% when 25 to 50% of bolls have opened on a susceptible cultivar (Conner et al. 2013). Reductions in lint yield and, to a lesser extent, turn out or fiber quality are associated with damaging target spot outbreaks (Hagan et al. 2013; Hagan et al. 2015; Hagan et al. 2016). Strong-growing cotton with a yield potential of 1500 lb/acre (1680 kg/ha) or greater are most vulnerable to target spot, particularly when irrigated and/or in close proximity to the Gulf Coast where frequent afternoon showers in July and

August favor early disease onset and rapid development (Hagan 2014). As was demonstrated at multiple Alabama locations in 2017, the absence of a closed cotton canopy during bloom through boll fill minimizes target spot development, regardless of rainfall or irrigation patterns (Hagan, personal observation).

While cultivars with partial resistance to target spot dominate the cotton seed market in Alabama (USDA-AMS 2016), fungicides are an effective tool for limiting premature defoliation and disease-incited yield loss, particularly in intensively managed target spot susceptible cultivars (Hagan, 2014). Yield protection obtained with registered fungicides may range up to 250 lb lint/A (Hagan et al. 2014; Hagan et al. 2016). Despite sizable reductions in premature defoliation, significant yield gains with Headline [pyraclostrobin; BASF Ag Products, Research Triangle, NC] but not Quadris [azoxystrobin; Syngenta Crop Protection, Greensboro, NC] applied with a drop but not broadcast nozzle arrangement were noted for the target spot susceptible PhytoGen 499 WRF but not the partially resistant Deltapine 1252 B2RF cultivars (Hagan et al. 2017). Price et al. (2015b) in Louisiana, Hagan et al. (2013b) in Alabama, and Walls et al. (2013) in Georgia and Virginia also failed to consistently link target spot control with the above fungicides to significant yield gains. Mehl et al. (2017) also reported inconsistent yield gains from the Headline, Quadris, and the more efficacious Priaxor Xemium Brand Fungicide [fluxapyroxad + pyraclostrobin, BASF, Research Triangle Park, NC] on PhytoGen 499 WRF and Deltapine 1137 B2RF despite reductions in premature defoliation across multiple study sites in six states over multiple years.

The objective of this study was to assess the efficacy of recommended rates of the registered fungicides, Headline, Quadris, and Twinline, for control of target spot as well as yield protection on susceptible and partially resistant cotton cultivars at a site where production practices and weather patterns favored disease.

Materials and Methods

The study site at the Gulf Coast Research and Extension Center located in Fairhope, AL, 20 miles (72 km) southeast of Mobile, AL, was cropped to peanut or corn in the years preceding this study. Soil fertility and pH were adjusted according to the results of a soil assay done by the Auburn University Soil Testing Laboratory. Cotton varieties were hill dropped on 38 inch rows at rate of 3 seed/ft on 9 May 2012, 9 May 2013, and 9 May 2016 in a Malbis fine sandy loam behind a KMC strip till unit. Weed and insect control along with cotton growth management recommendations of the Alabama Cooperative Extension System were followed (Reed et al. 2017). While the study site was not irrigated in 2012 or 2013, 0.5 in. of water was delivered via a lateral irrigation system on 22 June, 27 June, 8 July, 11 July, and 1 September 2016. The experimental design was a factorial set of treatments arranged as split-split-plot with study year as the whole plot, cotton cultivar as the split-plot, and fungicide program as the split split-plot treatment. Individual experimental units consisted of four 25 foot rows spaced 3 feet apart in four replications of treatments. The target spot susceptible cultivar PhytoGen 499 WRF [PhytoGen Cottonseed, Indianapolis, IN] was used in all study years, while the partially resistant cultivar differed by study year with Deltapine 1050 B2RF, Deltapine 1137, and Deltapine 1252 B2RF [Deltapine Seed, St. Louis, MO] being sown in 2012, 2013, and 2016, respectively. Previously, the above Deltapine cultivars displayed similar levels of target spot-incited defoliation and yield response (Hagan et al. 2013a, Hagan et al. 2017a). Fungicide treatments were: i) a non-treated control, ii) Headline 2.09SC @ 6 and 9 fl oz/A or iii) Quadris 2.08SC @ 6 and 9 fl oz/A and iv) Twinline @ 7 and 8.5 fl oz/A [pyraclostrobin + metconazole; BASF Ag Products, Research Triangle, NC] broadcast 1.5 to 2 foot over the top of the cotton canopy with 11002 nozzles (TeeJet Technologies, Glendale Heights, IL) on 1.7 ft centers. Fungicides were applied with a high clearance sprayer calibrated to deliver 15 gal/A at 40 psi. Fungicide applications were scheduled around the 1st week and 3rd week of bloom on 5 and 23 July 2012 and 16 and 31 July 2013, and on the 3rd and 5th week of bloom on 18 July and 1 August 2016.

