IMPACT OF PLANTING DATE AND SEEDING RATE ON THE SEVERITY OF TARGET SPOT IN COTTON

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Abstract

Seeding rate and planting date studies were conducted at the Gulf Coast Research and Extension Center and Field Crops Research Unit, respectively. A factorial arranged as a split-split plot with variety (Phytogen 499 WRF and Deltapine 1555 B2RF) as the whole plot, seeding rate of 2, 3, and 4 seed/ ft of row as the split plot, and fungicide program as the split-split plot for the former study; and a 12 May and 27 May planting date as the whole plot, variety (Phytogen 499 WRF, Phytogen 444 WRF, and Deltapine 1538 B2XF) as the split plot, and fungicide program as the split-split plot for the latter study. The fungicide program consisted of four applications of Headline SC at 9 fl oz/A or three applications of Priaxor at 6 fl oz/A beginning at first bloom on a 14 day schedule and a non-fungicide treated control. Both studies were irrigated. Overall, rainfall totals were higher at the former than latter study site. In the seeding rate study, final defoliation differed by variety and fungicide program but not seeding rate, while yields rose with increasing seeding rates. Defoliation was greater regardless of fungicide program on Phytogen 499 WRF than Deltapine 1555 B2RF. Drier weather suppressed target spot at the Field Crops Research Unit. Significant planting date × cotton variety, planting date × fungicide program, and variety × fungicide program interactions for defoliation were noted. For the non-fungicide treated control and Priaxor program, defoliation was higher in the 27 May than 12 May-planted cotton. While no differences in defoliation were noted between varieties planted on 12 May, 27 May-planted Phytogen 499 WRF suffered greater defoliation than Phytogen 444 WFR and Deltapine 1538 B2XF, which had similarly lower defoliation ratings. Greater yields were reported for the latter than the former variety. For all varieties, reduced defoliation and higher yields were obtained with the Priaxor program than the non-fungicide treated control.

Introduction

Target spot, which is caused by the fungus *Corynespora cassiicola*, is associated with significant premature defoliation in cotton that may translate into lint yield losses in excess of 400 lb of lint/A for susceptible varieties (Hagan et al, 2015a). While damaging target spot outbreaks occur primarily in intensively managed cotton with a yield potential of 2.5+ bales per acre in the southern third of Alabama and Georgia along with the Florida Panhandle (Fulmer et al, 2012; Conner et al, 2013; Hagan, 2014), significant disease-related defoliation, boll shed, and subsequent yield losses have been reported in Mid-Atlantic (Edmisten, 2012) and more recently in all Mid-South states (Butler et al, 2015; Kelly and Raper, 2017; Schultz 2017). Frequent showers sometimes coupled with irrigation events beginning at pinhead square, when the middles lap, through boll cracking contribute to early disease onset and rapidly accelerating defoliation often associated with sizable yield losses (Hagan, 2014; Hagan et al, 2015a).

Target spot-incited yield loss can often but not always be avoided by establishing a tolerant as opposed to a susceptible cotton variety (Hagan, 2014; Hagan et al, 2016b). While fungicides have previously been shown to consistently increase the yield of susceptible varieties under heavy target spot pressure (up to 250 lb lint/A), sizable yield gains with fungicide inputs have been less frequently recorded for target spot 'tolerant' varieties such as Deltapine 1050 B2RF, Deltapine 1137 B2RF, and Deltapine 1252 B2RF (Hagan, 2014; Hagan et al, 2015).

Production practices may be useful in reducing the risk of damaging target spot outbreaks in cotton, thereby limiting the need for costly fungicide inputs. Since a dense canopy is often cited as a prerequisite for disease onset (Hagan, 2014), a lower seeding rate could improve air circulation within the canopy, thereby slowing target spot and possibly hardlock development. To offset ever increasing seed and associated technology costs, many cotton producers, however, have already reduced seeding rates from the recommended 3 to 4 seed down to 2 or fewer seed per row ft without sacrificing yield (Whitaker et al, 2016). Previously, Hagan (2014) observed that damaging target spot outbreaks were more prevalent in early than later May-planted cotton. Presumably, target spot development would be suppressed in later planted cotton maturing under drier late August and September weather patterns.

The objectives of these two studies were to assess 1) the influence of seeding rate and 2) planting date on target spot development and subsequent yield response of susceptible and tolerant varieties as influenced by fungicide inputs in irrigated cotton at two Alabama locations in 2016.

Methods

Seeding Rate Study

The study site at the Gulf Coast Research and Extension Center (GCREC) in Fairhope, AL was tilled with a KMC ripper/roller on 8 April, 2016. A 23 March broadcast application of 227 lb/A of 18-46-0 analysis fertilizer (41N-104P-0K) was followed by a broadcast application of 222 lb/A 0-0-60 analysis fertilizer (0N-0P-133K) on 18 April. A layby application of 23 gal/A of 28-0-0-5S liquid fertilizer (70N-0-0-12S) was made on 22 June. Broadcast applications of 1 pt/A Full-Bor (0.7 lb boron/A) were made on 6 and 18 July. On May 9, the cotton varieties Phytogen 499 WRF (susceptible) and Deltapine 1555 B2XF (tolerant) were hill dropped at 2, 3, and 4 seed/ ft behind a KMC strip till unit in a Malbis fine sandy loam (organic matter <1%). Weed and insect control recommendations of the Alabama Cooperative Extension System were followed. Cotton growth was managed with multiple applications of recommended rates of Pix (mepiquat). The study received 0.5 in. water via a lateral irrigation system on 22 June, 27 June, 8 July, 11 July, and 1 September. Cotton was prepared for harvest with an application of 1.5 pt/A Folex + 1 fl oz/A ET + 1 qt/A Boll Buster + 0.25% non-ionic surfactant on 12 September followed by 1 fl oz/A Diuron + 2 oz/A Dropp 50W + 0.25% non-ionic surfactant on 26 September. A factorial set of treatments arranged in a split split-plot with cotton variety as the main plot, seeding rates of 2, 3, and 4 seed/ft (28,000, 41,000 and 55,000 seed/A, respectively) as the split plot, and a fungicide program as the split split-plot treatment. Individual plots consisted of four 30-ft rows spaced 3.2 ft apart in four replications. Priaxor at 8 fl oz/A was broadcast with a Spider sprayer with 11002 tips mounted on a four row boom in 15 gal/A of spray volume at 55 psi at the 3rd, 5th, and 7th week of bloom on 18 July, 1 August, and 17 August, respectively, for target spot control. A non-fungicide treated control was also included. Cotton was mechanically harvested on 28 September.

Planting Date Study

Prior to planting, the study site at the Field Crops (FC) Unit at the E. V. Smith Research Center in Milstead, AL, was in-row subsoiled with a KMC subsoil unit. The cotton varieties Phytogen 499 WRF, Phytogen 444 WRF, and Deltapine 1538 B2XF were hill dropped at a rate of 2 seed/row ft on 12 and 27 May in rolled rye stubble. A 16 May, 91 lb/A of 33-0-0 analysis fertilizer was broadcast. Layby applications of 17.9 gal/A of 28-0-0-5S liquid fertilizer (56 lb actual N/A) were made to the first and second planting on 13 June and 27 June, respectively. Weed and insect control recommendations of the Alabama Cooperative Extension System were followed. Cotton growth was managed with multiple applications of recommended rates of mepiquat. Plots received 0.5, 0.75, 0.55, and 0.75 in. of water on 2 June, 24 June, 5 July, and 8 September, respectively. The experimental design was a factorial arranged in a split split-plot with planting date as the whole plot, cotton variety as the split plot and fungicide program as the split split-plot treatment. Individual split split-plots consisted of four 25-ft rows spaced 3 ft apart. Four replications of treatments were included. Priaxor 4.17F at 6 oz/A was broadcast with a Spider sprayer on 11 July (2st week of bloom), 27 July (4rd week of bloom), and 16 August (6th week of bloom) for the first planting and on the above dates for the second planting at pinhead square, 1st week, and 3rd week of bloom with AITTJ60-11002VP nozzles on 18 in. centers using 15 gal/A of spray volume at 40 psi. A non-fungicide treated control was also included. Cotton was prepared for harvest with a 16 September application of 1 pt/A Folex + 6 fl oz/A Takedown + 1 pt/A Boll'd. The two center yield rows were mechanically harvested on 11 October.