Disease Assessment

Final target spot intensity was assessed on 13 September 2012, 24 September 2013, and 31 August 2016 using a 1 to 10 leaf spot scoring system where 1 = no disease, 2 = very few lesions in canopy, 3 = few lesions noticed in lower and upper canopy, 4 = some lesions seen and < 10% defoliation, 5 = lesions noticeable and < 25% defoliation, 6 = lesions numerous and < 50% defoliation, 7 = lesions very numerous and < 75% defoliation, 8 = numerous lesions on few remaining leaves and <90% defoliation, 9 = very few remaining leaves covered with lesions and < 95% defoliation, and 10 = plants defoliated (Chiteka et al. 1988). Defoliation values were calculated using the formula [% Defoliation = 100/(1+e(-(disease intensity score-6.0672)/0.7975)] (modified from Li et al. 2012). Cotton was defoliated and prepared for harvest according to the recommendations of the Alabama Cooperative Extension System (Reed et al. 2017) and mechanically harvested on 11 October 2012, 14 October 2013, and 28 September 2016.

Statistical Methods

Final % defoliation, and seed cotton yield were the measured responses analyzed with a mixed model approach (PROC Glimmix; SAS 9.2). Year, cotton cultivar, and fungicide treatment were treated as fixed factors; random effects were block, block × year, and block × year × cultivar. Statistical analyses were done on rank transformations of the non-normal final % defoliation and yield data. Non-transformed data are reported. Means were separated using Fisher's protected least significant difference (LSD) test ($P \leq 0.05$) unless otherwise indicated.

Results and Discussion

Year × cultivar interactions were highly significant for final % defoliation, indicating variability among years and cultivar to weather as well as fungicide treatment (Table 1). Regardless of the study year, the target spot susceptible PhytoGen 499 WRF has greater final % defoliation levels than any of the partially resistant Deltapine cultivars (Table 2). In 2012, greater % defoliation was noted for the susceptible PhytoGen 499 WRF and partially resistant Deltapine 1050 B2RF than in 2013 and 2016 on the former and other Deltapine cultivars. For PhytoGen 499 WRF, final % defoliation levels were also greater in 2016 than 2013. Similarly low final % defoliation levels were recorded in 2013 and 2016 for the partially target spot resistant Deltapine 1252 B2RF and Deltapine 1137 B2RF.

Table 1. *F* values for generalized linear models for effects of year, cultivar, and fungicide program on boll counts, final target spot defoliation, and seed yield.

Source of Variation	Target spot % final defoliation	Seed yield lb/A
Year	15.86**[z]	14.59**
Cultivar	109.25***	3.02^
Year × cultivar	8.28***	2.79^
Fungicide	9.70***	2.87*
Year × fungicide	1.11	1.52
Cultivar × fungicide	0.71	2.44*
Year × cultivar × fungicide	0.29	0.96

[Z] Significance at 0.10, 0.05, 0.01, and 0.001 levels is indicated by ^, *, **, and ***, respectively.

Table 2. Final % target spot-incited defoliation as influenced by an interaction of year and cultivar.

Year	% final defoliation [Z]		Deltapine cultivar
	PhytoGen 499 WRF	Deltapine	
2012	71 a [Y]	34 d	Deltapine 1050 B2RF
2013	47 c	25 e	Deltapine 1137 B2RF
2016	58 b	21 e	Deltapine 1252 B2RF

[Z] Target spot intensity was rated using a leaf spot scoring system (1 to 10 scale) and converted to % defoliation values.

[Y] Means in each column followed by the same letter are not significantly different according to Fisher's protected least significant difference (LSD) test ($P \leq 0.05$).

When compared with the non-fungicide treated control, significant reductions in final % defoliation were obtained with both rates of Headline, Quadris, and Twinline (Fig. 1). Headline at the 9 fl oz/A rate gave better target spot control than either rate of Quadris, but the 6 fl oz/A rate of Headline or the 7 and 8.5 fl oz/A rates of Twinline. In addition, the final % defoliation ratings were significantly lower for the 7 fl oz/A rate of Twinline compared with the 9 fl oz/A rate of Quadris. Overall, application rate did not significantly impact the level of disease control obtained with Headline, Quadris, or Twinline. Absence of a significant year × cultivar interaction indicates that application timing, which differed between the two early study years and 2016 did not influence target spot control with either rate of Headline, Quadris, or Twinline (Table 1).