Disease Assessment and Statistics

Target spot intensity was visually assessed on 8 September at the GCREC and on 9 September and 26 September for the first and second plantings at FC 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. Defoliation values were calculated using the formula [% Defoliation = 100/(1+e(-(leaf spot scale value-6.0672)/0.7975)] (Li et al, 2012). Counts of open, hardlock, and rotted bolls were made on 3.2 ft of row in a border row of each plot in each study immediately before harvest. Significance of interactions was determined using PROC GLIMMIX procedure in SAS. Statistical analysis was done on rank transformations of non-normal target spot defoliation and rotted boll count 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

Seeding Rate Study

At the GCREC, rainfall totals for May and June were below the historical monthly average, as compared with average rainfall totals for July, August, and September (Fig. 1). Temperatures were near normal for the entire study period. Target spot onset in early to mid-August followed several weeks of July showers and rapid disease intensification continued, particularly on Phytogen 499 WRF, through the final 8 September rating date (data not shown).

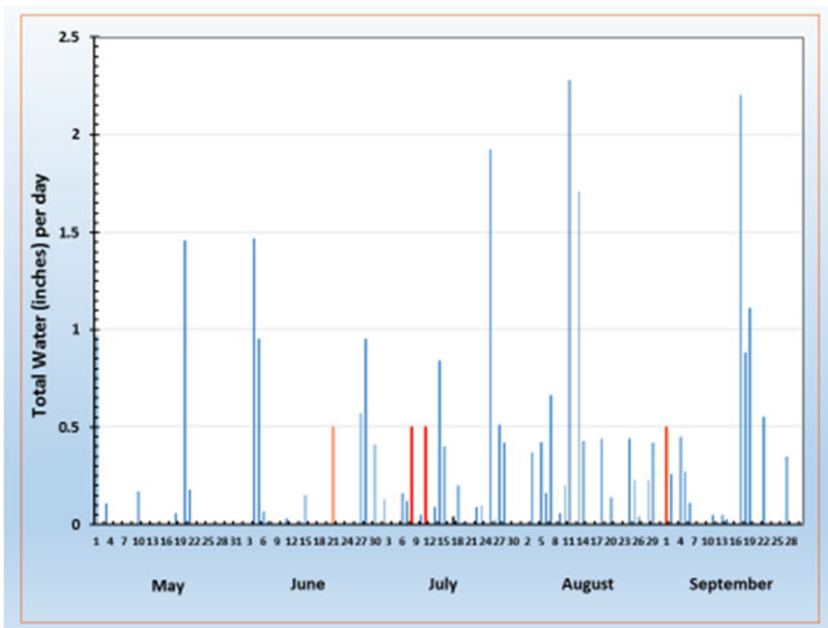

Figure 1. Daily rainfall and irrigation totals (in red) at the GCREC in 2016.

Due to a significant variety × fungicide interaction for target spot defoliation, data are presented by cotton variety and fungicide program (Table 1). For both the non-fungicide treated control and the Priaxor fungicide standard, defoliation levels were higher for Phytogen 499 WRF than Deltapine 1555 B2RF (Fig. 2). On both varieties, the Priaxor fungicide program significantly reduced target spot defoliation when compared with the non-fungicide treated control. Defoliation was not impacted by seeding rate (Table 2).

Open and unopen boll counts did not differ by cotton variety, seeding rate, or fungicide program (Tables 1 and 2). Overall, counts of hardlock bolls on both varieties were very high and likely are responsible for the lower than anticipated yields. While fewer locked and rotted bolls were noted for Phytogen 499 WRF than Deltapine 1555 B2RF, counts of hardlock and rotted bolls were similar across all seeding rates and both fungicide programs.

Despite significant differences in % defoliation, yields were similar for Phytogen 499 WFR and Deltapine 1555 B2RF (Table 2). Greater seed yields were recorded at 4 than 2 seed/ft seeding rate with intermediate seed yields noted for the 3 seed/ft seeding rate ($P \leq 0.10$). Yields were also greater for the fungicide-treated than the non-fungicide treated control

Table 1. *F* values for generalized linear models for effects of cotton variety, seeding rate and fungicide on target spot incited defoliation and seed yield at GCREC in 2016.

Source of Variance	Boll Counts				Target spot	Seed
	Open	Unopen	Locked	Rotted	% defoliation	Yield
Cotton variety	0.00 [Z]	0.51	7.32*	2.91^	73.74***	1.24
Seeding rate	0.32	2.49	2.11	1.64	0.07	2.92^
Variety × seeding rate	1.85	2.38	0.15	0.32	3.19	0.96
Fungicide program	0.27	0.15	0.00	0.99	186.00***	10.08**
Variety × fungicide program	0.24	1.37	0.00	0.99	48.63***	0.15
Seeding rate × fungicide program	2.40	0.20	0.42	0.52	0.45	0.09
Variety × seeding rate × fungicide program	0.53	0.87	0.07	0.67	2.02	0.44

[Z] Significance of F values at the 0.10, 0.05, 0.01, and 0.001 levels is indicated by ^, *, **, or ***, respectively.

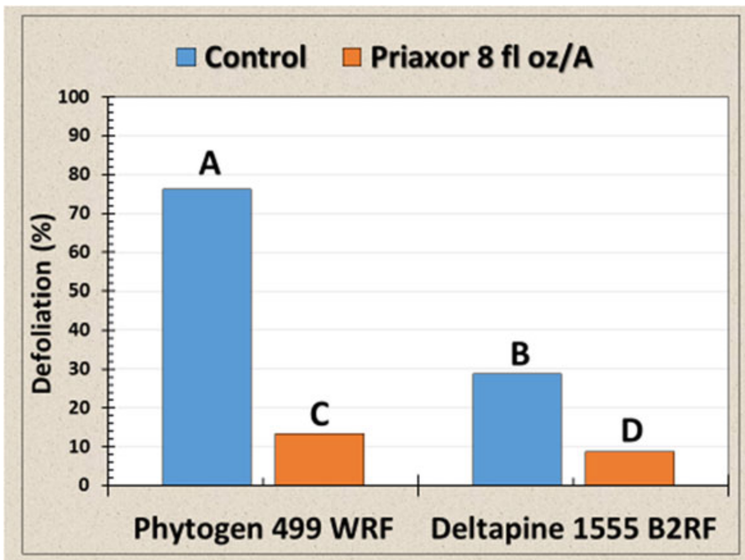

Figure 2. Target spot defoliation as influenced by a variety × fungicide program interaction.

Table 2. Bolls counts, % target spot defoliation, and yield as influenced by cotton variety, seeding rate and fungicide program.