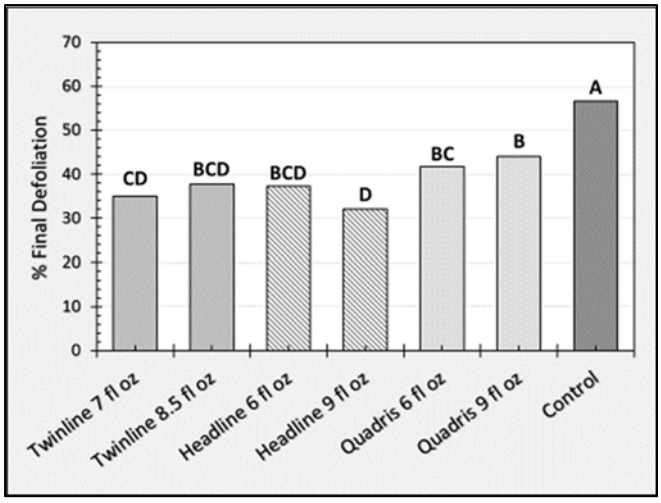

Figure 1. Impact of fungicides on % final target spot-incited defoliation averaged across study years and cotton cultivars. Bars for means with the same letter are not significantly different according to Fisher's protected least significant difference (LSD) test ($P \leq 0.05$).

Seed yield was significantly influenced by year × cultivar ($P \leq 0.10$) and cultivar × fungicide interactions (Table 1). While similar yields were recorded in 2012 and 2016 for the target spot susceptible PhytoGen 499 WRF, and partially resistant Deltapine 1050 B2RF and Deltapine 1137 B2RF, respectively, Deltapine 1252 B2RF produced higher seed cotton yields than PhytoGen 499 WRF in 2013 (Fig. 2). For PhytoGen 499 WRF, greatest seed yields of 3239 lb/A were recorded in 2012 with lower yields of 2869 lb/A reported in 2016 than the 3001 lb/A noted in 2013. Seed yield for Deltapine 1050 B2RF, Deltapine 1252 B2RF, and Deltapine 1137 B2RF also differed significantly among years.

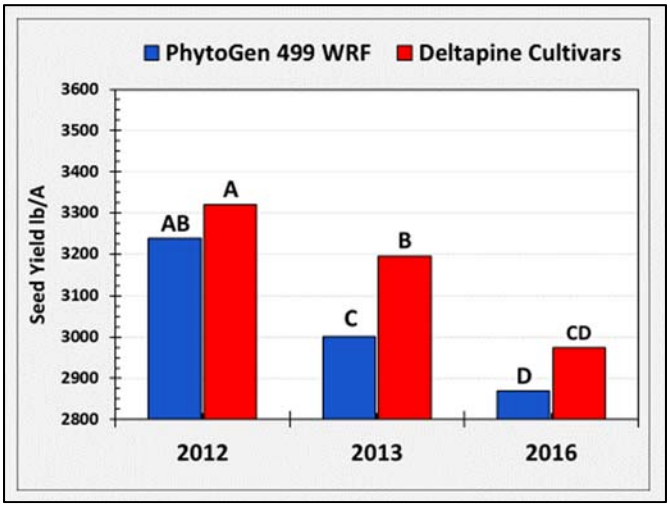

Figure 2. Seed yield as influenced by year and cotton cultivar. Deltapine 1050 B2RF, Deltapine 1252 B2RF, and Deltapine 1137 B2RF were planted in 2012, 2013, and 2016, respectively. Bars for means with the same letter are not significantly different according to Fisher's protected least significant difference (LSD) test ($P \leq 0.05$).

For partially resistant Deltapine cultivars, seed yields were similar for all fungicide treatments including the non-fungicide treated control with application rate having no influence on yield response with Headline, Quadris, or Twinline (Fig. 3). When compared with the non-fungicide treated control, significant yield gains for PhytoGen 499 WRF were recorded with all fungicide treatments except for the 6 fl oz/A rate of Quadris. Also, seed yields were greater for both rates of Twinline than for the 6 fl oz rate of Quadris. As was noted above for final % defoliation, yield response with the low and high rates of Headline, Quadris, or Twinline did not significantly differ. For the

partially resistant Deltapine cultivars, greater yields were reported for the non-fungicide treated control and both rates of Quadris but not either rate of Headline or Twinline when compared with the same treatments on the susceptible cultivar PhytoGen 499 WRF.