Cotton variety	Boll Counts				Target spot	Seed
	Open	Unopen	Locked	Rotted	% defoliation [Z]	yield [Y]
Phytogen 499 WRF	68 a [X]	4.7 a	8.0 b	1.7 b	---	3153 a
Deltapine 1555 B2RF	68 a	5.5 a	13.8 a	2.7 a	---	2975 a
Seeding rate (seed/ft row)						
2	69 a	6.8 a	11.9 a	2.7 a	32 a	2975 b
3	66 a	4.1 a	11.9 a	2.4 a	31 a	3055 ab
4	69 a	4.4 a	8.8 a	1.4 a	32 a	3161 a
Fungicide program						
Non-fungicide treated control	69 a	4.9 a	10.9 a	2.5 a	---	2964 b
Priaxor 8 fl oz	67 a	5.3 a	10.9 a	1.9 a	---	3164 a

[Z] Target spot intensity was rated using a 1 to 10 leaf spot scoring system on 8 Sep and converted to % defoliation values.

[Y] Seed yield = total weight of seed + lint.

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

Planting Date Study

Monthly rainfall totals for May, June, July, August, and September were below to well below the 30 year average for the FC unit at the E. V. Smith Research Center in Milstead, AL (Fig. 3). In contrast, daily temperatures during the above period were above to well above the seasonal average.

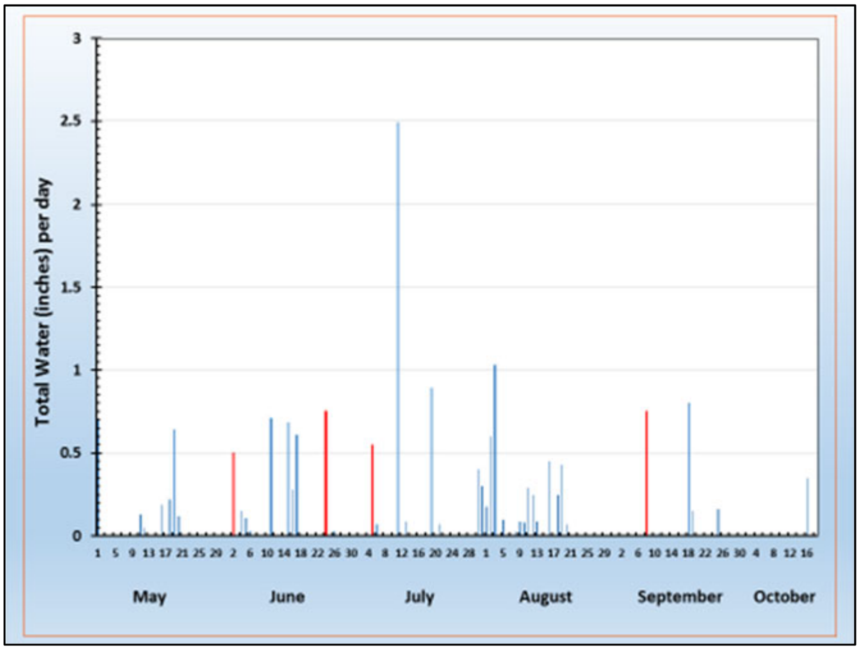

Figure 3. Daily rainfall and irrigation (in red) totals for the Field Crop Unit in 2016.

Open boll counts significantly differed ($P \leq 0.10$) by planting date and cotton variety (Table 3). In the absence of significant interactions between planting date, variety, and fungicide program, data for unopened, hardlock, and rotted bolls were pooled for each of these variables. Higher open boll counts were noted for Phytogen 444 WRF but not Phytogen 499 WRF and Deltapine 1538 B2XF at the first than second planting date (Table 4). At the first planting date Phytogen 444 WRF also had a higher open boll count than Phytogen 499 WRF but not Deltapine 1538 B2XF. While greater unopen boll counts were noted for the second than first planting date, variety and fungicide program did not impact this variable. Hardlock and rotted bolls counts were similar for both plantings and fungicide programs, but were higher for Phytogen 444 WRF than Deltapine 1538 B2XF with Phytogen 499WRF having intermediate counts for both variables.

Table 3. *F* values for generalized linear models for effects of planting date, cotton variety, and fungicide program on boll counts, defoliation, and seed yield, Field Crops Unit, 2016.

Source of Variance	Boll Counts				Target spot defoliation	Seed Yield
	Open	Unopen	Hardlock	Rotted		
Planting date	16.04***[Z]	4.15*	0.02	0.01	21.94***	127.15***
Variety	2.04	1.24	4.69*	3.47*	20.92***	1.12
Planting date × variety	2.62^	0.61	0.58	0.66	7.18**	2.66^
Fungicide program	3.70^	0.46	0.46	1.15	40.49***	9.62**
Planting date × fungicide program	0.01	0.00	0.16	0.21	5.15*	2.85
Variety × fungicide program	0.33	0.03	0.17	0.66	7.23**	0.25
Planting date × variety × fungicide program	0.83	1.12	0.34	0.85	2.89	0.90

[Z] Significance of F values at the 0.10, 0.05, 0.01, and 0.001 levels is indicated by ^, *, **, or ***, respectively.

Table 4. Open, unopen, hardlock, and rotted boll counts as influenced by planting date, variety, and fungicide program.

	Boll count (#/3.2 ft row)				
Planting Date	Open		Unopen	Hardlock	Rotted
First (12 May)	---		0.2 b [Z]	2.4 a	0.8 a
Second (27 May)	---		0.7 a	2.3 a	0.8 a
Variety	1st PD [Y]	2nd PD			
Phytogen 444 WRF	114 a	76 c	0.7 a	3.6 a	1.2 a
Phytogen 499 WRF	88 bc	76 c	0.3 a	2.3 ab	0.8 ab
Deltapine 1538 B2XF	92 ab	79 bc	0.3 a	1.3 b	0.3 b
Fungicide program					
Non-fungicide treated control	82 b		0.3 a	2.6 a	0.6 a
Priaxor 4.17F 6 fl oz/A [w]	93 a		0.5 a	2.2 a	0.9 a

[Z] Means in each column followed by the same letter are not significantly different according to Fisher's protected least significant difference (LSD) test ($P \leq 0.05$) unless otherwise noted.
[Y] 1st PD = 12 May and 2nd PD = May 27.

Target spot defoliation differed by planting date and variety, planting date and fungicide program, and variety and fungicide program (Table 3). For all varieties, lower defoliation was noted with the first than second planting date. While Phytogen 499 WRF suffered greater defoliation at the second planting than Phytogen 444WRF and Deltapine 1538 B2XF, the latter two varieties had similarly low defoliation ratings (Fig. 4A). Similar defoliation ratings were noted for the Priaxor-treated Phytogen 499 WRF and the non-fungicide treated Phytogen 444 WRF and Deltapine 1538 B2XF. Lower defoliation values were recorded at the first than second planting for each respective fungicide program (Fig. 4B). Also, significant reductions in premature defoliation were obtained for both plantings with the Priaxor fungicide program as compared with the non-fungicide treated control. While the non-fungicide treated control defoliation levels for all varieties were similar, premature defoliation was significantly greater for the Priaxor program for Phytogen 499 WRF than either of the other varieties, both of which had equally low defoliation values (Fig. 4C).

Seed yields differed by variety and planting date ($P \leq 0.10$) (Table 3). Greater seed yields were recorded at the first than second planting date for all varieties (Fig 5A). Seed yields were similar at the first planting for all three varieties; however, at the second planting, Deltapine 1538 B2XF outyielded Phytogen 444 WRF but not Phytogen 499 WRF. A significant gain in seed yield was obtained with the Priaxor program compared with the non-fungicide treated control (Fig. 5B).