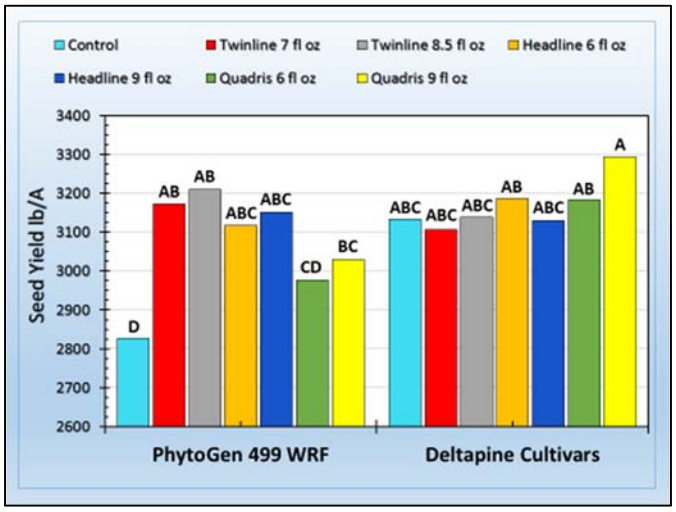

Figure 3. Seed yield as influenced by the interaction of cotton cultivar and fungicide program. Deltapine 1050 B2RF, Deltapine 1252 B2RF, and Deltapine 1137 B2RF were planted in 2012, 2013, and 2016, respectively. Bars for means with the same letter are not significantly different according to Fisher's protected least significant difference (LSD) test ($P \leq 0.05$).

As has been previously reported by Hagan et al. (2017a), target spot incited defoliation levels were considerably lower for the partially resistant Deltapine cultivars when compared with the susceptible cultivar PhytoGen 499 WRF. Greater defoliation was recorded for Deltapine 1050 B2RF in 2012 than Deltapine 1252 B2RF and Deltapine 1137 B2RF in 2013 and 2016, respectively. However, PhytoGen 499 WRF also suffered greater defoliation levels in 2012, which suggests that target spot activity likely was higher in the latter compared with the former study years. Despite significant differences in premature defoliation between PhytoGen 499 WRF and the Deltapine cultivars, a higher yield was noted for a Deltapine cultivar compared with PhytoGen 499 WRF in only 2013. Hagan et al. (2017a) previously observed mean yields for fungicide and non-treated PhytoGen 499 WRF were similar to Deltapine 1137 B2RF and Deltapine 1252 B2RF despite sizable differences in target spot-incited defoliation.

When compared with the non-treated control over three study years, Headline, Quadris, and Twinline significantly reduced target spot-incited defoliation with the high rate of Headline (9 fl oz/A) providing better disease control than either rate of Quadris. The 7 fl oz/A rate of Twinline also proved more efficacious against target spot than 9 fl oz/A Quadris. Previously, Price et al. (2015b) failed to observe a significant reduction in target spot-incited defoliation or yield protection with one or two applications of 6 fl oz/A Headline or Quadris on PhytoGen 499 WRF when compared with the non-treated control. In the same study, Priaxor at 4 fl oz/A significantly reduced defoliation levels but also provided no yield protection. While the 6 oz/A Headline and 8.5 fl oz/A Twinline programs were equally effective against target spot, similar yields were recorded for both fungicide programs and the non-treated control (Walls et al. 2013). In contrast to those results (Price et al. 2015; Walls et al. 2013), significant yield protection was obtained here with either rate of Headline and Twinline along with 9 fl oz/A but not the 6 fl oz/A rates of Quadris. Notably, the low and high rates of the former fungicides gave the same level of yield protection.

Summary

In summary, study results demonstrate that fungicides protected the yield of a target spot susceptible but not partially resistant cotton cultivar. In addition, application rate did not significantly impact disease control or yield response with either Headline, Quadris, or Twinline, so cotton producers can employ the lower and less costly rates, particularly of the former and latter fungicides without sacrificing efficacy or yield, while improving the profit potential from

employing fungicides against target spot on target spot susceptible cultivars. With the absence of any yield response from fungicide inputs, the value of fungicide inputs on partially resistant cultivars for managing target spot remains questionable.

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