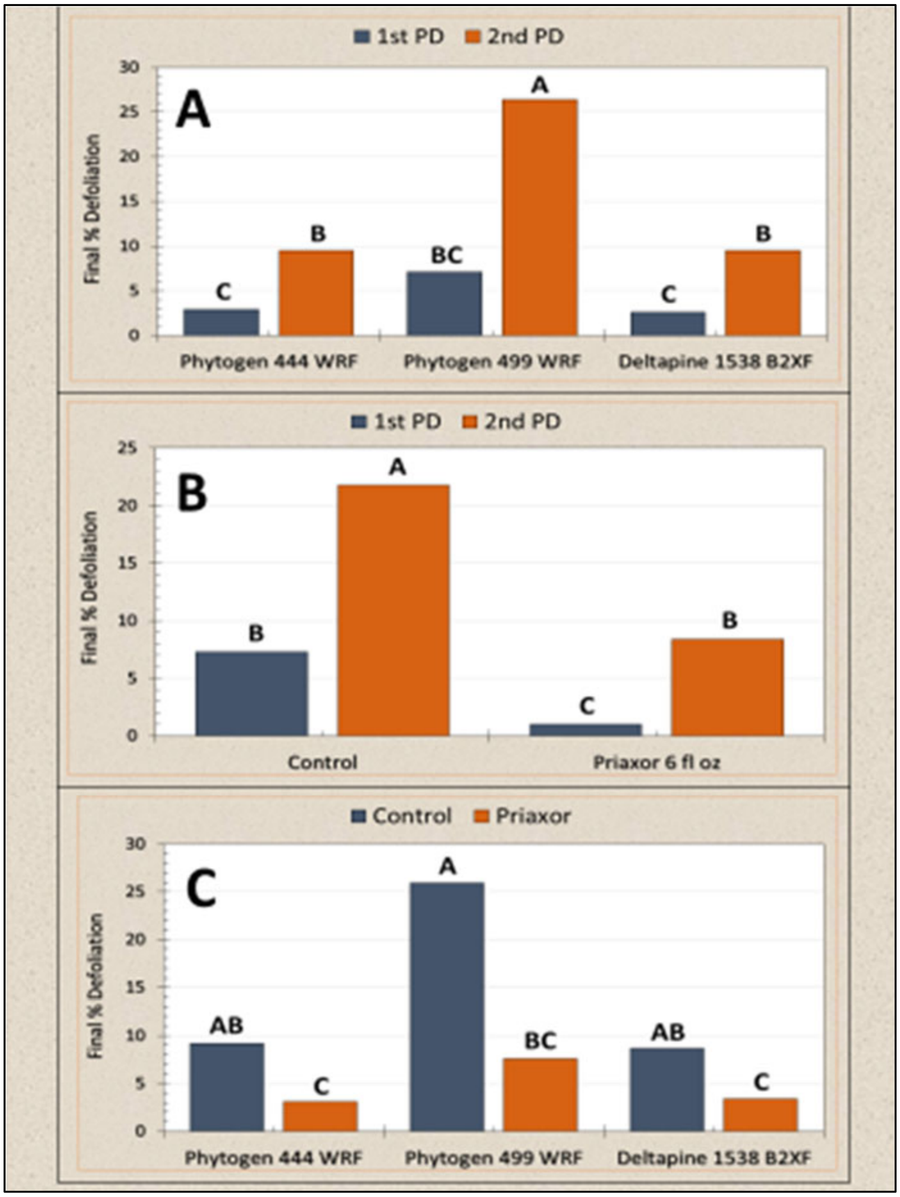

Figure 4. Interaction of A) planting date and variety, B) planting date and fungicide program, and C) variety and fungicide program on target spot % defoliation. Means in each figure followed by the same letter are not significantly different according to Fisher's protected least significant difference (LSD) test (P<0.05) unless otherwise noted.

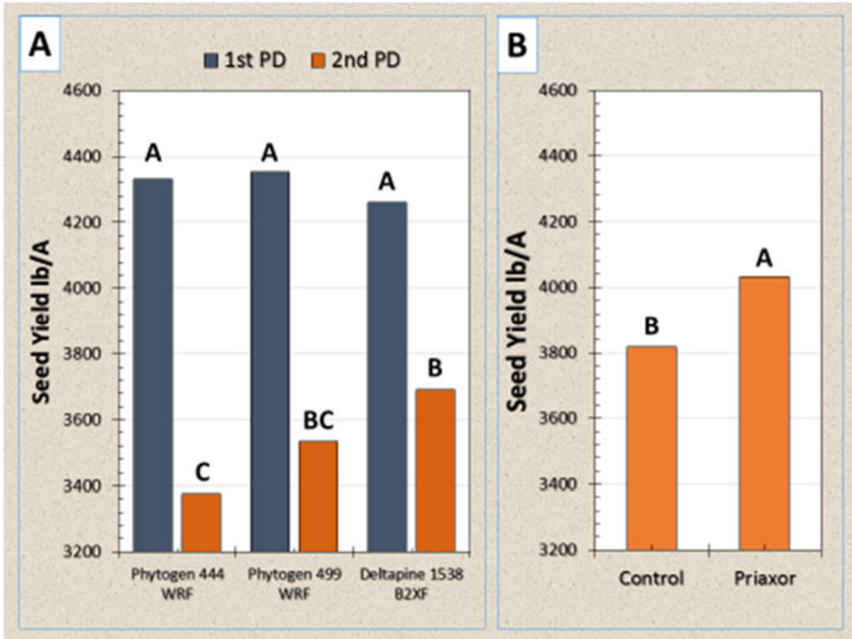

Figure 5. Seed yield as impacted by A) planting date and variety and B) fungicide program. Means in each figure followed by the same letter are not significantly different according to Fisher's protected least significant difference (LSD) test ($P<0.05$) unless otherwise noted.

Summary

In addition to frequent rainfall from pinhead square through boll cracking, damaging target spot outbreaks have been associated with rapid canopy closure and a dense leaf canopy (Hagan, 2014). In theory, reducing the seeding rate below the recommended 4 seed per ft of row should reduce crowding and slow the rate of canopy coverage, as well as improve air circulation within the canopy to reduce relative humidity sufficiently to suppress the onset and development of target spot. As indicated by similar final % defoliation values, however, seeding rate failed to slow disease development across three cotton varieties. Previously, Teague et al (2016) and Whitaker et al (2016) but not Nichols et al (2004) reported that seeding rates can be reduced well below the above recommended seeding rate without negatively impacting cotton yield. Here, however, yields declined when seeding rates were reduced from the recommended 4 to widely employed 2 seed per ft of row (Whitaker et al, 2016). In addition, reducing the seeding rate also failed to reduce hardlock incidence. The Priaxor fungicide program reduced the level of target spot-incited defoliation, which resulted in a significant increase in yield but did not reduce hardlock incidence. Open, unopen, and rotted boll counts were not impacted by any study variables.

Despite dry late summer and early fall weather conditions at the FC Unit, target spot defoliation was higher on the late than early May-planted cotton. Previously, Hagan et al (2015b) reported increased late leaf spot severity in late May and late April planted peanut, where increasing inoculum levels throughout the production season increases the risk of damaging leaf spot outbreaks in later as compared with earlier planted peanut. Apparently, inocula from earlier cotton plantings intensified disease activity in the later planted cotton. In this study, delaying planting so that cotton matures under cooler and drier early fall weather patterns failed to provide any protection from target spot, which also suggests that early planting may be of some help in avoiding damaging disease outbreaks in cotton. In addition to less target spot-incited defoliation, yield was much higher for the early- than late-May planted cotton. While planting date and fungicide inputs did not influence any boll count variables, Phytogen 444 WRF had greater hardlock and rotted boll counts than Deltapine 1538 B2XF.

Overall, reducing seeding rates and delayed planting do not appear to be effective strategies for reducing the impact of target spot in cotton and both resulted in lower seed yields. In contrast, differences in variety reaction to target spot along with fungicide inputs were shown to be effective tolls for managing this disease in cotton.

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